UNIVERSITY of RWANDA

COLLEGE OF SCIENCE AND TECHNOLOGY

Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE)

Design and Prototyping of Monitoring System for Asthma Patient

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A dissertation Submitted to the Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE), University of Rwanda as partial fulfillment of the requirements for the Master's Degree in Biomedical Engineering.

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Declaration

I, BIZIMANA Jean Bosco, declare that this dissertation entitled **“Design and Prototyping of Monitoring System for Asthma Patients”** is my original work based on research and prototype and has not been submitted for any other degree or professional qualification.

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Certificate

This is to certify that the project entitled "Design and Prototyping of Monitoring System for Asthma Patients" is a record of original work done by BIZIMANA Jean Bosco 220020525 MSc. Degree student in Biomedical Engineering.

This work has been submitted under the guidance of Dr. Pierre BAKUNZIBAKE and Dr. Kizito NKURIKIYEYEZU.

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Acknowledgment

First of all, my thanks and respect to almighty God for blessing me with the capability to do this work. I am especially grateful to my thesis supervisors Dr.Pierre BAKUNZIBAKE and Dr.Kizito NKURIKIYEYEZU for their professional supervision, guidance, and precious ideas during the conception of this research project.

I am grateful to all authorities and lecturers of the Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE)/the University of Rwanda, the for intellectual packages they offer us.

I would like to thank my Family, friends, and classmate for all their advice, encouragement, and moral support until the completion of this research project.

ABSTRACT

In both children and adults, asthma is a chronic disease of the respiratory system that affects lung function and results in breathing problems because it narrows and inflames the airways. Even though it cannot be cured, the appropriate strategy and action plan can help in managing it. To properly treat asthma, self-management is a crucial component. Vital signs need to be checked frequently for people who have chronic illnesses. Digital monitoring gadgets that warn users of impending asthma attacks have been created thanks to improvements in health technology.

These monitoring systems enable access to data so that it may be transmitted to a personal device, or clinicians follow up and appropriately record the time of each monitoring session that the patient performs it. This study offers real-time monitoring based on an IoT system, which is utilized to measure the values of the patients' body temperatures, heart rates, oxygen saturation, and body temperatures as the most important measurements required for critical care.

It has been noted that outdoor environmental factors, such as air pressure, humidity, and temperature, can cause asthma attacks and cause various asthmatic symptoms.

The proposed system will track body temperature, heart rate, and oxygen saturation. It will also employ an ambient sensor to track changes in temperature, humidity, and air quality that might trigger asthma episodes when they are outside of the ideal range.

The prototype monitoring system is equipped with pressure, temperature, humidity, and pulse oximeter sensors. The pulse oximeter sensor is applied to the finger, and it simultaneously measures the patient's pulse rate and oxygen saturation levels in asthmatic patients. After that, the microcontroller collects the data from the pulse oximeter and sends it over Wi-Fi and a cloud database to the GSM module, where it is displayed on the LCD. Information could be accessed online via a web-based application. When a measurement from the sensor exceeds a threshold value, the system was sent SMS alarm notifications via GSM to caregivers or doctors.

Keywords: asthma, triggers, heart rate, sensor, Pulse oximeter sensor.

LIST OF ACRONYMS

ADC: Analog to Digital Converter

AQI: Air Quality Index

BPM: Beats per Minute

CO: Carbon Monoxide

COPD: Chronic obstructive pulmonary disease,

ESP8266: Espressif Systems

FeNO: Fractioned exhaled nitric oxide

FEV1: Force expiratory volume in one second

FVC: Forced Vital Capacity

GDP: Gross Domestic Product

GPIO: General-Purpose input/output

GPRS: General Packet Radio Service

GSM: Global System for Mobile Communication

I2C: Inter-Integrated Circuit

IDE: Integrated Development Environment

IoT: Internet of Things

LCD: Liquid Crystal Display

LEDs Light-Emitting Diode

LM35: Integrated Circuit / Temperature Sensor

MOH: Ministry of Health

NCDs: Non-communicable diseases

NO: Nitric Oxide

OLED: Organic Light-Emitting Diode

PEFR: Peak Expiratory Flow Rate

PFM: Peak Flow Monitoring

ppb: parts per billion

ppm: parts per million

SMS: Short Message Service

SPI: Serial Peripheral Interface

WHO: World Health Organization

Wi-Fi: Wireless Fidelity

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CHAPTER 1. GENERAL INTRODUCTION

I.1 Introduction

Children and adults have asthma struggle to breathe because it affects the lungs and narrows the airways, causing inflammation [1]. Asthma is a chronic respiratory disorder. Common asthma symptoms include wheezing, coughing, chest pain, and shortness of breath [2]. More than 461,000 deaths worldwide in 2019 has attributed to the chronic disease asthma, which affects both low- and high-income countries[3], with low-income countries accounting for 80% of deaths because the condition is not well monitored and managed [4]. According to estimates in the literature, there were more than 262 million asthma patients worldwide in 2019. WHO estimates that 58 percent of all annual fatalities in Rwanda are caused by NCDs like diabetes, chronic respiratory illnesses, cancer, and cardiovascular diseases. Asthma is mentioned in this study[5]. The average life expectancy has increased from 47 to 69 years, indicating an aging population and an increased risk of NCDs, according to a study on the demography and epidemiology of NCDs in Rwanda. Rwanda's national strategy and costed action plan set a 25% reduction in NCD-related mortality by 2025. In Rwanda, the majority of asthma sufferers do not receive a diagnosis as it is required, and, as a result, not enough therapy is done. Approximately 7.5% of asthmatic patients are now covered. It is identified to increase this number to 50% by 2025. To do this, they have provided a guideline for action on tackling NCDS in Rwanda, naming community action and engagement as essential to combating chronic respiratory disease in Rwanda by increasing early detection[5].

The most common asthma triggers are divided into two main categories: personal and environmental. Physicians observe the patients' factors and record data in their health records. Weather, air pollution, and pollen are among the environmental variables. Asthma attacks are primarily triggered by physiological vital signs, air pollution, and smoking [1],[4]. Due to physiologic vital sign changes and the weather change in the environment, people with asthma suffer the most and may become stressed if they do not receive immediate assistance.

Asthma is still a challenge in the healthcare system, as it is an incurable disease, but it can be manageable, and an asthma attack can be identified when a patient is likely to cough, wheeze, or feel breathing difficulty. However, clinical researchers have established systems that can decrease asthma attacks, such as inhalers, nebulizers, and herbal treatments that help asthma patients [6].

Even though this medication method has been adopted, it is not recommended to continue taking it as medicine. It may decrease lung function and make some people’s asthma worse. Asthma can cause the blood oxygen levels of a person to drop because it damages and irritates the respiratory system, so oxygen saturation contributes to determining asthma severity. If a person's oxygen saturation falls below 92 percent or rises, it indicates that they are suffering from respiratory failure and should seek medical attention as soon as possible [7]. To control the asthma severity in adults, the medical practitioner utilizes oxygen saturation as a key measure in distinguishing asthma levels[8].

Some asthma patients get unexpected attacks for different reasons, such as weather changes or allergic reactions. Controlling asthma attacks should also be a good way to help asthma patients with exacerbations. As asthma is a chronic disease that requires adaptation at home, it is possible to prevent attacks by practicing breathing exercises and taking fruits and vegetables as natural therapies to enhance human immunity. As well as maintaining a healthy weight, exercising regularly has also been shown to prevent asthma attacks. However, this method has been adopted, and there are no adequate methods for assisting asthma patients in the event of an unexpected attack that can be triggered by any factor at any time, such as a change in the weather, an allergic reaction, or any other sudden attack that may occur when the patient is unaccompanied [6]. Such a condition should be monitored and controlled by giving caregivers information about the asthma patient's status so that any support may be supported at the appropriate moment.

The Internet of Things, which allows the diagnosis of various diseases and health monitoring through miniaturizing devices such as sensors, network devices, communication systems, and software development, is a significant material and component used to control asthma attacks due to weather changes. The internet of things can contain a variety of applications, such as cloud storage, which increases the availability of data transfer. With the internet of things, there are also numerous ways to control the environment, the environment's surroundings, and weather changes, physiologic data of asthmatic patients[4].

The heart rate is also known as the pulse rate, defined as the number of pulses per minute. The normal pulse rate range is between 60 and 100 beats per minute for typical individuals. Adult males and females have resting pulse rates that are approximately 70 and 75 bpm, respectively.

Healthy adults' body temperatures range from 97.8°F (36.5°C) to 99°F (37.2°C) [9]. In common chronic diseases such as asthma, a temperature is a common symptoms , so it is very crucial to take a body temperature reading. In people with asthma, oxygen saturation is a critical element. The normal range of the human body's oxygen saturation (SpO2) is 95 to 100 %. If the SpO2 level of the asthmatic patient is low than 94%, they require immediate medical care (supplemental oxygen)[10]. For the proper monitoring of asthma patients and to avoid asthma attacks, it is vital to monitor early symptoms and signs such as temperature, cough, heart rate, SpO2, and environmental triggers that lead to asthma attacks.

Here we proposed a smart wearable monitoring system to monitor asthma patients' health conditions or keep track of their physiological behavior and weather conditions and send out alerts to medical personnel so that patients can get help and support in case an expected asthma attack happens.

1.2 Problem statement

The respiratory system is affected by a chronic illness known as asthma. Although it is incurable, proper asthma management can minimize the severity of symptoms, enhance general health, and reduce treatment expenses. Insufficient self-care management is the primary cause of asthma severity, which can limit daily activities, lower quality of life, and require less physical effort and entertainment [5] [12]. Uncontrolled asthma can lead to excessive use of rescue inhalers. This may result in increased immunity to medication, causing the dosage to be increased, which affects the user. Self-management is still essential for the proper management of asthma. Taking these factors into account, however, there are commercial wearable devices available for monitoring asthma, but their usage in medical research is currently somewhat limited [13].

According to digital health technology, embedded systems, microcontroller Wi-Fi-based sensors, smartphone applications, web applications, and the internet of things significantly impact the real-time monitoring of chronic diseases like asthma. These technologies include mobile internet and Bluetooth-connected devices. The self-management of asthma can be enhanced with this technology. Understanding the severity of the asthmatic problem inspired us to design and prototype a smart monitoring system to keep track of asthma patients.

1.3 Research Questions (Hypotheses)

1. How can an asthma patient monitoring tool be designed and developed?
2. How can an asthma attack be reported to clinicians?
3. How can the asthma monitoring prototype be tested to see if it satisfies the demands of patients with asthma?

I.4 Objectives

1.4.1 General Objective

This study aims to design a monitoring system that allows doctors and users to monitor heart rate, blood oxygen, level, and body temperature for asthmatic patients as well as the weather change and provide a notification

1.4.2 Specific Objectives

1. To design and develop a prototype system for asthma patient
2. To design an application-based user interface for system performance remote monitoring and send an SMS notification to caregivers in early warning (in advance) when the asthma attack is probable occurred.
3. To test the developed system

1.5 Study Scope

This research was conducted to design and develop a prototype monitoring system for asthmatic patients. Adult asthma patients with ages 45 and above who were being treated at Kibuye referral hospital were the primary concern of the scope. This research is based on an IoT-based real-time monitoring system to measure heart rate, oxygen saturation, and body temperature as physiological data for patients. Outdoor triggers, including humidity and air quality, were also studied. The data were analyzed using a web-based server. In this research, sensor data has been transmitted to GSM/GPRS protocol. The humidity and temperature sensors can record environmental conditions, the pulse oximeter sensor can measure pulse rate and $Sp0_2$, and an Arduino UNO microcontroller can take data from the sensors. Data from the microcontroller is transmitted to a web-based application for analysis and storage and sent to clinicians for additional analysis and prescription.

1.6 Significance of the study

The proposed system aims to assist an asthmatic patient by designing and developing a monitoring system to minimize some situations that make breathing difficult and detect early asthma attacks. An asthma patient takes measurements using pulse oximeter sensors and a temperature sensor. The system uses sensors and an ATMEGA 328 microcontroller to monitor heart rate, SpO_2, body temperature, humidity, and air quality, as well as the patient's specific location. The data from the sensor is transferred to a microcontroller, and all data is transmitted over Wi-Fi to a cloud server, after which it will be made available to patients and doctors via mobile applications and websites, respectively. The system is designed to offer quick and effective storage of patient information. The proposed system would send a notification to caregivers to alert asthma patients to an impending asthma attack so that any necessary assistance could be provided via SMS. Clinicians provide feedback to asthmatic patients, adjusting their behavior as necessary to maintain a good quality of life. This indicates that the caregivers and clinicians had real-time monitoring to make better clinical decisions on the treatment and care of asthmatic patients. This can be done to manage, and save unnecessary deaths, frequent hospitalization, and ill health as a result of poor monitoring of asthma patients.

The recorded information via the web-based application will help the clinicians in selecting the correct level and frequency of treatment and in taking action plans for self-management practices. Accurate knowledge of asthma will be crucial in both health education and research; it can serve as a baseline, particularly for future studies. E-health applications seek to enhance patients' quality of life while simplifying communication across various organizations that have an impact on patients' treatment plans. The data attained from the patient is essential for completing an electronic health record, making the right diagnoses, and creating future treatment plans.

1.7 Organization

This project starts with a general introduction that gives an overview of the project and other information. It ends with the conclusion and recommendation. It is divided into five chapters.

- The first chapter provides a general an introduction
- The second chapter discusses the literature review
- The third chapter talks about the Research Methodology
- The fourth chapter discusses with results and findings of the study
- Finally, the fifth chapter is about challenges, conclusion, and recommendations

1.8 Summary

By 2025, Rwanda's national policy and costed action plan aim to reduce NCD-related mortality by 25%. The majority of individuals with asthma in Rwanda do not receive a diagnosis and consequently have no treatment. Around 7.5 percent of an asthmatic patient is currently covered. Asthma can cause blood oxygen levels of a person to drop because it damages and irritates the respiratory system. It is possible to prevent attacks by practicing breathing exercises and taking fruits and vegetables as natural therapies.

Maintaining a healthy weight and exercising regularly have also been shown to prevent asthma attacks. The Internet of Things (IoT) allows the diagnosis of various diseases and health monitoring through miniaturizing devices such as sensors, network devices, and communication systems. There are numerous ways to control an environment, weather changes with the internet of things, and physiological data of asthmatic patients. The physiological data from patients are heart rate, oxygen saturation, and body temperature, which influence asthma attacks. In addition, in this project, we monitored environmental parameters such as temperature, humidity, and air quality are considered triggers of asthma attacks.

CHAPTER 2. LITERATURE REVIEW

2.1 Related work

The authors of the literature review have explained the living condition of an asthma patient and indicated that patients do not stick to medication rather than self-care practices to prevent asthma attacks [11].

The researchers have demonstrated that in-depth research into asthma control, poor adherence, asthma triggers, and inhalation techniques should be investigated [11] [14].

The spirometer and peak flow meter are utilized to detect any asthma symptoms or signs, which are traditional techniques for preventing asthma attacks. By measuring the airflow throughout one breath cycle, a peak flow meter is used to evaluate the strength of lung function. Peak Expiratory Flow Rate (PEFR), the recorded value from this test, is used to assess the severity of the patient's bronchial tubes and the level of airway obstruction [15]. Patients who use the device afterward adopting this method report feeling shocked, which is not always positive.

Spirometry is a non-invasive tool used to measure the breathing force of the lung. It involves breathing into a mouthpiece-shaped tube that is connected to a sensor that monitors airflow and force. The forced expiration volume for one second to forced vital capacity ratio (FEV1/FVC) variations are assessed during the measurement. An obstructive lung condition, such as asthma or chronic obstructive pulmonary disease (COPD), is indicated by a lower FEV1/FVC ratio [16]. A normal ratio is 70% to 80% in adults and 85% in children. There is a minuscule chance that you could experience an asthma attack during the test. A lot of effort put into breathing may sometimes result in momentary or permanent respiratory issues. However, the test can be carried out under medical guidance, which can assist in handling any circumstances that might arise [16]. When compared to the peak flow meter, the spirometer's measurement is precise.

Fractioned exhaled nitric oxide (FeNO) is a noninvasive marker used to monitor airway inflammation in asthmatic patients [17].

The Measurement of FeNO level was determined using an electrochemical portable analyzer that estimates the concentration of exhaled nitric oxide in parts per billion (ppb) classification of FeNO was categorized by the scale of low or intermitted / high (low <25ppb, intermediate/high,>25ppb). The method was achieved using a nose clip. The patient exhaled air from the lungs at a steady flow rate of 50mL/s for 10 seconds.[18]. During measurements, the normal exhaled NO (Nitric Oxide) values were defined at 5–35 ppb for healthy adults and 5–25 ppb for children[17]. This monitoring system is better to deal with asthma severity and safe but it is very expensive.

Raji, A, Kanchana, and Golda monitor the respiration rate using an LM35 temperature sensor and detect continuously patients' respiration based on inhalation and exhalation voltage, but the respiration was not predicted properly[19].

In line with digital health technology, embedded systems, microcontroller Wi-Fi-based sensors, smartphone applications, web applications, and the internet of things significantly impact the real-time monitoring of chronic diseases such as asthma. With this technology, the self-management of asthma can be improved[20]**.**

Tabarek has monitored asthma using a heart pulse sensor communicating with a microcontroller, where the data was transferred to an ESP8266 and the data was sent to a cloud database for further analysis. The heart pulse did not indicate the precision result[21]

R. L. Soiz explained how to identify and evaluate a patient with asthma who might benefit from omalizumab medication and determine the exact cost-effectiveness of additional omalizumab treatment[22] and cost between $500 and $2,000 per month[23]. This method was very costlier for low-income and middle countries where the medical system is under development.

E. A. Brooks, M. Massanari has used FeNO Monitor as a biomarker to identity asthma severity unfortunately the cost was very high and cost, current FENO monitor costs $2,400 [24], ToxCO Breath Analyzer is a noninvasive screen for CO poisoning through breath and ambient air testing, and there are so expensive. Khan explained that pulse oximeter devices are commercially available but too expensive for example a fingertip pulse oximeter, costs roughly 299 USD [9].

Abinayaa proposed an inexpensive asthmatic monitoring system that contains an activity sensor, gas sensor, humidity sensor, and temperature sensor. Clinicians can determine the patient's condition based on the detected data [25].

Safayat Reza Anan et al developed the Asthma Tracker app and website-based application for online tools for remote monitoring of patients 'health. This system was at a low cost, and provide satisfactory results but does not include the GPS for determining the location of patients[26].

Vasilateanu has designed an Asthmate application that is used to monitor environmental conditions. Asthmate provides benefits to both the individual and the community by presenting a web application that enables residents to monitor the quality of the air in their area. This paper had not focused on the physiological data of asthmatic patients.[27]

Lukyanov has presented an IOT based on health technology that connects sensors and devices. The data can be collected, kept, transmitted, and shared by these devices and sensors for classification and analysis, the main focus of this author is to increase the security of data collected by using the watermarking technique., on the cloud side, it helps to examine, store, monitor, and securely communicate patient data for medical recommendation. For security purposes, the patient respiration data are collected using a sensor encrypted by watermarking technique and then transmitted to a cloud server through a network connection. This author didn’t use real patient data[28].

K. Islam et al have developed an asthma monitoring device based on IOT components, physiological parameters such as heart rate, and oxygen saturation, and environmental parameters like ambient temperature, humidity, and air quality are monitored, they provide perfect results, but this system solution wasn’t measured body patient temperature[29]. According to this current asthma monitoring devices is very expensive, this indicates that it is a burden for low and middle-income countries to get appropriate monitoring devices due to the poorest living condition.

Sakat et al. have developed the Identi-Wheez device, a portable and inexpensive technology that promises to reduce the challenges of asthma diagnosis. It is made up of a hardware measurement system and an algorithm for diagnosing problems. Multiple stethoscopes have been used to collect measurements simultaneously and send them to the device. The recordings are then forwarded to a specialist who uses assisted diagnosis algorithms that allow auscultation (stethoscope listening for lung sounds) at any point in the lung volume by sound focusing. Additionally, the specialist is shown a sound "heat map" that displays the area of sound sources within the lungs. Additionally, attempts have been made to design systems that measure environmental factors like air quality and trigger alarms and alerts to improve the status of asthma patients [30].

This is still challenging for asthma management in low- and middle-income countries with low GDP. Even if there is no cure for asthma, we should implement mitigation measures to track and monitor it to avoid its progression. We proposed a low-cost monitoring system to monitor asthma symptoms that are composed of a pulse oximeter sensor, a differential pressure sensor, a temperature sensor, an air quality sensor, a humidity sensor, and a GMS module, in addition to using a global positioning system to track the current status and location of patients [31].

2.2 Existing Monitoring Technology for asthma management

Numerous technologies have been used in the field of medicine to track how asthma is treated both in hospitals and at home. These tools comprise visualization technologies that track asthma management while a patient is hospitalized and home-based programs that monitor asthma management at the patient's residence. These tools are designed to ensure that asthmatic patients are served as the national clinical guidelines are required. PFM is a tool that involves collecting measurements by patients and regular clinical assessment. PFM's utility in enhancing asthma control has been widely investigated and contested[32]. PFM measurements taken by asthmatic patients were inconsistent when compared to healthcare visits. The capacity of PFM to promote asthma control was doubtful. Spirometry is a non-invasive tool used to measure the lung's breathing force. The measurement taken by the spirometer is accurate when compared to the PFM. It is simple to provide remote asthma monitoring using a spirometer, but the challenge is the current high price of those products on the market [33].

Currently available products are expensive and have fewer monitoring parameters, such as the fingertip pulse oximeter WearO2 and the Vibeat wearable oxygen monitor, which record only blood oxygen and pulse rate. Due to the high cost of available product devices, we suggested designing a low-cost monitoring system and monitoring many parameters in a single package for tracking asthma symptoms that are made up of a pulse oximeter sensor, temperature sensor, air quality sensor, humidity sensor, and GMS Module. In addition to using a global positioning system to track patients' current conditions and locations.

According to Table 2.1, Tabarek designed a real-time motoring device for asthma patients using only a heart pulse sensor communicating with a microcontroller, where the data was transferred to an ESP8266 and the data was sent to a cloud database. The body temperature and SpO_2 sensors were not detected [21].

Table 2. 1: Comparison between proposed systems and existing asthma monitoring models

Parameters monitored and tool functionalities	IoT-Based Cloud Smart Monitoring for Asthma Patients[21]	Asthmate [27]	Asthma tracker app[29]	Identi-Wheez[30]	Asthma severity monitoring [34]	Proposed system
Heart rate	Yes	No	Yes	Yes	Yes	Yes
SP02	No	No	Yes	No	Yes	Yes
Body Temperature	No	No	No	No	No	Yes
Air quality	No	Yes	Yes	No	No	Yes
Ambient temperature	No	Yes	Yes	No	No	Yes
Humidity	No	Yes	Yes	No	No	Yes
GPS sensor	No	No	Yes	No	No	Yes
Alerts clinicians via SMS in real-time	Yes	No	Yes	No	Yes	Yes
Web-based application(Allow recordings for future uses)	Yes	Yes	Yes	Yes	Yes	yes
ECG and blood glucose monitor	No	No	No	No	No	No

2.3 Research contribution

In the management of chronic diseases, health monitoring tools have become increasingly important. In this study, we propose a real-time monitoring system for asthma in healthcare that can have positive effects on the patient's comfort. The system consists of hardware sensors, including a pulse oximeter sensor that detects heart rate and SpO2 parameters, a thermistor sensor that measures body temperature, and an air quality sensor that detects dangerous gases in the atmosphere. The system is based on the Internet of Things; additionally, this device includes a GPS module that tracks geolocation. It also includes a web application and a GMS/GPRS module for sending SMS notifications in the event of an asthma attack. The sensors detect vital physiological parameters from a patient and are remotely monitored in real-time by a doctor. The sensors are linked to a microcontroller, which processes and stores the data on the cloud platform. The implemented devices are low-cost compared to existing monitoring devices; they could use less power, which means that power saving is another feature of these devices. In comparison to existing devices, the proposed system is cost-effective, power-saving, and reports sensory data in real-time.

Table 2.1 shows a comparison of the sensors and other articles. Analysis reveals that some studies have only used one, two, or a maximum of three sensors, while others have only used application- or web-based sensors, but this system has used websites and GSM/GPRS modules with a total of six sensors to monitor six parameters, including a heart rate, SpO2, body temperature, air quality, ambient temperature, humidity, and determining the location of patients. When we compare this study to the other systems shown in Table 2.1, we can monitor more parameters.

2.4 Summary

Existing asthma monitoring systems are highly expensive, and due to the poor living conditions in low- and middle-income countries, it's been found that it is very difficult to afford the necessary monitoring equipment. In low- and middle-income nations with low GDP, managing asthma is still difficult. Even if there is no way to cure asthma, we should adopt mitigation measures to keep track of and monitor it to avoid its progress. We proposed a low-cost monitoring system to monitor asthma symptoms that are composed of a pulse oximeter sensor, a temperature sensor, an air quality sensor, a humidity sensor, and a GMS module, in addition to using a global positioning system to track the current status and location of patients.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Introduction

This chapter indicates the methods and approaches used to conduct the study that is outlined. This includes the steps undertaken to complete the study, the system design methodology, tools used in data collection, and prototyping of the proposed solution. This process normally involves creating conceptual models, methods, and qualitative and quantitative modeling strategies. The overall methods used to implement the "Design and Prototyping Smart Wearable Monitoring System for Asthma Patients" using IoT components. It contains the necessary hardware components and software requirements, key technologies used for their communication as a gateway used to send data, and the data types involved in this system. The sensors collect the data and send it to the microcontroller for processing, sending it to the system and providing desired outputs that can be notification messages or actionable decisions.

3.2 Research Process

The research process is crucial for emphasizing the workflow components, sequence phases, tasks, human abilities, and information and communication technology.

In this study, we used a qualitative research methodology, where participants were asked to express their feelings, perceptions, opinions, and experiences with asthma monitoring technologies together with those of the end user. We utilized a qualitative research approach to gather this data. Descriptive information is provided using the participants' own words, whether they were spoken or written. The audience's opinion on a given study or project is taken into consideration when choosing this strategy. The qualitative research design helped collect comprehensive data and information about asthma monitoring tools in Kibuye Referral Hospital. Here are the steps taken to design a prototype device.

Problem identification: This stage consists of identifying the root cause of asthma poor management, effective asthma management can lead to a reduction in asthma severity, improved overall health, and lower treatment costs. The main reason for asthma severity is inadequate self-care management. Commercial wearable devices sensor for monitoring asthma are available but use in medical research is still rather limited.

User requirement: This stage is used to collect information concerning the system to be developed. Data is gathered from caregivers or asthmatic patients as well as end users.

System design: This stage consists of system architecture, components, modules, interfaces, and data.

System development: This stage deals with the actual programming and integration of several system components.

Testing: This consists of evaluating the functionality of the prototype and adjusting it to meet the requirement of asthma monitoring devices. The process was repeated until the result satisfied the needs of the users.

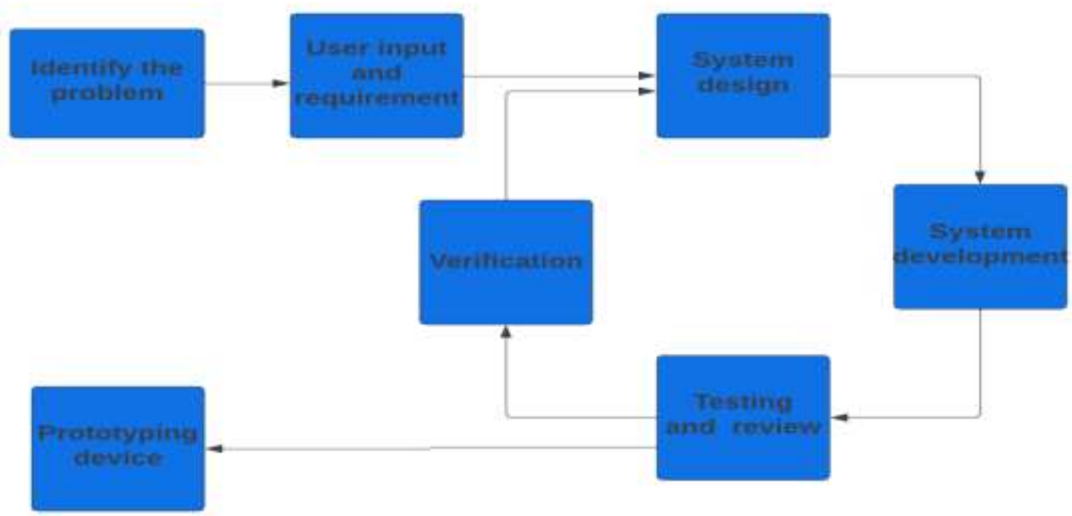

Figure 3.1. Research process [31] Source: Own Drawing

3.3 Proposed System

The proposed system, namely Design and Prototyping Monitoring System for Asthma Patients. This system consists of various sensors interfaced with the microcontroller. The microcontroller gets the results from various sensors and sends them to the web based-application system through a GSM internet connection for further analysis. The developed system systematically monitors the parameters to get down various results so that early detection of asthma symptoms is possible. The block diagram of the proposed system is shown in Figure 3.2 below:

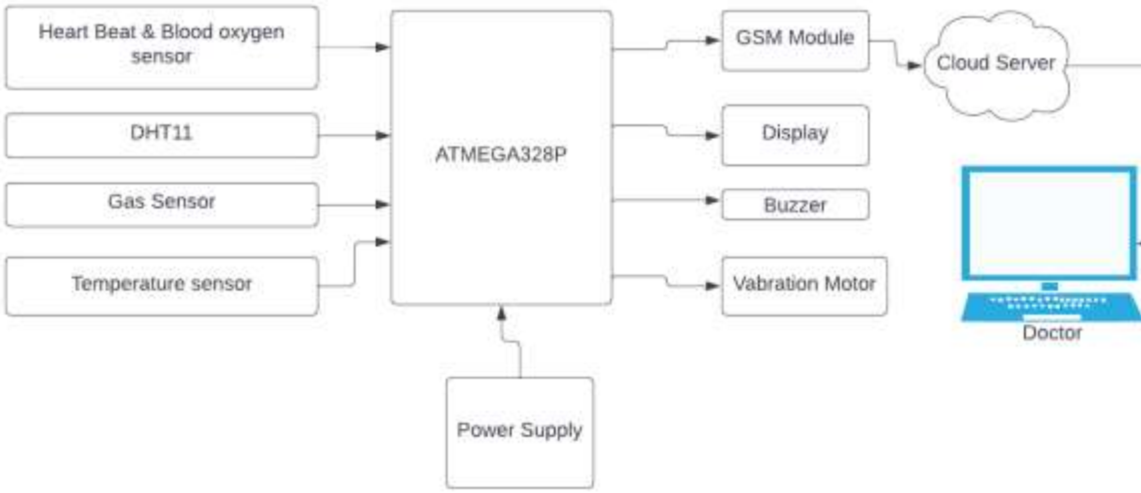

Figure 3.2. Proposed system block diagram

1. **Power supply:** The power module has a rectifier, which is an AC-to-DC converter, and a battery power bank. The battery is used to maintain a constant power supply when there is no main power. A power supply is there to give the capacity to scale sensor and controller modules, which will work at 5V.
2. **Sensing part**: The sensor module comprises four sensors, such as a heartbeat sensor, a DHT11 sensor, a gas sensor, a temperature sensor, and GPS. These sensors are connected to microcontrollers as input parts and are used for detecting asthma patient parameters from time to time**.**
3. **Controller module:** It is the brain of this architecture. The ATMega 328P is used as a controller and GPRS as a gateway device. This controller module is low-budget. The GPRS system sits on top of the TDMA and GSM networks to provide subscribers with an uninterrupted data connection instead of a dial-up connection. This allows subscribers to access data without having to dial in and authenticate. A packet control unit is present in

a GPRS cellphone. This control unit provides a bridge for data to travel across mobile networks and the Internet by making use of radio channels.

4. **Output module:** Design and Prototyping Monitoring System for Asthma Patients have a web application as the first output part by using their mobile phone, tablet, or computer. An authorized person in the control station will receive SMS notifications, collect data, and output a decision made after data analysis. The OLED display displays on the screen. The third part is that the alarm system will use the buzzer to make a loud noise with a vibration motor when there is an abnormal situation for an asthma patient.
5. **Storage module:** Cloud storage is a server; it is a service model in which data is sent and stored on distant storage systems before and after data analysis, where it is retained, controlled, backed up, and made accessible to users over a network; it will store all the data gathered and transmitted by the GPRS module.

3. 4 System operation

The proposed system design is based on Figure 3.1, which has three primary sides: a sensing side, a controlling side, and an output side. The sensing side is composed of a pulse oximeter, a body temperature sensor, a humidity sensor, and an air quality sensor. The controlling side is composed of an ATGMA 328 and a cloud server for data analysis. The output side is made up of the GSM module and LCD for notification and displaying a message.

In this system, sensors are attached to the patient, and they gather the needed data, as indicated by the direct connection of the sensors to Arduino and SIM 800L. The data is then analyzed and sent to a web app that interacts with the cloud server. An internet connection is necessary for sending data to the web application database using Arduino and SIM-800L. The sensor's data is delivered to a web database, where it is saved for future purposes and predictions as well as shown on an LCD.

A patient can measure their pulse rate, oxygen level (SP02), respiration rate, humidity, temperature, and air quality via sensors. The measurement is processed by a microcontroller, analyzed by a cloud server, and saved to a database; the result is displayed on an LCD monitor, and the result will be transferred to the doctor or clinician, who is capable of reviewing it regularly, adjusting treatment according to the changing severity state, and giving medicine prescriptions and advice.

The main component of this work is an ATMEGA328 microcontroller compatible with the Arduino Integrated Development Environment (IDE), which controls the whole process. The pulse oximeter sensor and body temperature sensor are used to collect data from patients. The DHT sensor and air quality sensor are used to collect data from environmental factors that may trigger asthma attacks.

The physiological data of asthma patients, such as oxygen saturation and heart rate, are important parameters that should be measured by using a pulse oximeter. The pulse oximeter is placed on the finger at regular intervals, and the sensor can record both the oxygen saturation and pulse rate of asthmatic patients. There are also external factors such as environmental conditions (temperature, humidity, and air quality) that are considered asthma triggers. GSM/GPRS was utilized to set up a connection to the cloud, allowing the linking of a web application to assist in visualizing and analyzing the real-time data gathered by the sensors. GSM was also used to send SMS alert notifications to doctors or caregivers.

3.5. Hardware components

3.5.1. Arduino UNO

The Arduino UNO is essentially an ATmega328P microcontroller with 13 digital input/output pins, 6 analog input pins, 6 PWM output pins, and a 16 MHz crystal oscillator. The USB power jack is used to supply the board with electricity. Arduino is used for linking with digital devices and other kinds of sensors [35]. A USB cable is interfaced with serial communication to load the program from the system. Along with the embedded C language, we use it for real-time monitoring and value conversion. The key component for overall implementation is a microcontroller known as the ATMEGA328P, which has high performance and low power consumption for an 8-bit AVR microcontroller. It can normally be used as a processor in Arduino boards such as the Uno [36].

Figure 3.3. Atmel ATMEGA328.

Technical specification:

IC type: AVR microcontroller Core size: 8-bit

Speed: up to 20MHz Number of I/O: 23

Program memory size: 32Kb (16K x 16)

Program memory type: Flash EEPROM size: 1K x 8

RAM size: 2K x 8 Operating Voltage Range (V): 1.8 to 5.5V

Temperature Range-40 to 85deg

Manufacturer: Atmel, Manufacturer part number: ATmega328P[37]

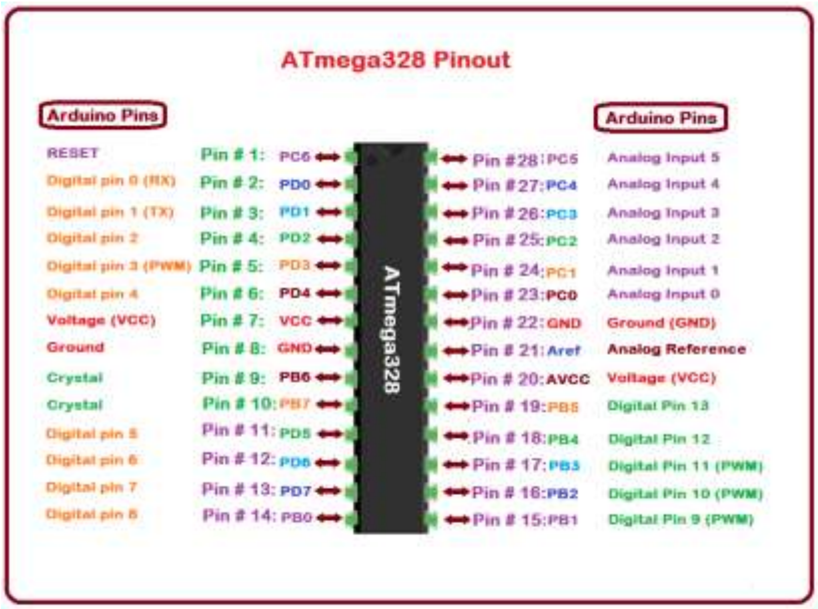

Figure 2: Pinout configuration of ATMEGA328[37]

The pin-out configuration is detailed in Figure 2. The configuration of these pins facilitates the use of protocols and functions in programming. For instance, interrupt pins and digital I/O pins may use the same protocols and operations.

The C, C++, or other language-written program is loaded into the microcontroller to communicate with input data and outputs (the display, buzzer, and other hardware devices and systems). It is now time to discuss other system components (display, input, and output devices) that are added to the microcontroller to ensure appropriate program execution.

3.5.2 Input, output, display unit, and gateway hardware

The sensors for data input and the general operational display. The SSD1306 0.96-inch I2C OLED display, the MAX30100 sensor that measures the heart rate and blood oxygen levels, the DHT11 digital temperature and humidity sensor, the thermistor for measuring body temperature, the MQ135 sensor that measures the level of atmosphere gas, the air pressure sensor that is responsible for measuring breath rate, and the buzzer 3V-5V for producing sound alert output are the different types of devices for the display.

2. **Organic light-emitting diodes (OLEDs)** are digital displays on devices like screens.
The technical specification, OLEDs, LCD type: OLED, Operating Temperature -40 to +80 ℃, and Supply Voltage: -0.3 5.3 V[38]

Figure 3.4. SSD1306 0.96 inch I2C OLED display

3. Pulse oximeter (MAX30100)

A pulse oximeter is a non-invasive sensor that is used to assess a patient's blood oxygen saturation and pulse rate. The MAX30100 is a sensor with a pulse oximeter and a heart rate monitor built-in. It has a voltage range of 1.8 to 3.3 V. (volts). The sensor has a quick data output rate and a high sample rate [26].

Figure 3.5. MX30100 sensor

4. DHT11 Sensor

The DHT11 is a Humidity and Temperature Sensor that produces a calibrated digital output. Any microcontroller can be interfaced with the DHT11. It has a humidity sensor and a thermistor that measures the surroundings and produces a digital signal on the data pin. The DHT11 is a low-cost humidity and temperature sensor with excellent long-term stability and reliability. It is simple to use, however, it takes longer to find data.

Figure 3.6.DHT11 sensor

Thermistors are available at a reasonable price, and precise components that make obtaining temperature information for a project. Its resistance is a function of temperature. By monitoring the resistance of the thermistors, this function allows us to measure the temperature or change in temperature

Figure 3.7.Thermistor sensor

7. MQ125-Air quality sensor

MQ135 sensor is an adjustable comparator circuit using an LM393 IC which detects alcohol, CO_2, Smoke, and other gas.

Description

1. MQ135 sensor coupled with an adjustable comparator circuit using an LM393 IC.
2. Detects Ammonia (NH_3), Benzene, Alcohol, CO_2, Smoke, and others in the air.
3. Designed to interface to an Arduino or other microcontrollers.
4. Power: 5VDC
5. LEDs for Output and Power status indication.
6. Detection Zone: 10-300ppm[39]

FIGURE 3.8: MQ135 sensor

8. Global Positioning System(GPS)

GPS is a system that uses satellite data to pinpoint an earthly position and assist travelers in finding their way to their destination and location. GPS uses a satellite navigation system to determine the location of individuals anywhere on Earth.

The NEO-6 module series is one of the stand-alone GPS receivers with a high-performance 6 positioning engine, and the time to first fix is under 1 second. This GPS is designed with technology to suppress jamming sources and multipath effects and work in the most challenging environments. The SPI interface allows for the connection of external devices with a serial interface.[40]

Figure 3.9: GPS NEO-6 modules.

The module has 4 pins:

- VCC**:** Power supply
- GND**:** Ground
- RX**:** Receiver
- TX**:** Transmitter

Specification[40]

- Power supply voltage: -0.5 to 3.6 V
- USB supply voltage: 0.5 to 3.6V
- DC current 10mA
- Storage temperature: - 40 t0 85 ℃

3.5.3 Cloud computing and data communication system

The continuing research uses cloud computing resources for quick operation execution because ATMEG's capabilities (processing hardware resources, memory, and storage) are constrained. Cloud computing technology makes it possible for users to access computer system resources (such as storage, processing power, databases, networking, analytics, artificial intelligence, and software applications) on demand without having to actively manage themselves. For data connectivity in the study, GSM SIM-800 and GPRS technologies will be used. The GSM SIM800 is a cellular communication module that provides an internet connection through GPRS, makes calls, and sends email and SMS texts. General Packet Radio Service (GPRS) is a method for sending and receiving data via 2G and 3G cellular communication networks on the global system. It operates on voltages: of 3.6 to 5.20 Volts and Operating Current: of 1 to 2.5 Amps[41].

Figure 3.10: GSM800 with GPRS modem and antenna

The data collected through the sensors and associated employee conditions (normal or not normal) are stored and analyzed on the cloud.

3.6. Software of the proposed system

The software development methodology for the design of an IoT-based system for monitoring asthmatic patients and providing warning alerts to the concern.

A. Arduino IDE

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions, and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.

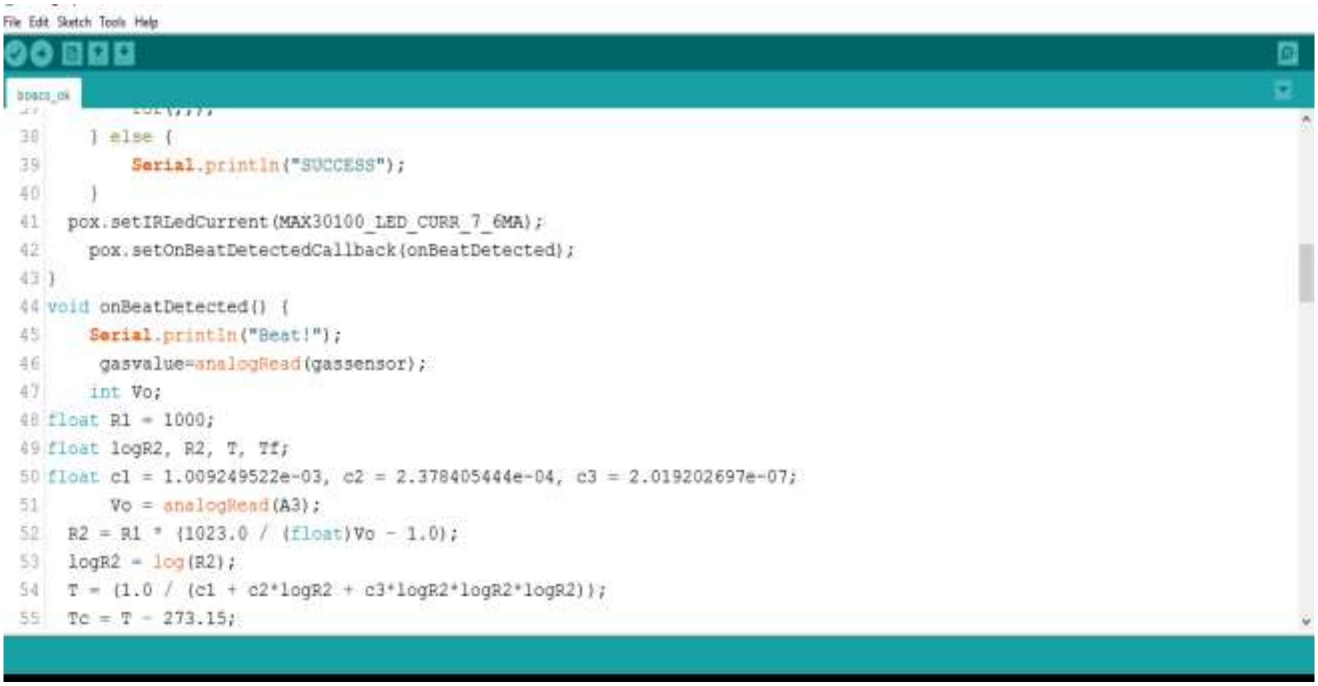

Figure 3.11: Program in Arduino IDE

B. Software Algorithm

The following describes the algorithm used by the program to identify and analyze asthma symptoms:

- Add header files and macros for starting serial communication and connecting sensors, an LCD, and other devices.
- Set up the GPIO header's connection to the GSM module.
- Initialize the ADC to obtain the sensor output analog values.
- Set aside digital and serial ports to use for sensor data collection and transmission to the physician side.
- Check the heart rate, SpO2, and body temperature values.
- Get the temperature, humidity, and volatile gas values from the respective sensors.
- The physical activity of the patient is sensed by the activity sensor.
- The sensed data from the patient side is sent to the doctor through GSM.

The message sent to the doctor has been received for further processing and examination

The flow chart

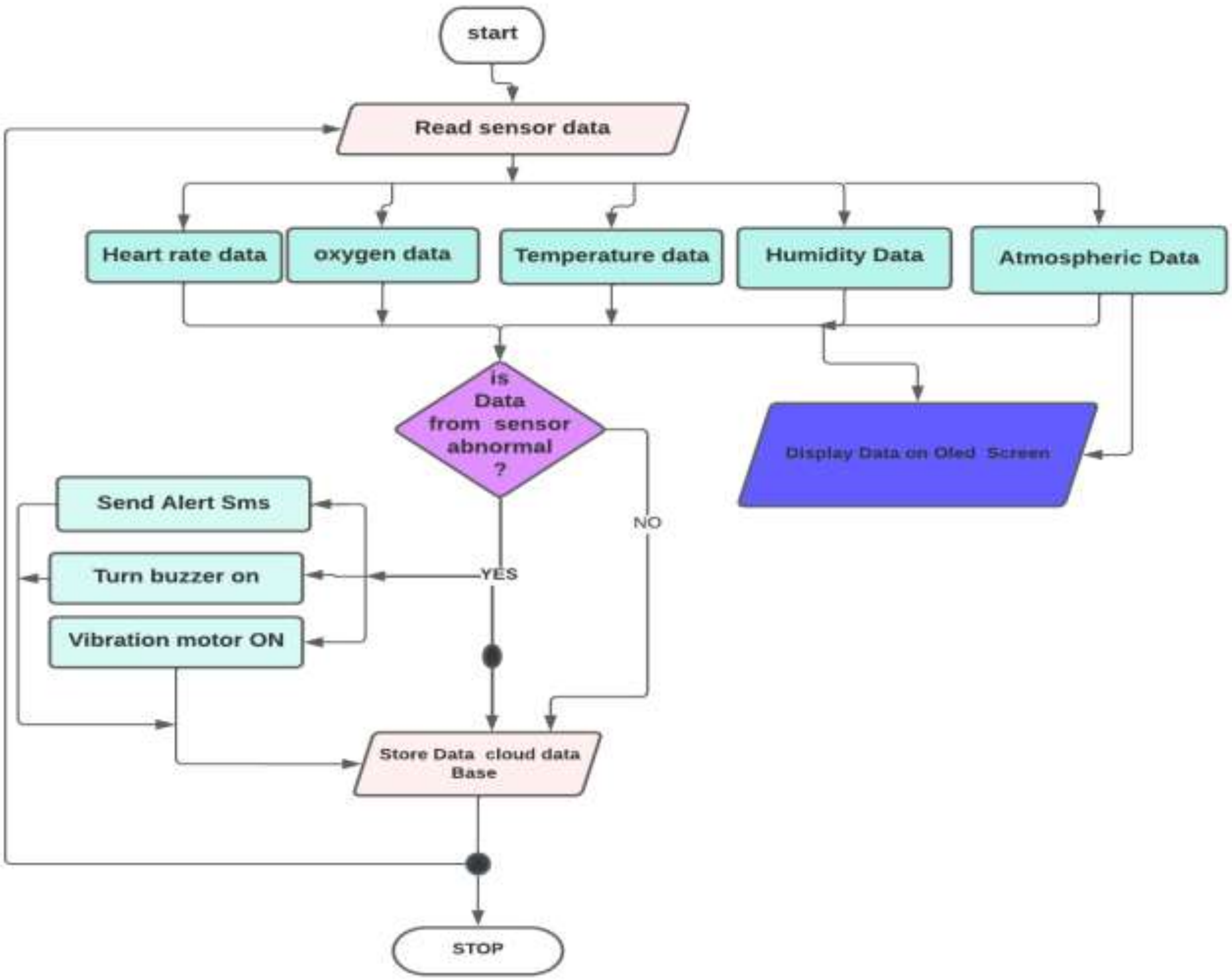

Figure 3.12: Flowchart of the system.

The overall data collection and input-output operations for the display and communication messages are done on this part. Cloud computing technology provides essential resources to record data and performs the basic analysis.

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Figure 3.13 indicates a prototype system consisting of all components connected using the Easyeda circuit simulator

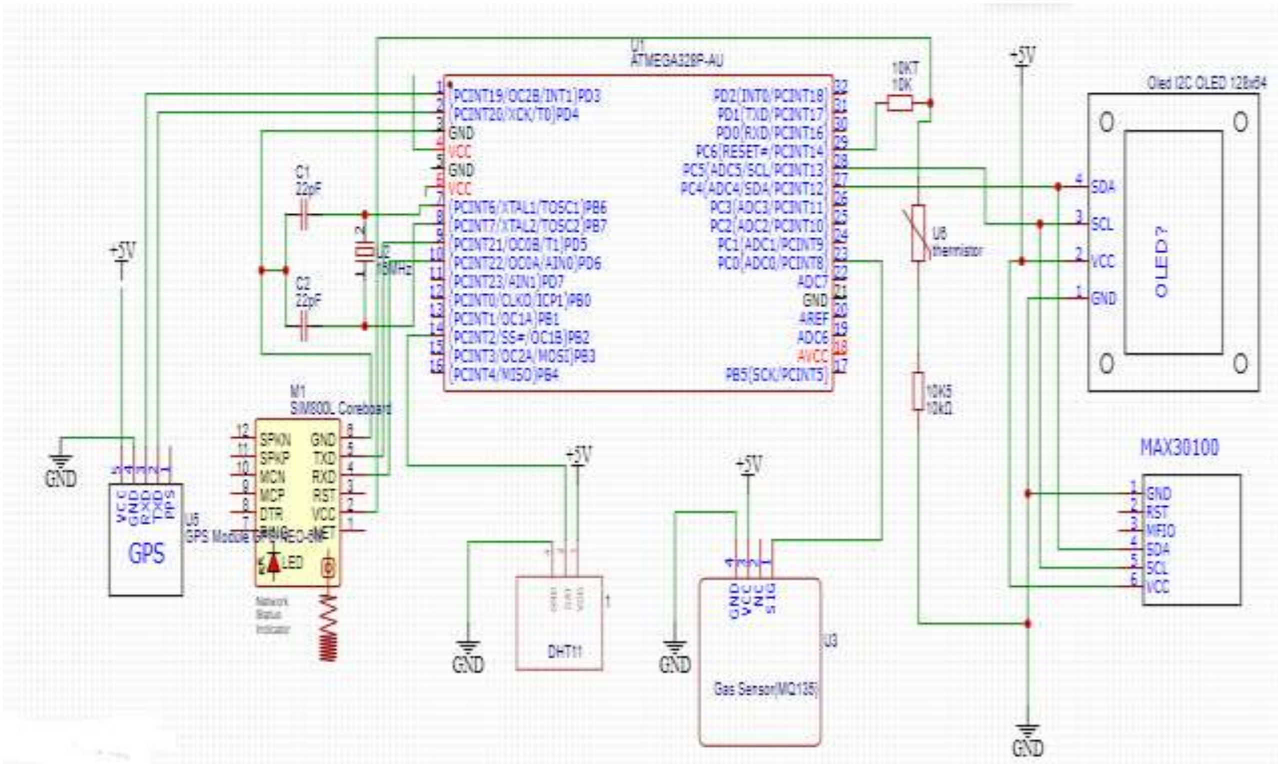

Figure 3.13: Prototype circuit diagram

3.7 Summary

This process normally involves creating conceptual models, methods, and qualitative and quantitative modeling strategies. The overall methods used to implement the "Design and Prototyping Monitoring System for Asthma Patients" using the IoT components. It contains the necessary hardware components and software requirements, key technologies used for their communication as a gateway used to send data, and the data types involved in this system. The sensors collect the data and send it to the microcontroller for processing; they then send it to the cloud platform via the GSM network and provide desired outputs that can be notification messages, after which actionable decisions are taken.

This involved tasks like reading component datasheets, journals, the internet, and reference books, all of which were important to the project's success.

The Microchip Studio environment, the Arduino Development Environment, and the Easyeda circuit simulator can be used to simulate the monitoring system.

CHAPTER 4 PROJECT RESULTS AND IMPLEMENTATION

4.1 Introduction

The findings for the solution are presented in this section, the prototype results are given and discussed, and then the prototype results. Also included a description of the objectives and a system performance analysis.

The proposed system prototype was designed using an Arduino Uno, MAXI30100, DHT11, GPRS/GSM, Gas sensor module, GPS, and LCD. All of the components were connected properly and logically. Using the Arduino IDE software, the program codes were uploaded into the actual Arduino Uno board hardware. Additionally, a web application was established to serve as the user interface for information visualization and the database for patient data storage.

4.2 Prototype circuit diagram

The implementation system consists of hardware and software components.

Hardware modules have five modules, the power module, the sensor (input) module, the controller module, the gateway module, and the output module.

Implemented Power Supply: The power module has a rectifier as an AC-to-DC converter power supply with 12 V DC. By using a regulator, we get 5 V to supply all parts of the system (sensors, controller modules, and gateway modules) at 5 V.

Implemented Sensor Part: This part comprises four types of sensors: the MAX30100 pulse oximeter heart rate sensor, temperature sensors, humidity sensors, gas sensors, and pressure sensors. These sensors are connected to the microcontroller as an input part and are used for detecting the patient's parameters from time to time.

Controller module: It is considered the brain of this architecture. An Arduino-based Atmega328p microcontroller is used as a controller.

Gateway module: A GSM/GPRS module is a unique kind of device that accepts a SIM card and uses a mobile operator subscription to operate. To upload data to the web server, this system utilizes the GSM/GPRS module.

A display screen can be seen on the output module. The Arduino IDE is the program used for hardware.

The system was built and tested; figure 4.1 depicts all of the components that were used to create the device. The physical circuit indicates how connections are made.

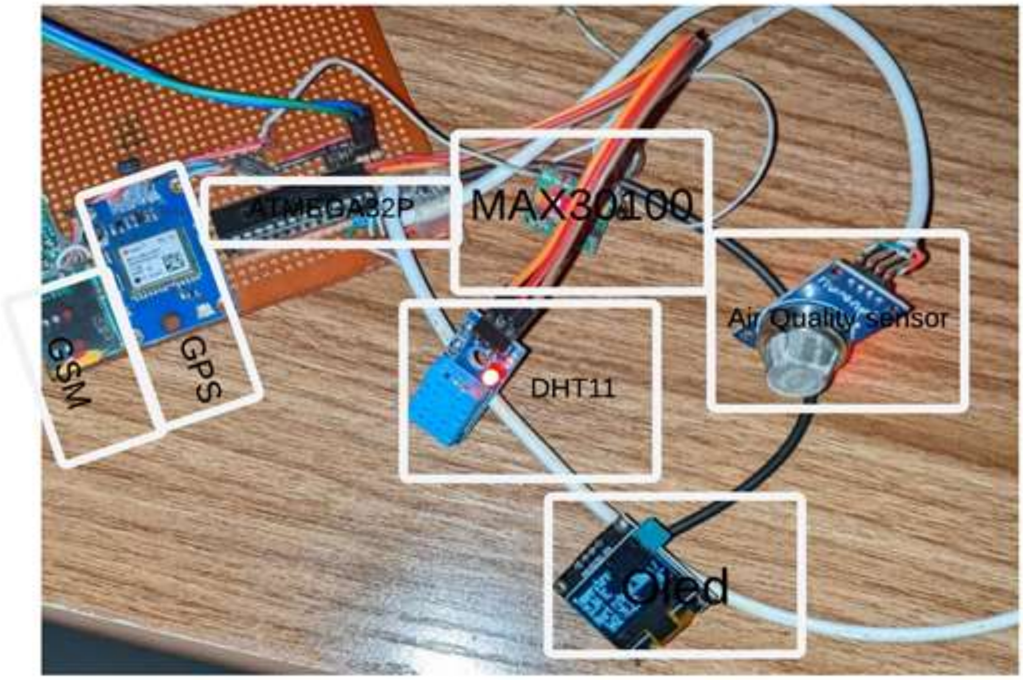

Figure 4.1: Prototype hardware photo

4.3 Discussion and results of the analysis

The implemented application stores data in the cloud and different analyses can be accessed by providing a username and password using the following login form:

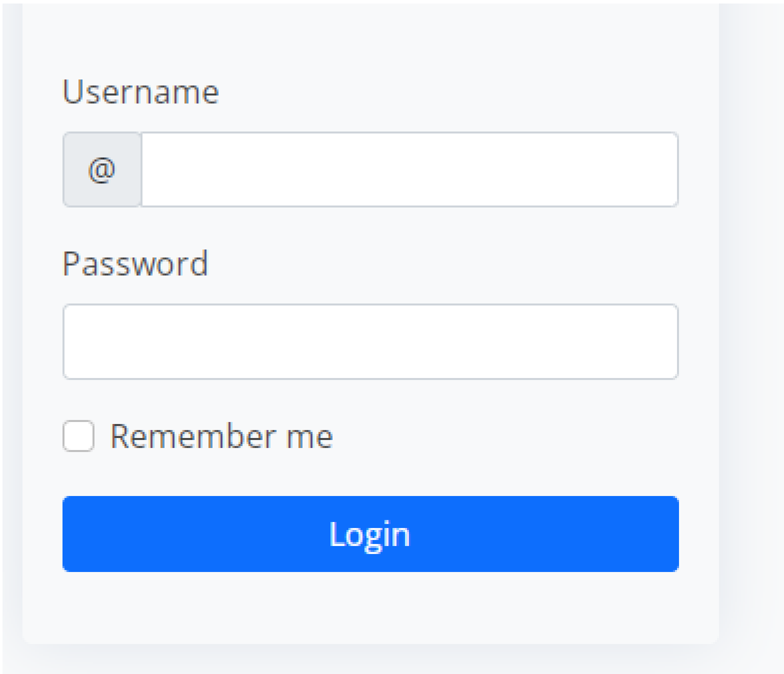

Figure 4.2: Login

The above login page allows a registered user to access the application by entering their username and password.

After measuring patients, the data of patients are forwarded into the system via the internet. As following in figure 4.4

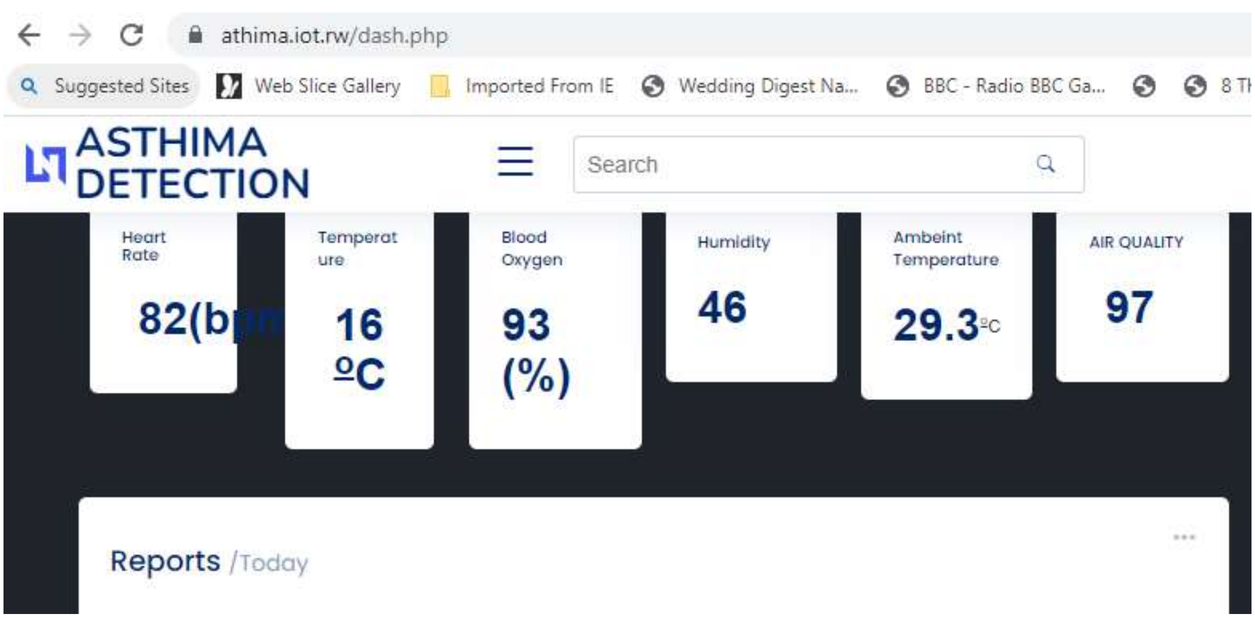

Figure 4.3: all data on the dashboard

4.1 Functionality testing

The functionality tests have been performed by the designer to make sure that all parameters were addressed and the system satisfied the study's main objectives. The functionality testing was crucial in ensuring that the system operated properly and that the customer requirements were fulfilled.

According to figure 4.1 of heart rate and blood oxygen saturation, real-time monitoring of asthma patients has been accomplished. The data is displayed on the dashboard via the web application when the proposed circuit is activated on. The expected results have been achieved to at least 98.8%, with minor errors due to network connectivity, sensor sensitivity, and capability.

Heart Rate Parameter: The heart rate sensor measures pulse rate properly and provides results according to human subjects' status; it works well. If results go beyond the recommended range, i.e., the normal heart rate indicated in table 4.1, the system sends a notification message to doctors as well as patients based on the heart rate sensor data and a patient's previous monitoring report stored in the web application server. A doctor can write a prescription.

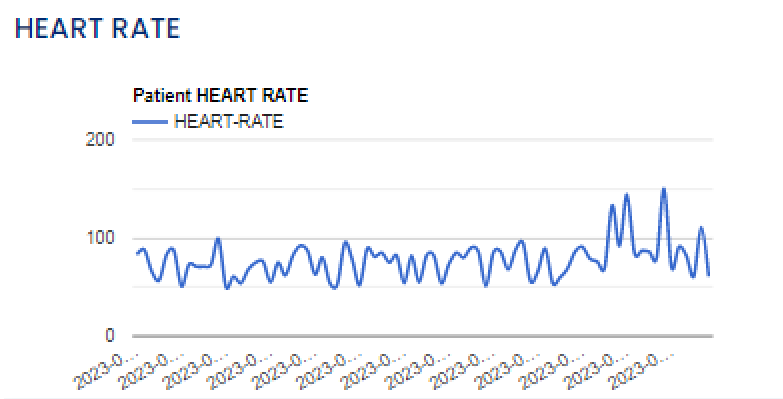

Figure 4.4 Heart rate measurement recorded.

Blood oxygen saturation (SpO2) parameters: According to the figure and patient motoring report, SpO2 is close to normal, ranging from 94% to 100% for health subjects [29], with only a minor change and delay due to sensor sensitivity and network connectivity.

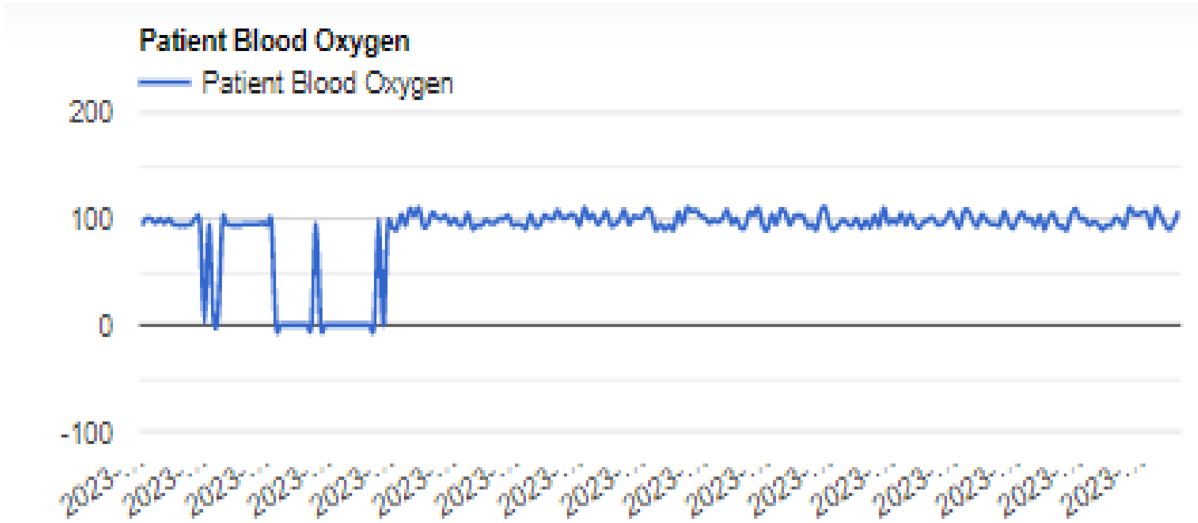

Figure 4.5:SpO2 Measurement.

Body temperature parameters: the result obtained for parameters was not accurate, but it began measuring the expected result for human subjects, but accuracy was lost. Below, there is a figure of body temperature on a graph.

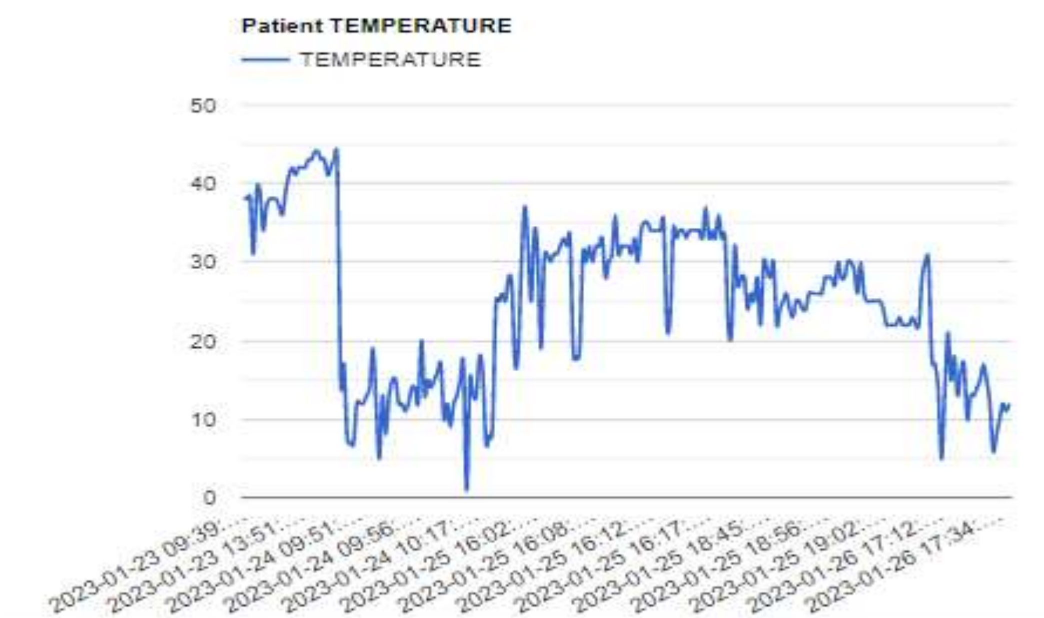

Figure 4.6: Body temperature

The chart below shows atmospheric data, which contains the atmosphere's air quality, ambient temperature, and humidity.

The same graph combines air quality, ambient temperature, and humidity parameters. The patient monitoring report indicated the result varies from 80 to 150 ppm, this indicates that the air quality index classification is in the range of unhealthy for sensitive groups. This means the result is accurate for the air quality index in the region of Kigali. Although the air quality is good, a very small proportion of people may breathe in certain pollutants and have mild health concerns.

When the AQI falls between 101 and 150, it is considered "unhealthy for sensitive groups," as indicated by the orange color. The general public is unlikely to be affected, however, individuals with lung conditions may be greatly at risk from exposure to ozone. [42].

The results obtained for ambient temperature are accurate when compared to the normal value presented in Table 4.1, and humidity is within the range

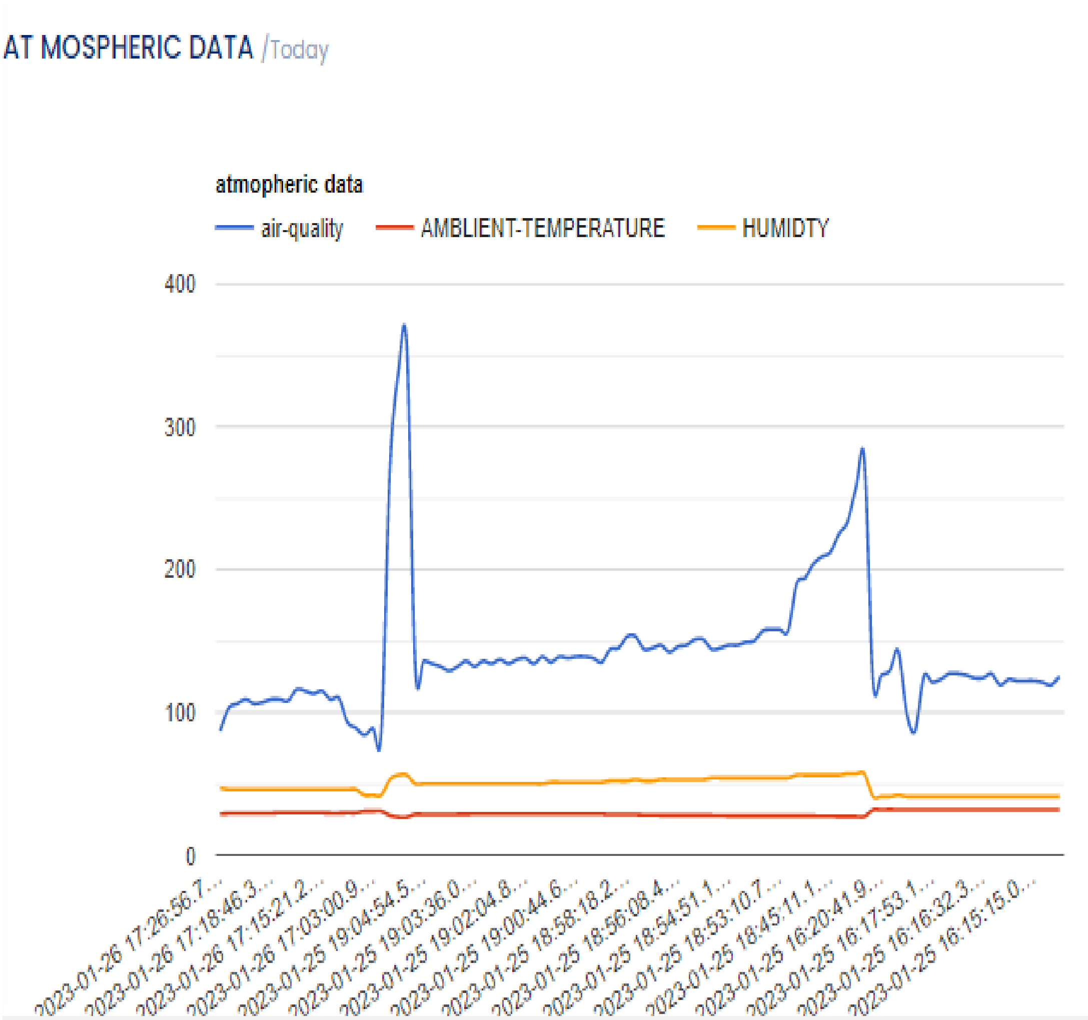

Figure 4.7: Summary Report for the System of atmospheric data

Table 4. 1: average of temperature, heart rate and SpO_2, and air quality [29]

Parameters	Average normal range
Heart rate	70-100 BPM(6-15) 60-100 BPM(18 and over)
SpO_2	95 to 100%
Body temperature	36.1-37.8℃
Ambient temperature	20-25℃
Humidity	30-70% based on temperature
Air quality	50ppm(good), 51-100(Moderate), 100-150 (Unhealthy for Sensitive Groups) 151-200 (Unhealthy)

The table4.1 is indicated a standard average range for body temperature, heart rate, blood oxygen saturation, humidity, and air quality. This serves as a standard, for the accuracy of the device to refer for it.

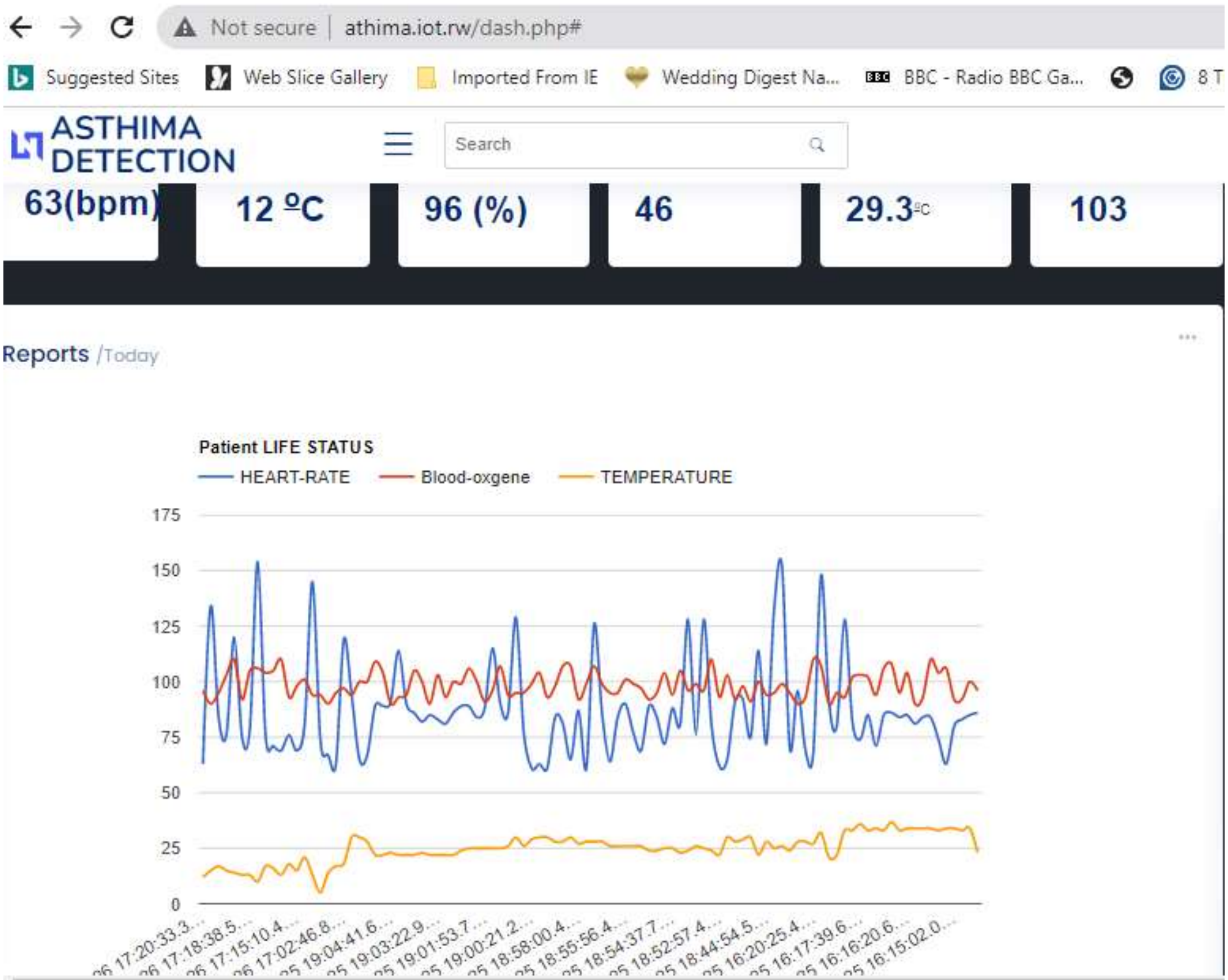

Figure 4.8: Summary Report for the System.

The above figure is a combination of all parameters (temperature, humidity, air quality, atmospheric data, and heartbeat) on a single dashboard. Doctors can analyze them independently, and the system generates a final result.

The data that was recorded for heart rate, oxygen saturation, body temperature, air quality, ambient temperature, and humidity measurements are shown in figure 4.2

Table 4. 2: Data Report on the System of recording the parameters of some users.

ASTHIMA DETECTION

Search

Patient Monitoring Report

10 entries per page

Search...

#	Patient Id	Heart Rate	Temperature	blood Oxygen	air-quality	amb-temperature	humidity	location	Time
#2457	PP- 37368	87	12 ºC	92	84	26.9	47		2023-01-26 17:35:36.865104
#2457	PP- 67372	127	11 ºC	93	88	26.9	47		2023-01-26 17:35:24.842025
#2457	PP- 97376	90	12 ºC	106	91	26.9	47		2023-01-26 17:35:05.885592
#2457	PP- 127380	65	10 ºC	97	86	26.9	47		2023-01-26 17:34:56.713387
#2457	PP- 157384	142	8 ºC	97	91	26.9	47		2023-01-26 17:34:37.994513
#2457	PP- 187388	145	6 ºC	107	87	26.9	47		2023-01-26 17:26:56.764846
#2457	PP- 217392	63	12 ºC	96	103	29.3	46		2023-01-26 17:20:33.317242
#2457	PP- 247396	134	15 ºC	90	106	29.3	46		2023-01-26 17:20:17.502713
#2457	PP- 277400	84	17 ºC	95	109	29.3	46		2023-01-26 17:20:03.557194
#2457	PP- 307404	76	15 ºC	103	106	29.3	46		2023-01-26 17:19:42.982333

This data report lets you see all the updates from your patients. These data reports can answer basic health questions for each patient. The obtained measurement for heart rate is the range between 60 to 100 bpm if it does include in this range, it means that the system provides a warning alert that may indicate that asthma attacks may arise, and it is urgent to communicate with doctors for analysis and advice. This is applied to all parameters during the measurements and notifies a doctor and user if the measurement obtained is out of recommended range for human healthy subjects.

If we compare the obtained value from table 4.2 to the standard value parameters in table 4.1 for normal subjects, it is clear that the result obtained is near the standard value.

Referring to Table 2.1, our approach performs some functions compared to related work in the following ways:

1. In contrast to other systems that do not employ IoT technologies, our solution uses an inexpensive and cost-effective material technology to monitor asthma.
2. In contrast to some systems, ours has an alert system via GSM notification for asthma attacks.
3. Our approach also makes use of a GPS to locate asthmatic patients.
4. Because this asthma monitoring system is used everywhere and stores data in the system, the database can be used in asthma policing to establish asthmatic patients' weekly, monthly, and annual report status.

CHAPTER 5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this research, we suggested asthma monitoring devices for asthma patients that gather physiological data, including heartbeat, SpO_2, and body temperature, and are also used to monitor environmental parameters using sensors like air quality, temperature, and humidity. Unlike current methods, this method would allow early detection of asthma attacks based on people's physiological data and the surrounding conditions. An asthma patient monitoring system is a proposed solution so that patients can be constantly monitored. It is a method that enables asthmatics to focus attention on their vital signs and environment. Based on the results, the heart rate ranged between 60 and 100 BPM for a normal person, but beyond this recommended range, it was classified as abnormal, indicating the possibility of being attacked by severe asthma. For $SpO_{2,}$ the obtained results indicate that it was in the recommended range, which lies between 95 and 100% for a normal person; otherwise, it is seen that you may have a chance of having asthma attacks. Body temperature results were real and compatible with the normal range.

The measured data is transferred to cloud storage, where clinicians can then see it on websites via internet connectivity. This system is used to monitor the asthma attack, and the system sends information to the doctor via GSM or GPRS for notification. Both doctors and patients can communicate with each other through websites or SMS notifications. Doctors can also write prescriptions for patients. The heart rate, SpO2, and body temperature of a human being can all be measured by the suggested system in real-time. It can also gauge the surrounding environment's temperature, humidity, and air quality. It might reveal where patients are located.

During the testing period, this device worked perfectly and displayed pin-point accuracy. The proposed system was tested on many individuals to demonstrate the device's performance, and the accuracy was very close to perfect. Temperature and humidity were also tested using fire and wet towels. Smoke is another indicator of the stark differences in air quality.

The results of this study have demonstrated that the proposed system has to quantify the location of an asthma patient and its status, whether it is healthy or attacked by asthma. The result is efficient and reliable.

During the project implementation, we faced the challenge of lacking sensors compatible with medical sensors in a reasonable timeframe because we couldn't find them in the Rwandan market and had to order them from somewhere else. Once again, calibrating those new market sensors was really

We successfully developed and implemented a real-time asthma monitoring system in this study. The end was nearly perfect. This was therefore influenced by the design and prototype of an asthma monitoring device as a remedy to fill the gaps in the management of asthma in Rwanda.

5.2 Recommendations

We recommend that future research emphasize the data security issue. Here are some ideas to incorporate in any future work: Once fully implemented, video calls and cameras can be integrated into the system for precise treatment and prescription, as well as quick information on ongoing activities.

The system's robustness, the data's accuracy, the wireless network function, and the device's size are some of the things that could be improved in the future.

Future improvements to this device could enhance its robustness system, the accuracy of the data provided by the sensors, its ability to operate on wireless networks, and the size of the device.

1. The system's robustness can be improved by changing the hardware design, as detailed below.

- Integrating power supervisory circuits to turn off devices when a power outage or low battery is detected one example of a circuit suited for monitoring the power supply is the ADM 708 supervisory circuit. It can be linked to the sensor's power supply so that it can continuously check the voltage. If the voltage falls below 5 volts, the supervisory circuit provides a reset or delay to power up the sensor.
- A TVS (transient voltage suppressor) could be added to protect the suggested circuit from overvoltage.
- Along with an ESD protection circuit. It is advised to use the SRV05-4 because it can shield critical components linked to data and transmission lines from overvoltage produced by lightning, electrical rapid transients, and electrostatic discharge (ESD).

2. The dimension of the device could be decreased by optimizing the hardware printed circuit layout design.

We suggest that the center could fund research early on so that a student has time to conduct in-depth research that can benefit the community rather than the academic field. We have found that some projects (typically those involving medical equipment calibration issues, data collection, or the collection of large amounts of data) require more time than we have.

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APPENDICES

Table 6. 1: Components required

Number	Name	Specification	Quantity
	ATMega	ATmega328 DIP-28 Microcontroller Pre-loaded with Arduino UNO 16 MHz Bootloader CON22	1
	Ic holder	16 pins	1
	Oscillator	SMD Crystal 16 MHz CR44	1
	Capacitor	Capacitor 22 nF	2
	Arduino	Uno R3	1
	Humidity sensor	Digital Temperature Humidity Sensor Module DHT11 MOD56	1
	Gas sensor	Air Quality Sensor (MQ-135) SEN53	1
	Pulse Oximeter MAX30100	MAX30100 Pulse Oximeter Heart Rate Sensor Development Board for Arduino SEN34	1
	Pressure sensor	MPS20N0040D-D Sphygmomanometer Pressure Sensor 0-40kPa DIP-6 For Arduino OTH23	1
	Vibration Motor	Vibration DC Motor COM14	1
	LCD	White 0.96″ I2C 128X64 OLED LCD Display Module Arduino COM32	1
	GPS module	GPS Receiver Ublox NEO-6M MOD35	1
	GSM/GPRS Module	Smallest SIM 800L GPRSGSM BRD56	1
	Thermistor	Thermistor 5K SEN14	1
	Rechargeable Battery	Panasonic Original NCR18650B 3400mAh 3.7V Li-Ion high-current Rechargeable Battery COM42	1
	Resistor	10k	1
	Soldering wire	iron	1m
	PCB	PCB Board PRO24	1