UNIVERSITY of RWANDA

COLLEGE OF SCIENCE AND TECHNOLOGY

ACEIoT

**Website:**
**www.aceiot.ur.ac.rw**
**Mail: aceiot@ur.ac.rw**

African Centre of Excellence in Internet of Things (ACEIoT)

**Research Thesis Title:**

# IoT-based Remote Health Monitoring System for Infected People

**A dissertation submitted in partial fulfillment of the requirements for award of**

**MASTERS OF SCIENCE DEGREE IN INTERNET OF THINGS- *WIRELESS INTELLIGENT SENSOR NETWORKING***

Submitted By

**UWAMARIYA Mariette**

**(REF.NO: 219014505)**

**December, 2021**

UNIVERSITY of RWANDA

COLLEGE OF SCIENCE AND TECHNOLOGY

ACEIoT

**Website: www.aceiot.ur.ac.rw**
**Mail: aceiot@ur.ac.rw**

African Centre of Excellence in Internet of Things (ACEIoT)

**Research Thesis Title:**

# IoT-based Remote Health Monitoring System for Infected People

**A dissertation submitted in partial fulfillment of the requirements for award of**

**MASTERS OF SCIENCE DEGREE IN INTERNET OF THINGS- *WIRELESS INTELLIGENT SENSOR NETWORKING***

Submitted By:

**UWAMARIYA Mariette**
**(REF.NO: 219014505)**

**Supervisors**

**Dr. KABANDANA Innocent**

**Dr. Gaurav BAJPAI**

**December, 2021**

## DECLARATION

I declare that this research project report entitled "IoT-based remote health monitoring system for infected people" is presented for the award of Master's degree in the Internet of Things at African Center of Excellence in the Internet of Things, especially in WirelessIntelligent Sensor network, University of Rwanda, is my work. It has never been presentedor submitted in any University, Institution, or High learning for a similar award.

Declared by:

**UWAMARIYA Mariette**

Reg: 219014505

Signature: ..................................................

Date 20/12/2021..................................................

**BONA FIDE CERTIFICATE**

This is to certify that this submitted Research Thesis work report is a record of the original work done by Mrs. **UWAMARIYA Mariette (REF.NO: 219014505)**, MSc. IoT-Wireless Intelligent sensor Networking Student at the University of Rwanda / College of Science and Technology / African Center of Excellence in Internet of Things. Certified further, that according to the best of my knowledge; the work reported here doesn't form a part of any other research work.

**SUPERVISOR:**

**Dr. KABANDANA Innocent**

Signature

Date 15 9 2022

**CO-SUPERVISOR:**

**Dr. Gaurav BAJPAI**

CO-SUPERVISOR

Dr. Gaurav BAJPAI

Signature

Date 15 09 2022

**The head of Masters Studies and Trainings**

**Dr. James RWIGEMA**

Signature:

Date: ………./……../………

## ACKNOWLEDGEMENTS

Great thanks to God Almighty for enabling me to reach this stage in my life and academics andfor holding me through this research. Special thanks, and gratitude go to my Supervisors, **Dr. KABANDANA Innocent** and **Dr. Gaurav Bajpai** for their time, inspiration guidance, and commitment to the success of this work. I appreciate you so much for the unending support.

## ABSTRACT

A great number of positive tested covid-19 deaths due to illness related to complications none monitored. Regular detection of complications can help avoid many cases of death without having the patient's health status. Due to many factors like illness from chronic diseases, lack of knowledge, and insufficiency information to the pandemic, monitoring covid-19 cases are still a huge concern and more prevalent in several countries. This thesis research project was aimed at designing and prototyping a system, intended to monitor the vital signs and abnormalbehavior of positively tested for covid-19 in the home. It was providing a rather easy way to care for or to monitor the infected people's health status and also provides vital information forfuture use. A survey was conducted to investigate the capabilities of the existing systems, identify the challenges with the systems, and find out the awareness and readiness integration of the internet of things in health monitoring systems for infected people that staying at home for isolation purposes. Remote health monitoring plays an outstanding role in healthcare services, from monitoring different chronic diseases, monitoring elders' persons in the home with or without Caregivers for providing care or attention to them.

However, there is a lack of a real-time health monitoring system based on abnormal behavior for covid-19 infected people especially for those who live alone. The analysis made in a periodof data collection shows that the current systems are ineffective to monitor infected people forcovid-19 with gastrointestinal symptoms. Therefore, smart system-based solutions integrated with a camera are needed for capturing all activity made by the patient without any interventionof the caregiver [1]. IoT-based remote health monitoring systems for infected people are proposed to improve efficiency to the vital signs, and human behavior monitoring thus in reduction of covid-19 complications and deaths cases. It was a continuous monitoring system for the physiological parameters of an infected person by covid-19 while patient infected staying at home, integrated with the image-based human behavior such as vomiting. This method of sensor-based remote health monitoring can overcome the problem of continuous monitoring status of a patient infected by covid-19 from distance facilities. Therefore, medical care staff and healthcare personnel will be aware regularly of the physiological signs of their patients. Body temperature, blood oxygen, heart rate, and

human activity are very important parameters to be used and are deployed to monitor the health status of an infected patient by covid-19. The purpose of this system is to design a patient health status monitoring for the persons tested covid-19 positive and have to be in the isolation room at home. This system will also allow the health facilities to do the follow-up to ensure if the patients' vital signs remained controlled or they reach the level of the critical case. The system uses a pulse sensor,temperature sensor, and accelerometer sensor to collect data with an Arduino to acquire readingthe sensor data, and also Raspberry pi as the microcontroller. The collected data is then sent tothe cloud wirelessly, from the cloud data is stored, processed, and then sent to the health worker.

**Keywords:** IoT, Remote health monitoring system, Vital signs monitoring for the Infected people for Covid-19, Wearable technology.

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF ACRONYMS

ACEIoT: African Center of Excellence in the Internet of Things
ADC: Analog to digital convertor

API: Application programming interface
Fig: Figure
GND: Ground
HR: Heart rate
IoT: Internet of Things
PWM: Pulse width Modulation
SCL: Serial clock line
SDA: Serial data
UR: University of Rwanda
WHO: World Health Organization

Wi-Fi: Wireless Fidelity

# Table of Contents

# CHAPTER ONE: GENERAL INTRODUCTION

## 1.1 Overview and Background.

The World Health Organization (WHO) announced that a Coronavirus pandemic (covid-19) began on December 31, 2019, in Wuhan, China [2], and has now expanded globally. Coronavirus infection killed a large percentage of the world's population, and no one has ever faced a covid-19 threat [3]. Several governments have implemented a new policy to combat the spread of Covid-19 illness by implementing Covid-19 Self-quarantine (Self-isolation at home) [4]. Health organizations have issued an assessment of the health status of people infected with Covid-19 who are staying at home while their vital signs exceed the normal scale of measurement. As a response, several researchers designed and deployed several systems conducted to evaluate the covid-19 vital signs [5].

As a result, this thesis research is an attempt to remedy a healthcare problem that people are currently suffering from as a result of the severity of the coronavirus pandemic. The infected people were categorized based on the severity of covid-19 symptoms [6]. Among these symptoms might developed by covid-19 infected people, diarrhea and vomiting should occur. The main goals of this research were to design a prototype of a remote healthcare system suitable for evaluating vital signs and gastrointestinal effects linked with covid-19. This practice is being applied to measure every status while covid-19 infected people are still at home. It is categorized into three sections, the first one is a sensor with the task of detecting patient vitals and behavior, and the second that is responsible for transmitting data to cloud storage,and the third is data detection for remote viewing. This combination of the technology enablesdoctors or guardians to assess the patient's health status and take rapid action from afar.

### 1.1.1 Remote health monitoring system for infected people based on theInternet of Things

A wearable sensor-based IoT-based remote health monitoring system for infected persons is a device that focuses on continuous [7] physiological parameter measurement. That has certain design features and is suitable for Covid-19 [8], notably communication technologies. Patient physical state data acquisition, a communication system based on Wi-Fi technology, a user interface system, and a processing analysis system are indeed part of the system architecture [9],[10].

Sensor data is collected and communicated to Things Speak on behalf of the hospital'sclients for judgment and analysis using a machine learning technique. The patient's data might be shown on an LCD screen based on the results of the physiological parameter evaluation. This system allows health workers to assess the health of people who are infected with the coronavirus. It is necessary for providing indicators from vital signs to overcome this tough situation in real-time, and fetching an image from an email to determine physical status [11]. As a result, the evidence gathered is continuously distant reviewed with the use of wearable IoT technologies, communication technology, and data analysis approaches. These are the advantages of this IoT architecture for assisting the doctor even while the patient is at home reviewing his conditions [12]. As an outcome, the quality of services, as well as the quality of life, may improve.

### 1.1.1 What is the vital sign?

Vital signs are an objective measurement of a living organism's vital physiological activities. Their measurement and assessment are the important initial stage in any clinical evaluation, hence the name "vital." The patient's vital signs are assessed as the initial series of clinical examinations. Patients are triaged at an urgent/prompt care or emergency room based on their vital signs, which tell the doctor how far they've deviated from their baseline. The many physiologic and pathologic processes affecting these sets of measurements, as well as their accurate interpretation, must be understood by healthcare providers. If we employ a triage approach that selects patients without evaluating their vital signs, the urgency of the patient's presentation may not be reflected. The severity of vital sign anomalies may also predict long-term patient health outcomes, recurrent trips to the emergency department, and frequency of visits of doctors.

- ❖ **Body temperature:** This is a vital parameter that helps to determine an individual's health status [4]. During the infected period, a human body could be attacked by an uncontrolled condition that can cause Hyperpyrexia. It is recommended that the temperature be monitored regularly to prevent a headache. A normal body can range from $98.^0$F to 99 $^0$F or 36.5 $^0$C to 37.5 $^0$C.

- ❖ **Blood Oxygen level:** This is a vital parameter used to check how well the human bodyis getting oxygen [5]. Most patients who die of acute covid-19 caused by the complication of hypoxemia referred to the low blood oxygen (> 94%), the normal rangeof oxygen saturation is 94% to 98% at rest without chronic lung disease.
- ❖ **Heart rate/pulse rate:** This is a method of measurement of heart rhythm [6], which isthe number of times your heart beats in one minute.
- ❖ **Activity monitoring:** This can refer to the tracking of behavior.

### 1.1.2 Remote-based Covid-19 vital signs monitoring

Is a continuous basis, that focuses on the real-time monitoring system with a non-stop-vital signs [2] evaluation system for positive tested for covid-19 with self-isolation while the patient staying in the home [3]. That is designed to prevent the risk caused by delay in case of deterioration. This technology enables clinicians to monitor patients and obtain healthcare support from their homes, freeing up hospital beds for important cases.

### 1.1.3 Covid-19 gastrointestinal symptoms monitoring

It is the way of monitoring human activity; this thesis research emphasizes digestive issues like vomiting [7]. The World Health Organization reported that some covid-19 infected people showed respiratory symptoms, the others did not, another part, the people should develop gastrointestinal symptoms like diarrhea and vomiting [15]. As usual, covid-19 continues to evolve day by day, from this evidence, this thesis focuses on vital signs and gastrointestinal symptoms monitoring refers to the human activity recognition based on an image captured. This can be a strategy to be used for monitoring the infected people with gastrointestinal issues[7].

## 1.2 Motivation

The health monitoring problem of infected people by Covid-19 is rising Day today along with the increasing number of contaminated and also the death of persons. The hospitals become obstructed with the infected people tested positive for covid-19, the patient with serious respiratory difficulty died waiting for the hospitals' beds for supplement oxygen [8],[9]. The others died while was alone in the home, and the family members are not aware of the current health status of the patients. Existing works often focus on assisting people who experience difficulties on respiration, to overcome the situation without hospitalization, this thesis research proposed a study of monitoring the symptoms of coronavirus infected people. It used nonstop checking off the symptoms by evaluating the physiological parameters and identification behavior (events) of patients. This envisages covid-19 infected people that staying at home for Self-isolation using a wearable biomedical sensor and smart camera.

Members are not aware of the current health status of the patients. Existing works often focus on assisting people who experience difficulties with respiration, to overcome the situation without hospitalization, this thesis research proposed a study of monitoring the symptoms of coronavirus-infected people. It used nonstop checking off the symptoms by evaluating the physiological parameters and identifying the behavior (events) of patients. This envisages covid-19 infected people that staying at home for Self-isolation using a wearable biomedical sensor and smart camera. it is difficult for a doctor to obtain updates from all patients at once. IoT-based smart healthcare devices have gained increased attention from a research perspective. This system helps patients with fever, low oxygen saturation, and an increasing or decreasing pulse rate. A person's pulse rate depends on their age, body size, heart health, and emotional stability.

The primary goal of this study is to create and deploy a novel IoT-based smart health monitoring system for COVID-19 patients that is based on human body temperature, pulse, and SpO2, the system can display measured human body temperature, oxygen saturation level, and pulse rate, allowing the patient to seek medical attention even if the specialist is physically unavailable. A doctor will need the patient's oxygen saturation level and pulse rate to treat a COVID-19 patient.

## 1.2 Problem Statement

Remote health monitoring for people infected by the coronavirus

The biggest issue is keeping track of a huge number of symptoms of numerous infected patients in household isolation who tested positive for covid-19. The latest technology continues to face a tremendous barrier in monitoring infected persons with Covid-19 [10]. These difficulties made it difficult for doctors to assess the unique behavior of covid-19 infected patients living in a domestic home. It was extremely difficult to conduct a fast follow-up and discover the severe problems that can occur in patients infected with the coronavirus. Remote health data analysis and clarification of critical indications, as well as human anomalous behavior, while diseased people remain at home, is still required [11]. Because of a lack of knowledge, it is difficult to preserve a patient's life who develops severe difficulties while staying alone at home.

### 1.2.1 Problem solution

An IoT-based remote health monitoring system for infected people comes to overcome this situation.

## 1.4 Research questions

i. What is the existing health status monitoring system that is used to evaluate the physiological parameters continuously and in real-time?

ii. Is there an architecture for integration of IoT with existing health status monitoring for the situation of Covid-19 with Self isolation in the home?

iii. Which analytics platform can be used for live data streams with a real-time health status monitoring system for positive tested results by Covid-19 while staying in the home?

iv. Can people with covid-19 symptoms be monitored from afar by medical staff?

v. What are the immediate benefits of adopting a remote health monitoring system for infected people for covid-19?

### 1.3 Study objectives

#### 1.3.1 General Objectives

To design a remote health monitoring system for people infected by covid-19, to examine the data taken from physiological variables measurement of the infected people through the IoT architecture design methods. The devices required to the system have to be monitored remotely to facilitate doctors to review the data and progress the treatment while the patient staying in the home.

#### 1.3.2 Specific objectives:

i. To design and prototype a real-time infected health care monitoring system using sensor technology, communication technology, and data analysis techniques.

ii. To evaluate the physiological parameters by measuring the vital signs of infectedpeople by covid-19 while staying in the home.

iii. To assist the patients through regular observation of their health status, even patient changes human behavior.

iv. Storing the monitored parameters and history from pandemics for future treatmentplans. Things speak for further analysis and visualization.

v. To integrate IoT architecture for monitoring the infected people while staying in the domestic home.

### 1.6 Hypotheses

The hypotheses of the study describe architectures for integration of IoT in Remote health monitoring systems for infected people for covid-19. But the improvement is one of using the smart camera to identify the physical status by monitoring body activity or abnormality behavior.

### 1.7 Study scope

This study emphasizes the evaluation of the physiological parameters with nonstop checking and monitoring the physical behavior in an isolation room or the home. That being specifically to the covid-19 situation while the infected people stay at home with and without Caregivers around.

### 1.8 Significance of the study

The system is meant to evaluate the vital signs of coronavirus infected people anytime anywhere, and health parameters can be reviewed by any Doctor even a patient can receive important information concern his health status.

### 1.9 Organization of the study

The document is organized as follows;

Chapter 1 introduces the idea of the project,

Chapter 2 present a review of related literature,

Chapter 3 Outlines the methodology applied in the study,

Chapter 4 presents the system design,

Chapter 5 shows system Analysis and Results,

Chapter 6 presents conclusions and recommendations.

**CHAPTER TWO: LITERATURE REVIEW**

## 2.1 Introduction

This section presents a review of previous works with IoT in health care, remote healthcare monitoring systems for covid-19 infected people, how it is currently done in remote communities, the challenges faced, and how they can be catered for. It also discusses the existing solutions and the existing open prototypes and their limitations. Previous works are presented and describe similarities technologies and contrasting features within conferences are discussed.

## 2.2. Review on Remote health monitoring system for covid-19 infected people

Remote monitoring in healthcare is a method of using technology to monitor, and caring patients anywhere anytime in the non-Clinical environment such as in the home to improve the efficiency engaged in healthcare services [12] to facilitate the treatment in real-time and to save the life of critical cases like when the health status of the patient reaches at high risk [13], [14]. Previous researchers studied different solutions to be used [15]to monitor infected people for covid-19 attacked by different chronic diseases such as diabetes, arrhythmia, and cancer those studies were concerned with the evaluation of the physiological parameters, as a result, the various healthcare system has been proposed to reduce the hospital visits for the patients and Doctor’s workload. By focusing on the potential solutions and the benefits of saving life and decision making during critical cases the researchers in [16], [17] worked on the systems with the target of monitoring infected people remotely using a wearable sensor. This wearable technology improves the efficiency of health care services and reduced the delay by evaluating physiological parameters of infected people for covid-19 while in self-isolation [18]. The vital signs collection information is displayed on the dashboard to be viewed by the doctor.

In [19], the researchers proposed the system to monitor the patients for early diagnosis, during quarantine, and after recovery. This study was determined the role of architecture, platform, and applications in the domain of healthcare.

In [17], a system proposed to monitor body temperature using wearable devices with IoT, integrated the real-time warning and stored data analysis. It is an advanced technology abnormalbehavior detection based on video was proposed a novel clustering to gather patient data from outside the clinical environment and caring for patients from afar with a long distance from healthfacilities, this method had been used by the medical staff to monitor the health parameters of the patient while the patient staying at home. A combination of enabling technology such as sensing technology, communication technology, and data analysis techniques have the potential capability to report the information about the patient's symptoms, self-quarantine this technology evaluates regularly the patient vital signs also can alert the hospital or caregiver in case the patient's status becomes critical [1] but it didn't consider the human activities. Monitoring humanbehavior while in self-isolation should be a response to the lack of information about covid-19 infected people who live alone without a caretaker around. In [20], the accelerometer-based wearable system was proposed for monitoring human behavior when the body performing sport or fitness activity. It should be noted that [21] did not address the human behavior issues like vomiting or diarrhea. The work in [22],[11], designed a system based on abnormal humanbehavior analysis by using the applications only and was designed for abnormality in real life, notfor coronavirus pandemic situations.

In [23], the researcher focuses on the respiratory, oxygen saturation, health rate, and temperature complication for covid-19, these parameters were measured every 15 minutes by using an in-ear device, but this study emphasizes the problem in the transmission of the data and when the patient moved too far from the gateway connectivity.

Integrating new technology solutions in healthcare services can overcome the current problem likein [24], the researchers designed a system to monitor the vital signs in a clinical environment. This system was focusing to the way of monitoring the patients who were attacked by the others diseases such as cancer diabetes, for reducing hospital admission [25] for non-covid-19 infected people. The fact that this remote monitoring for covid-19 infected people system was designed with a different patient (covid-19 infected people) is not feasible for the infected people that have the gastrointestinal issue for covid-19. Therefore, there is a need to emphasize human behavior indomestic isolation to prevent the risk of dehydration.

### 2.2.1 Existing system limitations

This part outline is related to the limitations of the past frameworks focusing on the healthcare monitoring systems based on IoT. Most studies integrated sensing technology in various

Health ecosystem services, in [17], the researchers proposed a system to monitor healthcare this wasdone using the information gathered from various sensors and the accelerometer. This study was focused on the limits of continuous monitoring the hospitalized patients. The researchers ignored monitoring human activities to ensure patient behavior while self-isolation in the home [10].

In [3], the study suggested an IoT-based health monitoring system that can measure physiological parameters and health symptoms in COVID-19-affected patients. The bracelet hadbeen used to monitor parameters, this device provides the location of potentially infected peopleand notifies those who are worried in the event of an emergency or a breach of self-quarantine requirements. Their data were transferred to an application peripheral interface (API) that worksas a database for perusing and infection monitoring. Wearable IoT layers such as cloud layer, mobile or web frontend layer make up the proposed solution. For wireless monitoring of covid- 19 infected patients, these layers have unique functions and are connected.

In [27], the researchers proposed the system using an accelerometer mounted on the trunk for patient monitoring. The data from the old patient status on mobility and functional capabilities ofthe patient's body was analyzed using Deep Neural Networks. Other studies focus on wearable technology to reduce the spread of coronavirus by using wearable monitoring devices but humanbehavior was ignored [28]. The researchers proposed a system to measure various symptoms related to covid-19, the system was designed with an android mobile application layer with notifications and alert responsibility for the infected patient’s caregiver. Triaging severe complications systems for reporting important information concerning the critical symptoms was common for remote health monitoring. In the past frameworks related to the remote health monitoring for positive tested for covid-19 who are in the home for self-isolation, there is the lackof gastrointestinal symptoms for covid-19 that being monitored based on human activity (behavior) [29].

In [30], the researchers describe the severe risk of covid-19, They emphasize the clinical deterioration in covid-19. In this study, they focused on the laboratory detection of cytokines andimmune cell subsets in patients with SARS-CoV-2 infection.

By using contactless methods [31], the researchers proposed a system with the potential of detecting fever and covid-19 infection using a camera-based vital signs measurement in the Intensive care Unit (ICU). It is a technology used to continuously monitor patients' vital signs. In [ 23], other researchers focus on wearable technology to reduce the spread of coronavirus used wearable monitoring devices, this study was ignored the way of gastrointestinal symptoms for covid-19 [26], [27].

### 2.2.2 Research contribution

Our research focuses on designing and prototyping a system to monitor the vital signs and to identify human behavior (events) for the covid-19 infected people using a machine learning approach. By considering abnormalities such as symptoms of gastrointestinal for covid-19 we decide to work on it on this research project by integrating human activity monitoring based on the image. This part outline is related to the past frameworks used in healthcare monitoring systems based on IoT. Most studies integrated sensing technology in various e-health ecosystem services, in [18] researchers proposed a system to monitor healthcare this was done using the information gathered from various sensors and was focused on the limits of proliferation. This study ignored monitoring human activities to ensure patient behavior while self-isolation in the home [10]. To overcome this situation, this thesis research focuses on the way of evaluating and analyzingphysiological parameters and human behavior by integrating a smart camera to monitor that activity in domestic isolation.

# CHAPTER THREE: RESEARCH METHODOLOGY

## 3.1 Introduction

The device was created to provide remote health monitoring for persons who have been tested for covid-19. It works by attaching various sensors to the patient's body that capture vital signs and allow them to be monitored. The suggested health monitoring system consists of the number of sensors divided into two groups. The first is used to track the vital signs of those who have been infected with Covid-19, while the second is intended to capture any physical indications linked to the virus. Sensor data is collected using a variety of sensors, including a temperature sensor, a SpO2 oximeter sensor, and two other sensors, a wearable accelerometer sensor, and a smart camera sensor, to identify any physical consequences in individuals infected with Covid-19. Their vital signals are analog signals that have been transformed into digital signals by acquiring readings from the appropriate analog sensor using an Arduino board with an inbuilt circuit. Arduino board to acquire readings from the appropriate analog sensor. The data acquisition was transferred on Raspberry pi for further data processing even wireless communication (it is used as an aggregator and a processor as well). The physical changes measured by the accelerometer can trigger the pi camera to capture an image due to the hemodynamic ally unstable condition that can influence abnormal human activity such as walking, sitting, sit-dawn, vomiting, or diarrhea. These signals, which give information, are continuously recorded and monitored to gain a better understanding of how the human body works. If the sets of these felt signals fall outside of normal ranges, it usually means that some attention is required or that a greater level of treatment is required, in which case it notify the doctor.

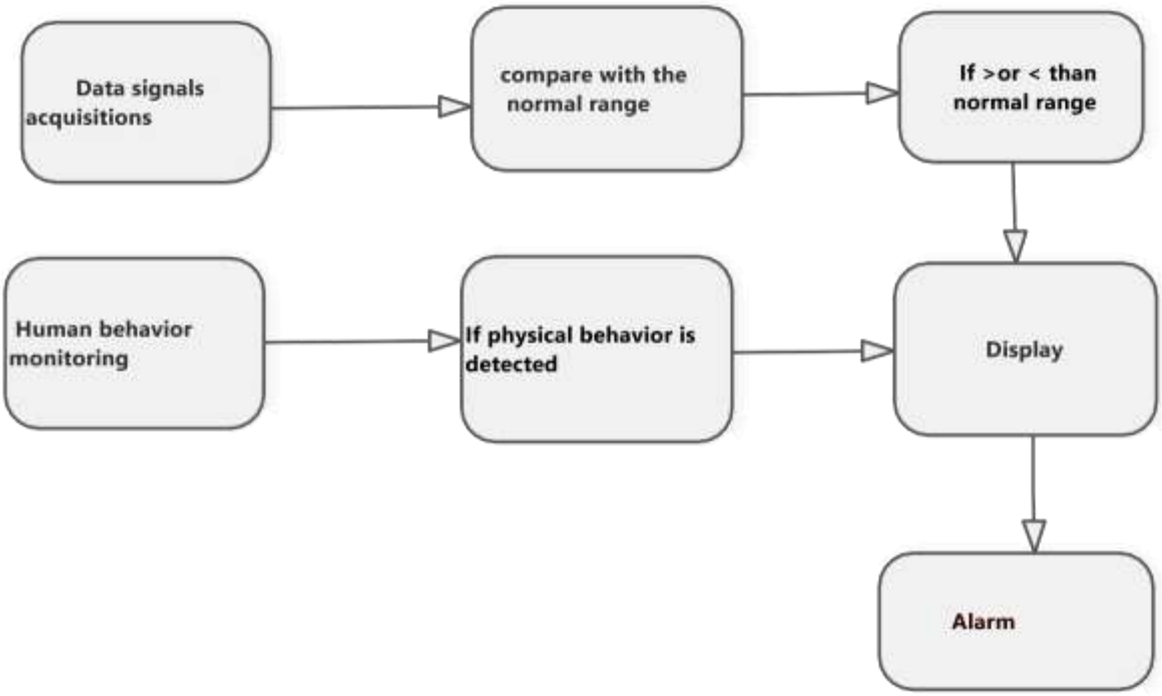



**Figure 1: Methodology used**

### 3.2 Exploratory data and Tools

This section of the study consists of a quantitative survey and qualitative interview. A mixed-methods design was used to understand the involvement of IoT devices over healthcare services especially for a remote health monitoring from covid-19 infected people while staying at home and the part of the qualitative interview for medical staff at one location who have been involved in the process of monitoring the infected people by covid-19 at a different location.

Data was collected from health facilities; questionnaires, interviews, and documents analysis guides were used for gathering the data. Physiologic data include body temperature (°F), oxygen saturation levels (% SpO2), and heart rate (bpm).

### 3.3 Findings

Out of the 120 people that were interviewed a total of 109 responses were received.55% of the respondents had been infected by covid-19 before and they had been developed symptomatic symptoms, 35% of those said they have had multiple covid-19 symptomatic symptoms with gastrointestinal symptoms, and 10% of the respondents indicated they did not develop anysymptom.

### 3.3.1The abnormal parameters

Table 1: The abnormal parameters

| **Parameter** | **Uncontrolled Condition** | **Measures** |
|---|---|---|
| Body temperature | Fever or Hyperpyrexia | 161.1 F $^{0}$ or 41.1 C$^{0}$ |
| Blood oxygen level | Hypoxemia | 90-92% |
| Pulse rate | *Tachycardia<br><br>*Arrhythmia | >100bpm<br><br>> 100 bpm and <60bpm |

### 3.3.2 Normal parameters

Table 2: Normal parameters

| **Parameter** | **Measure** |
|---|---|
| Body temperature | 98.6 $^{0}$F- 99 F$^{0}$ or 36.5 $^{0}$C - 37.5 C$^{0}$ |
| Blood oxygen level | 70% -100% |
| Pulse rate | 60bpm -100 bpm |

## 3.4 Tools

The system is a combination of hardware and software. The hardware consists of 2 boards: Raspberry Pi 3 Model B+ and Arduino UNO, for the sensors: temperature sensor, pulse oximetry, and heart rate sensor, accelerometer motion sensor) Sd card, Buzzer, LCD, Pi camera.

### 3.4.1 Hardware

Human body temperature sensor (MAX30205): is used to measure human body temperature, convert measurement temperature to digital form, and produce an over temperature alarm, interrupt, or call down output.

Table 3: Temperature threshold values

| Temperature | Recommended |
|---|---|
| 36.5 $^{0}$C - 37.4 $^{0}$C | Normal |
| < 35.0 $^{0}$C | Hypothermia |
| >37.5 $^{0}$C - 38.3 $^{0}$C | Hyperthermia |
| >=40 $^{0}$C – 41.5 $^{0}$C | Hyperpyrexia |


**Figure 2: Temperature sensor**

Pulse Oximeter Sensor (MAX30100): Pulse oximetry and heart rate monitor sensors are used to assess oxygen saturation levels in the blood and how good oxygen is delivered to different parts of the human body. MAX 30100 is a sensor that combines pulse oximetry and a heart rate monitor. The digital output data is saved in a first-in, first-out (FIFO) format (FIFO).

Table 4: Blood oxygen level threshold value

| **Spo2** | **Recommended** |
|---|---|
| >95 | Normal |
| 85-94 | hypoxemia |
| < 85 | severe hypoxemia |

Table 5: Heart rate threshold values

| | |
|---|---|
| Normal (60-100) | Normal |
| Law (<60) | Low heart rate |
| High (>100) | Abnormal state |


**Figure 3: Pulse Ox meter Sensor**

Accelerometer motion sensor: is a device that is used to monitor the change of position and human activity such as walking, running, standing, sitting, vomiting. It is a 3-axis accelerometer with output as voltage, vomiting is controlled by the accelerometer by setting the acceleration threshold value for any 3 -axis.


**Figure 4: Accelerometer sensor**

Buzzer sensor: This is a device that converts audio signals into sound signals and isused to attract someone's intention**.**

**Figure 5: Buzzer sensor**

LCD: Is a liquid crystal display of a certain type. Is a flat-panel display that isused for displaying the information

**Figure 6: Liquid crystal display**

Arduino board: This is a microcontroller board based on the AT mega 328P. Ithas 14digital input/output pins six of which are PWM outputs, 6 analog inputs, USB connector. Figure 7: shows the different pins of the board.

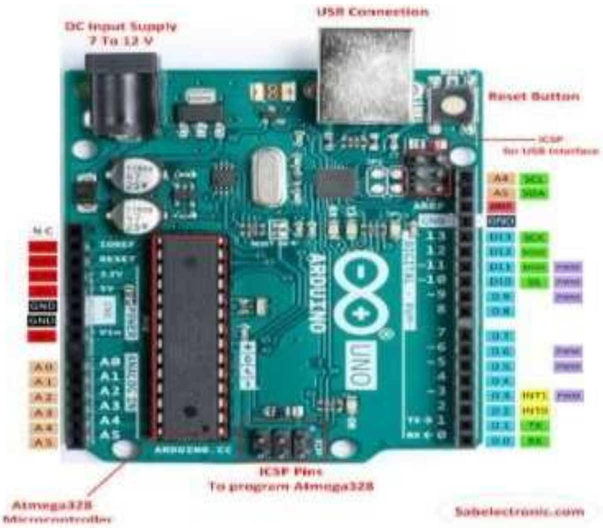



**Figure 7: Show different parts of Arduino UNO**

Raspberry Pi 3 Model B+: Raspberry Pi is a low-cost, credit card computer. It useswhat's called a system on a chip. Which integrates the CPU and GPU in a single integrated circuit

**Figure 8: Raspberry Pi board**

### 3.4.2 Software tools

Language libraries, code editors, test Monitor, diagramming tools,

### 3.4.3 The Cloud platform

The cloud platform allows products both software and hardware to co-exist remotely and enables data to be stored, analyzed, and processed remotely. The cloud platform used in this system is theThing speak IoT cloud platform. Thing Speak is an IoT cloud platform that allows sensor data to be sent to the cloud, analyzed, and visualized using MATLAB software. In this system, sensor data was sent using Raspberry pi to Thing speak, sent data is visualized and an alert system is sentto the health care provider via email in case the set rules are met. In this case when the data from covid-19 infected people threshold temperature, oxygen level, heart rate values exceed 38 degrees Celsius, 101%, 100bpm an automatic email is sent to the healthcare provider, caregiver, and patient via email to implicate the condition of the patient.

### 3.5. Existing system

From the interviews, observation, and analysis of documents, the researchers were able to analyze the systems currently in place. It was found out that manual paper records and systems areused to capture details about the tested cases and location of positively tested for covid-19. This makes it difficult to trace regularly the vital signs of patient positive tested for covid-19, and the abnormal behavior while staying at home for isolation purposes. Nurses in health facilitiesusually make phone calls to the patient positive tested for covid-19 to ask them about their health status. I was however noted that this is not enough for having full information for all complications faced by the infected people while staying in the home. Also, in cases of emergencies, the delays can cause the loss of life when the signs of deterioration with covid-19 occur the responses were witnessed leading to complications and in some cases deaths.

# CHAPTER FOUR: SYSTEM DESIGN

## 4.1 Introduction

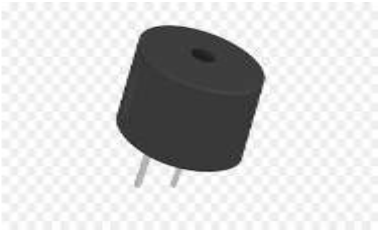
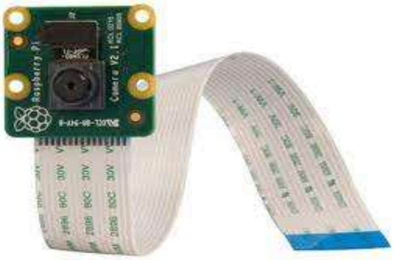
This section briefly describes the components, system architecture, and interfaces with the purpose to provide sufficient information details about the system requirement needed. UML is used as a model language to define the behavior, and structure of the system.

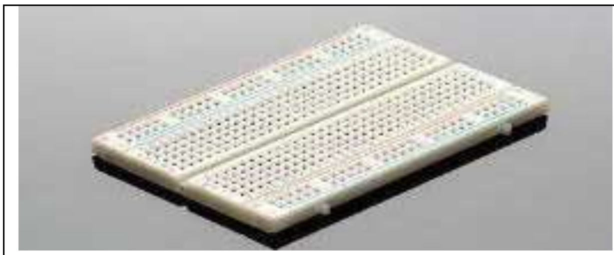
## 4.2 System components

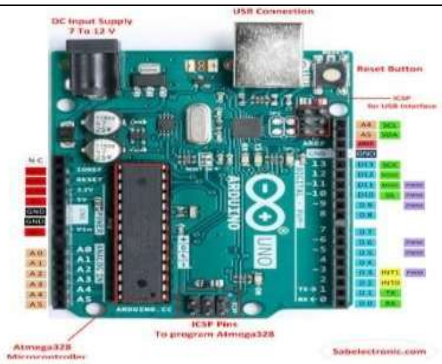
The system is a combination of hardware and software. The hardware consists of 2 boards: Raspberry Pi 3 Model B+ and Arduino UNO, for the sensors: temperature sensor, pulse oximetry, and heart rate sensor, accelerometer motion sensor) Sd card, Buzzer, LCD, Pi camera.

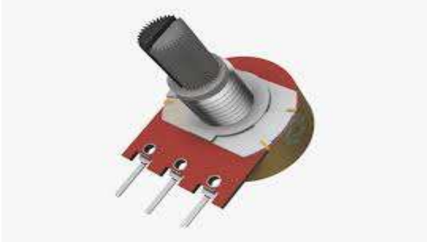
In this section, we emphasize the functionality of the system by discussing the operations of the sensors, the kind of parameters to be monitored, and the process of gathering data, storage, and analysis. Figure 3 depicts the major components of covid-19's remote health monitoring system for infected persons, which include a sensing unit, a communication unit, and a data analysis unit,each of which performs a specific function. The appropriate components like on the sensor technology human body temperature sensor, pulse oximeter sensor, accelerometer sensor, and Buzzer sensor have to be used; for communication technology, Arduino Uno is used for data acquisition from the analog sensor and transfer the data collected to Raspberry Pi connected to theThing Speak for storage, analysis, and processing. The processed data is sent to the Hospital’s website, email of medical staff, displayed in the LCD deployed in the nurse station room, and back to the patient’s smartphone or Caregivers for whom they have [16].

| **Components** | **Descriptions** |
|---|---|
|  | **The MAX30205**<br><br>This module is a Human body temperature sensor, it is used to measure body temperature and provide overtemperature alarm,interrupt/ shutdown output. It is ananalog device that can convert its analog signal into digital form by using a high resolution, sigma-delta, analog to digital converter (ADC). |
|  | **MAX30100 sensor**<br><br>This module is a pulse oximeter and heart rate monitor sensorsolution mean that can measure the oxygen level in the blood and heart rate. It has an I2C to facilitatecommunication with the microcontroller and it is faster fordata output capability. |
|  | **Accelerometer sensor**<br><br>This module is used to measure the static or dynamic acceleration of a body or any object, using the electromechanical sensor. It canbe used for inclination or vibration detection. It uses three-axis such as XYZ to read the values accordingly, and the measures thatappeared on the positive values indicated an increase in velocity, the negative values indicated the decreased velocity and the zeroindicated the constant velocity. It can capture the intensity of physical activity. |

| | |
|---|---|
|  | **BUZZER sensor**<br><br>The buzzer is like a magnetic sensor; it uses voltage and different frequencies for making a sound or beeper. It makes a sounddue to applied voltage to the piezoelectric, and this material deforms. |
|  | LCD 20*4<br><br>Is a liquid crystal display of a certain type. Is a flat-panel display that blends polarizer with liquid crystal's light-modulating characteristics. |
|  | Pi Camera<br><br>The pi camera is a smart camera used to capture image or video |
| <br> | Jumper<br>A jump wire (also known as a jumper, jumper wire, jumper cable, DuPont wire, or cable) is an electrical wire (or a group of them in a cable) with a connector or pin at each end (or sometimes without them – simply "tinned") that is used to connect the components of a breadboard or other prototype or test device. |

| | |
|---|---|
|  | **Breadboard**<br><br>A breadboard is a rectangular plastic board with several little holes. These holes make it simple to add electronic components to your prototype. |
|  | **Electrical Resistance**<br><br>Electrical resistance is an object used to measure the opposite of current flow in the circuit. |
|  | **Electrolytic Capacitor**<br><br>The capacitor is a device used to store electrical charge and electrical energy. |

| | |
|---|---|
|  | **Arduino**<br><br>This is a microcontroller board based on the AT mega 328P. It has 14digital input/output pins six of which are PWM outputs, 6 analog inputs, USB connector. Figure 7: shows the different pins of the board |

| | |
|---|---|
|  | **Raspberry Pi 3 Model B+**<br><br>Raspberry Pi is a low-cost, credit card computer. It uses what'scalled a system on a chip. Which integrates the CPU and GPU in a single integrated circuit |
|  | **Potentiometer**<br><br>The potentiometer consists of three-terminal resistors with an adjustable voltage divider. It is used as a variable resistor. |

### 4.2.1 System block diagram

Figure 3.5 explains the embedded block diagram. The MAX30205 sensor was used to sense body temperature, the MAX30100 sensor was used to measure the level of blood oxygen and the accelerometer is used to detect the motion of the human body. The Arduino UNO board was used for the acquisition of data from the appropriate sensor, the Raspberry Pi is the selected microcontroller with a Pi camera that is used to capture a small video for any activity that happens also Buzzer was used to attract someone's intention; LCD was used to display the result of any patient.

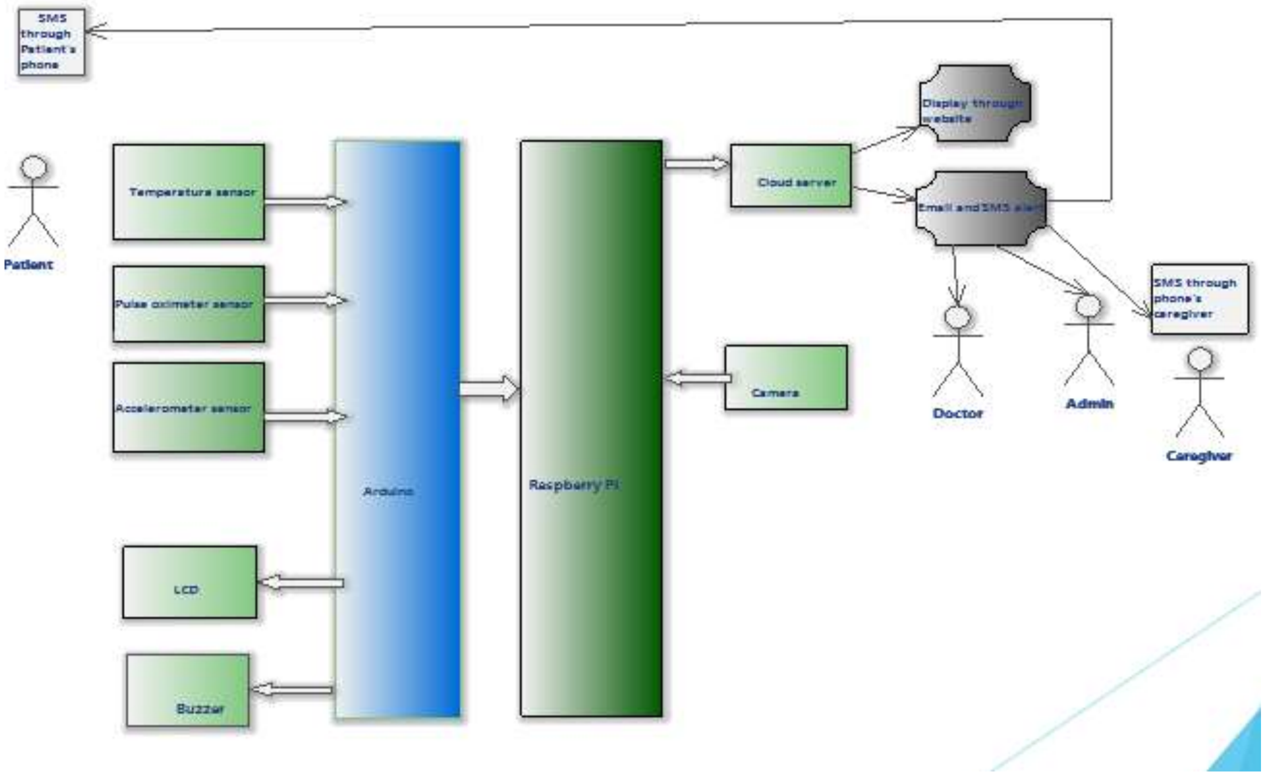



Figure 9: System block diagram

### 4.2.2 Hardware interfacing

The different components of the system were connected to the Arduino as follows

Temperature sensor CJMCU MAX 30205

Figure 10 shows how the temperature sensor is connected to the Arduino

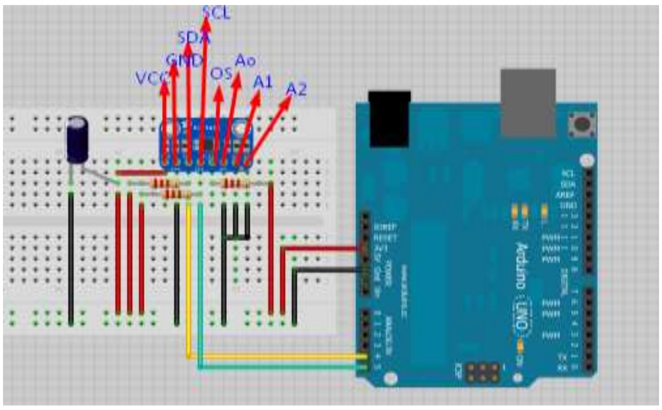



**Figure 10: Temperature sensor connected to Arduino**

Table 6: Pinout of MAX30205

| **MAX30205** | **Arduino** |
|---|---|
| VCC | 3.3V |
| GND | GND |
| SDA | A4 |
| SCL | A5 |
| OS | 3.3V |
| A0 | GND |
| A1 | GND |
| A2 | GND |

Pulse sensor MAX 30100

Different pins are connected as follows:

Table 7: MAX30100 pinout

| **MAX30100** | **Arduino** |
|---|---|
| Vin pin | 3.3V |
| GND | GND |
| SCL | SCL |
| SDA | SDA |

This figure shows how the pulse sensor is connected to the Arduino

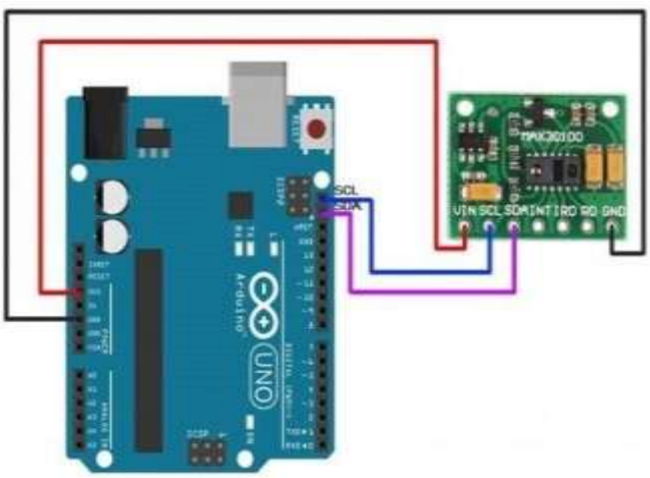



Figure 11: Pulse sensor connected to Arduino

LCD Connection

Figure 12: shows the pinout for the LCD. The LCD is connected to the Raspberry Pi 3 ModelB+ as follows:

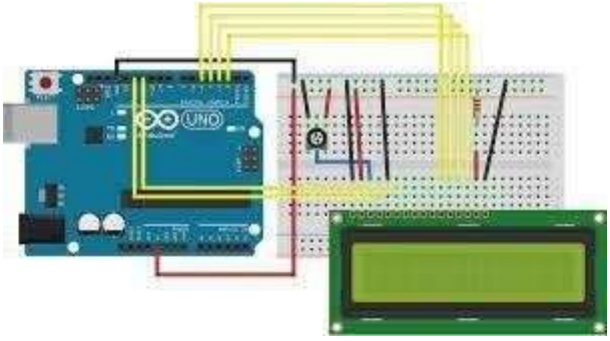


**Figure 12: Liquid crystal display pinout**

Table 8: Liquid crystal display pinout

| **LCD** | **Arduino** |
|---|---|
| LCD pin 1 | GND |
| LCD pin2 | 5V |
| LCD pin3 | GND |
| LCD pin4 RS | GPIO 26 |
| LCD pin 5 R/W | GND |
| LCD pin 6 E | GPIO 19 |
| LCD pin 11-14 (D4, D5, D6, D7) | GPIO 13,06,05,11 |
| LCD pin 15 | 5V |
| LCD pin 16 | GND |

Pi camera Connection

Installing the camera

Open the camera port on the Raspberry Pi located between the port of the HDMI and audio port

Insert camera cable

Close the camera

port Verify the

connection

Removing the cable from the camera itself

GoPiGo installation

GrovePi + installation

**Figure 13: Pi camera connected to Raspberry Pi**

Buzzer connection

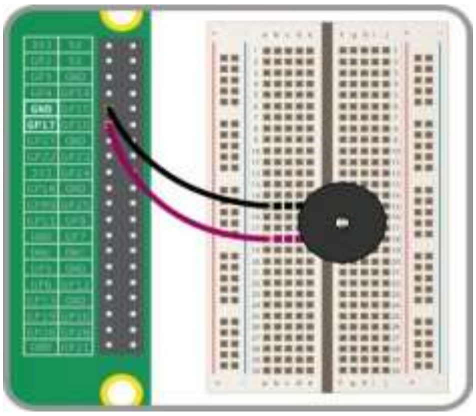


**Figure 14: Buzzer connected to Arduino**

### 4.2.3 Software requirement

In this thesis two boards are used such as Arduino UNO and Raspberry pi, therefore each board needs to use its appropriate software. The software used for the Arduino board is Arduino IDE (Arduino integrated development environment). Raspberry pi uses Thonny IDE as a software application with python programming language.

## 4.3 System Architecture

This system architecture consists of three tiers: tier-1 consists of wireless sensor nodes and control unit, tier-2 is intermediate receiving unit that is responsible for storage, processing, and displaying the data, and the third one is concerned with the alert system and data transmission to longer distances. According to the different activities on the layers, this system is in 5 layered architecture that consists of Perception layer (data acquisition layer), processing layer (data gathering and distribution layer), transport layer, storage layer (integration layer), the application layer.

A health monitoring system is made up of sensors that are connected to the patient and communicate with each other. This project entails data to the server via the processing unit, the Raspberry Pi serves as a data junction node and a computer processor. Smartphones or laptops could be used by the admin and

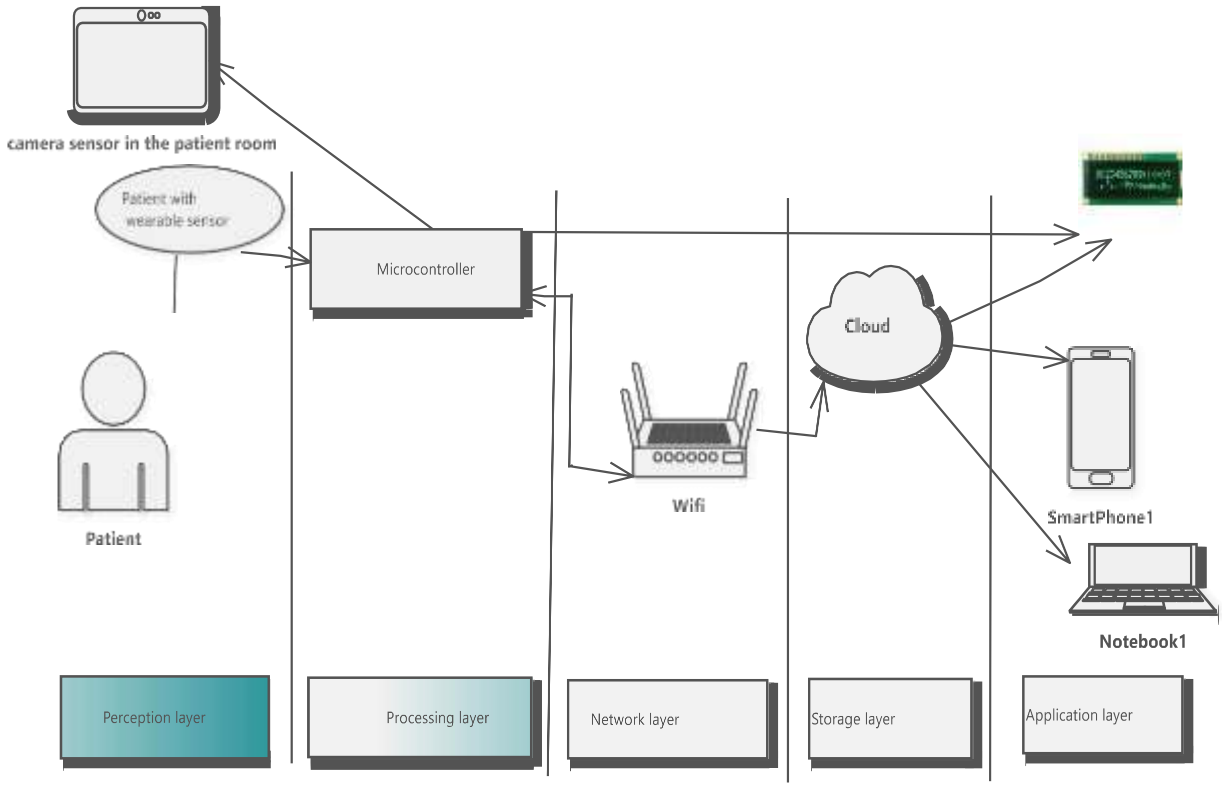



**Figure 15: System architecture**

The doctor to keep track of things. Smartphones are also used by the patientand caregiver after the patient's parameters have been determined, they are used as follows: measurements, which were then transformed into signals. These indications are given for Raspberry Pi processing. Then the information is displayed on a monitor by Raspberry Pi, as well as on a computer. With the help of IoT, information is stored in the cloud. The doctor has access to this information via his computer. Get the notice on your phone or computer. There's also the ability to send an alarm message to the doctor or another person is available. If any suspicious data is discovered, notify the patient's caregiver.

Perception Layer

This is the sensing layer at which data is collected directly from the covid-19 infected people. The data were collected from different sensors to capture the vitals of the covid-19 infected peoples and their physical abnormal behavior. The sensors will include a SpO2 sensor, temperature sensor, accelerometer sensor, and camera sensor in charge of streaming a video.

Processing Layer

At this layer, data is pre-processed and then sent to the cloud for further analytics and storage. An Arduino microcontroller is used to acquire, and Raspberry pi processes the data and sends data to the cloud.

Network Layer

This layer acts as a bridge between the processing layer to the application layer, it transmits the information from physical objects to the application layer.

Storage Layer (Integration Layer)

This layer derives the information and decisions making from the data. APIs are used in both sources to integrate the data to ensure more informed decisions.

Application Layer

At this layer different applications are used to enable the users to interact with the systems. Actuations are also done in this layer. A mobile application and an online dashboard are provided for the users. In case the data is beyond the threshold a buzzer can be automatically activated.

### 4.3.1 System functionality

System functionality describes the tasks and actors involved in the project by focusing on the system functions to be performed. It also explained the data flow with its function in the system It presents the processes details of how can be implemented.

### 4.3.2 System flowchart diagram

A flow chart is the way of displaying the data into the system and describes where the decision takes place.

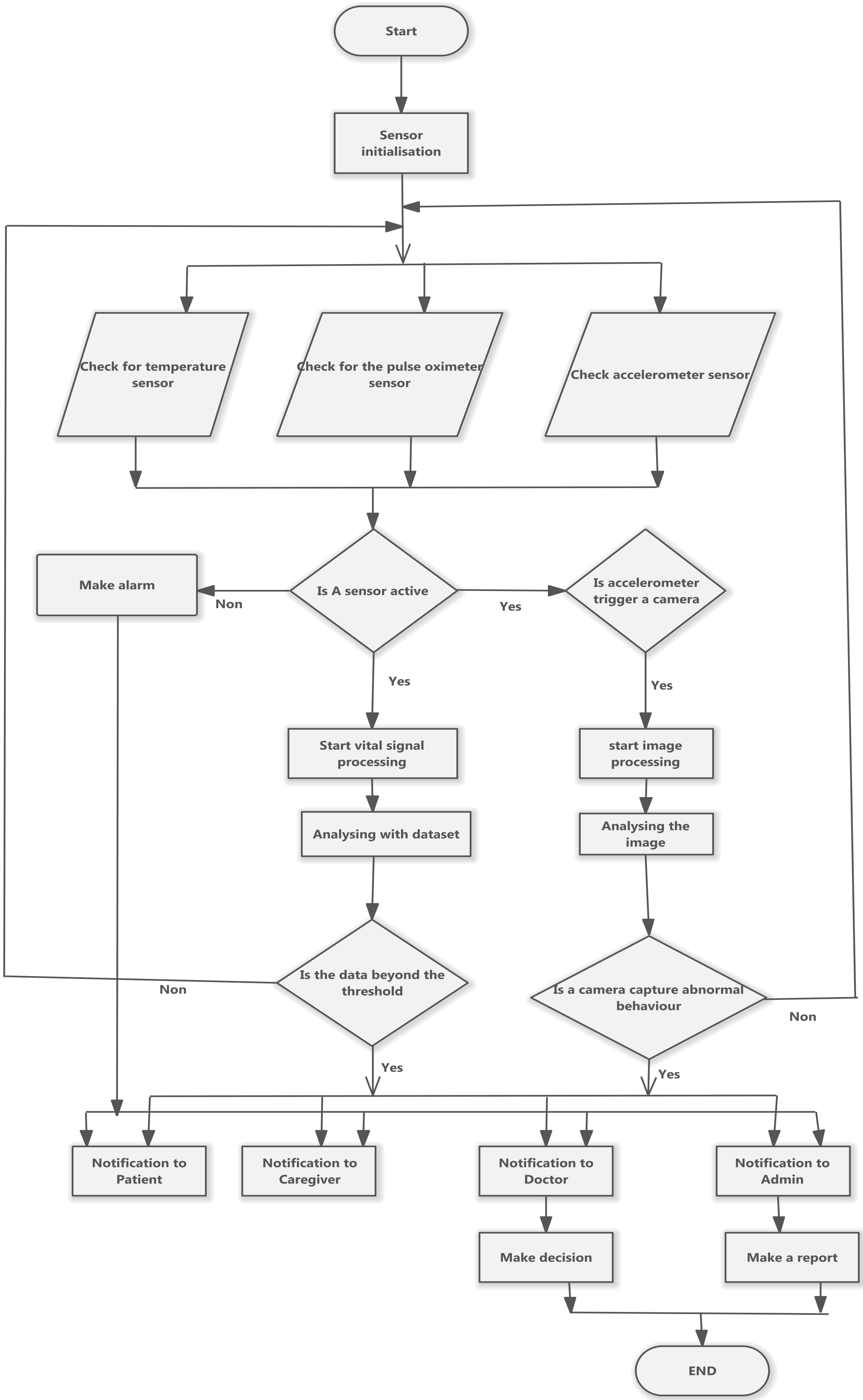



**Figure 16: Flow chart diagram**

### 4.3.3 Use Case Diagram

The use cases diagram was used to show the main actors for the system and the related actions they perform. The actors include the System administrator, Doctor, patient, caregiver, and the embedded system. Figure 17 shows the use case diagram.

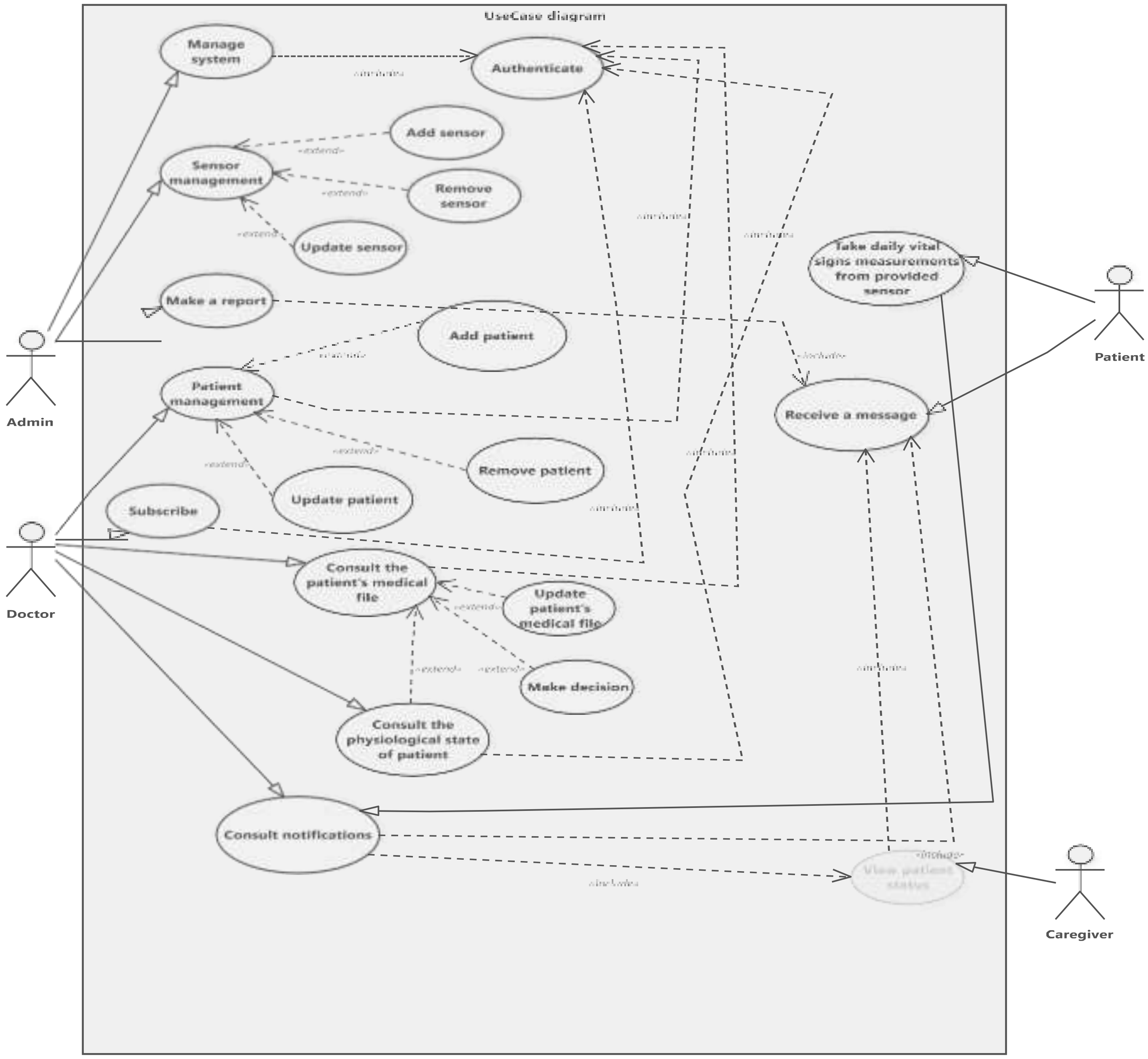



**Figure 17: Use case diagram**

### 4.3.4 Sequence Diagram

It is used to understand the system requirement.

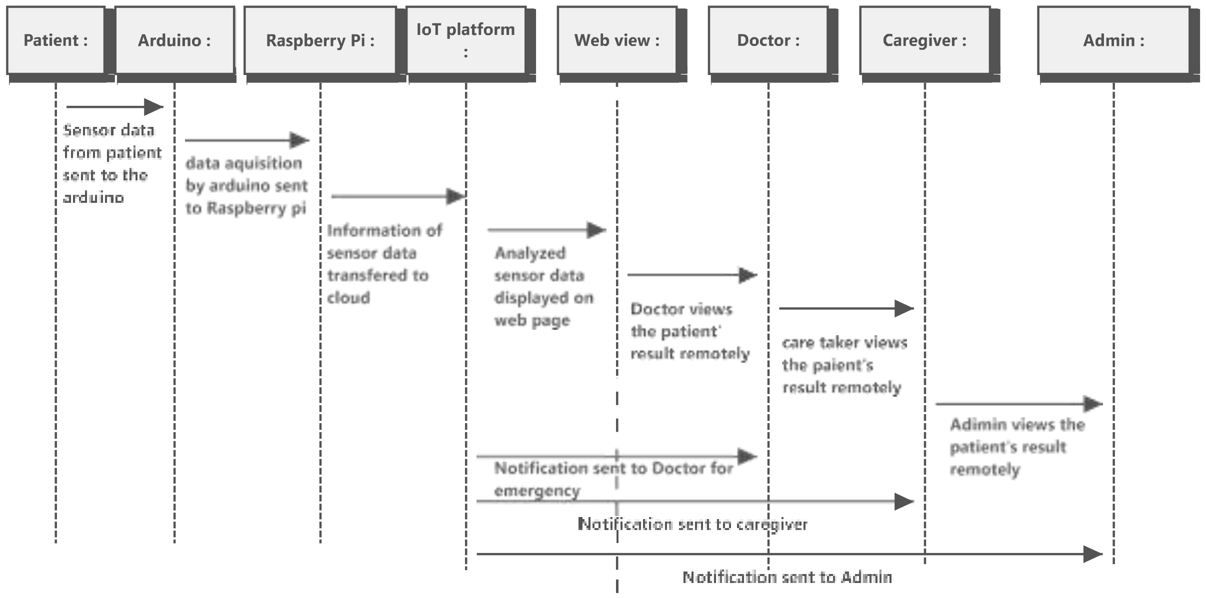



**Figure 18: System sequence diagram**

### 4.3.5 Class Diagram

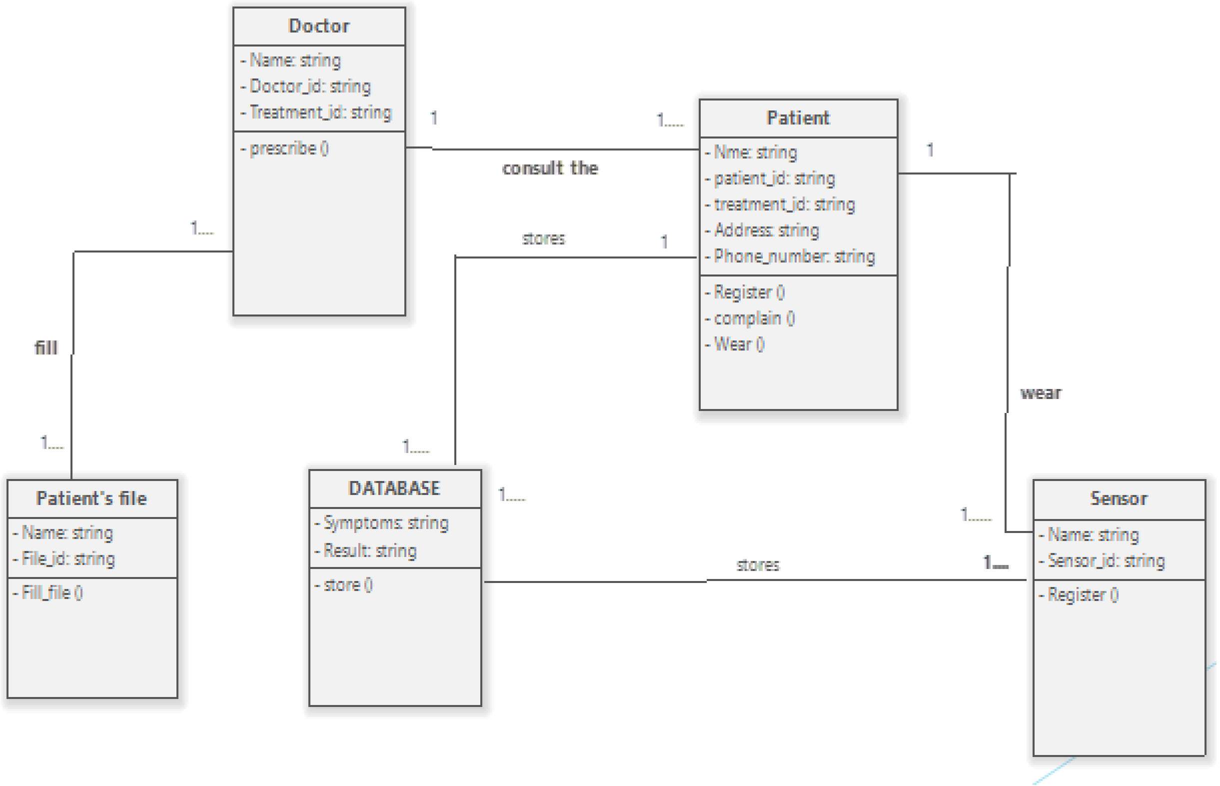



**Figure 19: Class diagram**

4.4 Design for prototype

In this thesis research, the physiological parameters such as patient's body temperature, blood oxygen level, heart rate, body comportment reading the results that are monitored by the system. The accelerometer has to be a wearable sensor also particularly to monitor the fall in inclination of the human body. The buzzer sensor might be interfaced to the Arduino with the assignment of alerting the incidence in case of the sensor is not active or the data beyond the thresholds. Chosen sensors are placed on the patient's body and they take different readings and transfer the sensor data to Arduino, the sensor data acquired by Arduino being transferred to the Raspberry pi using serial communication. The smart camera in charge of behavior monitoring is interfacing to the raspberry pi, so, the corresponding results per each parameter are being sent to the cloud for processing and analysis. The obtained results might be sent to the concerned people via email.

The accelerometer has an assignment of triggering the camera in case the human body changes the position, here the camera start captures the image based on head motion. The accelerometer is placed on the patient's body trunk to facilitate the action of measurement of acceleration used from the head movement during vomiting action.

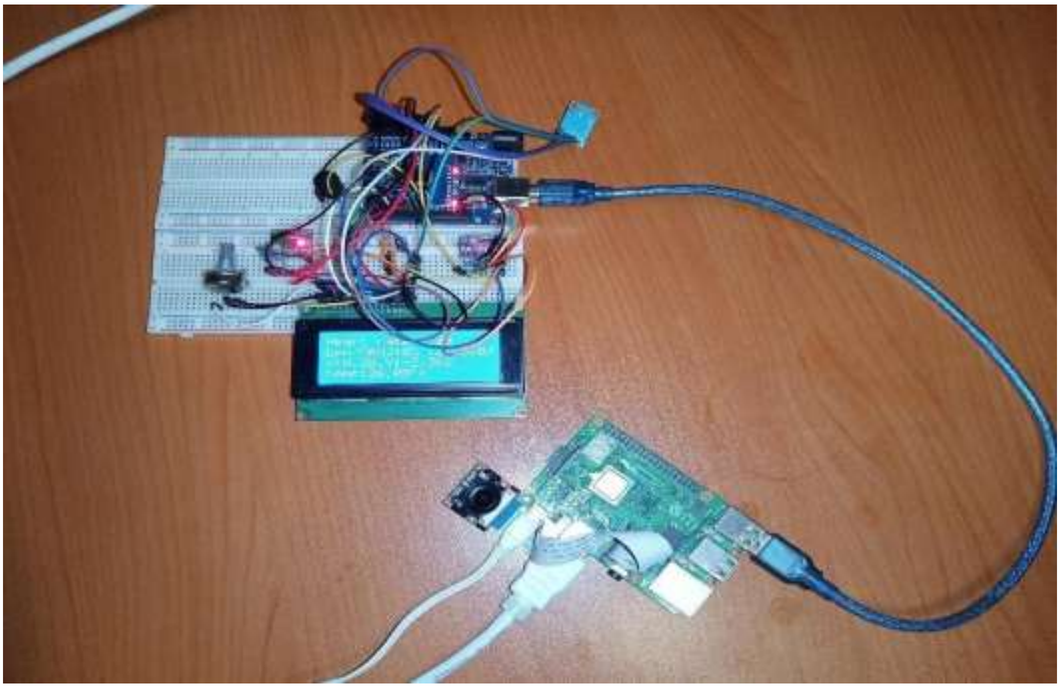


**Figure 20: System prototype displaying the pulse and temperature sensor readings**

# CHAPTER FIVE: ANALYSIS AND RESULTS

## 5.1. Introduction

This section consists of vital signs results and the image obtained from information given from the sensor data collected through covid-19 infected people and the image taken in case vomiting action.

## 5.2 ANALYSIS

### 5.2.1 Machine Learning Approach

The results of the covid-19 vital signs and human activity evaluation employing heart rate, blood oxygen level, body temperature, and vomiting monitoring of interest in this investigation. We employed a machine learning approach, such as decision trees and unsupervised learning, to conduct the analysis. As inputs, we used three channels of vital signs: heart rate (HR), blood oxygen level, and body temperature; as outputs, we used vital signs findings.

### 5.2.2 Training and evaluation implementation

The training and evaluation processes were implemented through programming codes and python libraries. The decision tree was used to train the dataset, training process and evaluation were started by importing the original dataset from the CSV file by using Jupyter notebook data frame implemented with panda's python package. The dataset used during model training and evaluation contains four inputs features and two outputs or target variables. The model inputs are temperature, blood oxygen level, heart rate, vomiting, the model output or target contains the recommended and acceleration used.

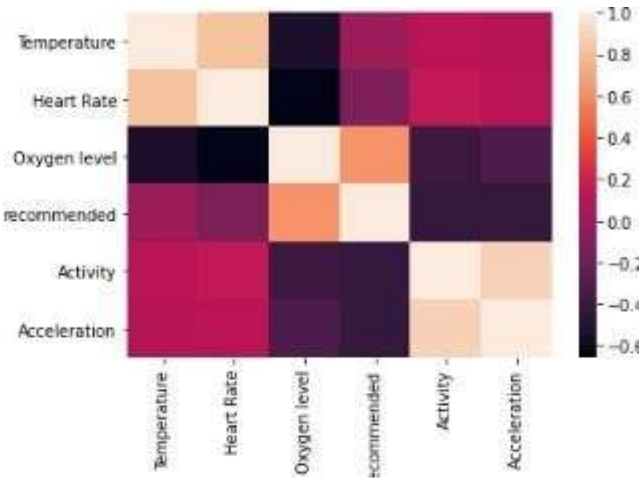



**Figure 21: Show the dataset after being trained**

Correlation Table explanation:

When two variables are negatively correlated, it means that when one variable increases in numerical value, the other variable will decrease, and vice versa. However, when two variables are positively correlated, it means that when one variable an increase in numerical value, the other variable will also increase. Throughout this research, the following data types have been found to have an impact on the results of the patient: temperature, blood oxygen saturation, heartbeat, vomiting, and acceleration. To create a correlation table, both 'vomiting' and 'recommended' values had to be changed to1 and 0.

Correlation values for each column

Table 9: Show the details of the correlation value

| Columns | Temperature | Blood Saturation | Heartbeat | Vomiting | Acceleration | Recommended |
|---|---|---|---|---|---|---|
| Temperature | 100% | -40% | 90% | 30% | 20% | -10% |
| Blood Saturation | -40% | 100% | -60% | -28% | -20% | -60% |
| Heartbeat | 90% | -60% | 100% | 30% | 20% | -20% |
| Vomiting | 30% | -28% | -28% | 100% | 90% | -30% |
| Acceleration | 20% | -20% | 20% | 90% | 100% | -40% |
| Recommended | -10% | -60% | -20% | -30% | -40% | 100% |

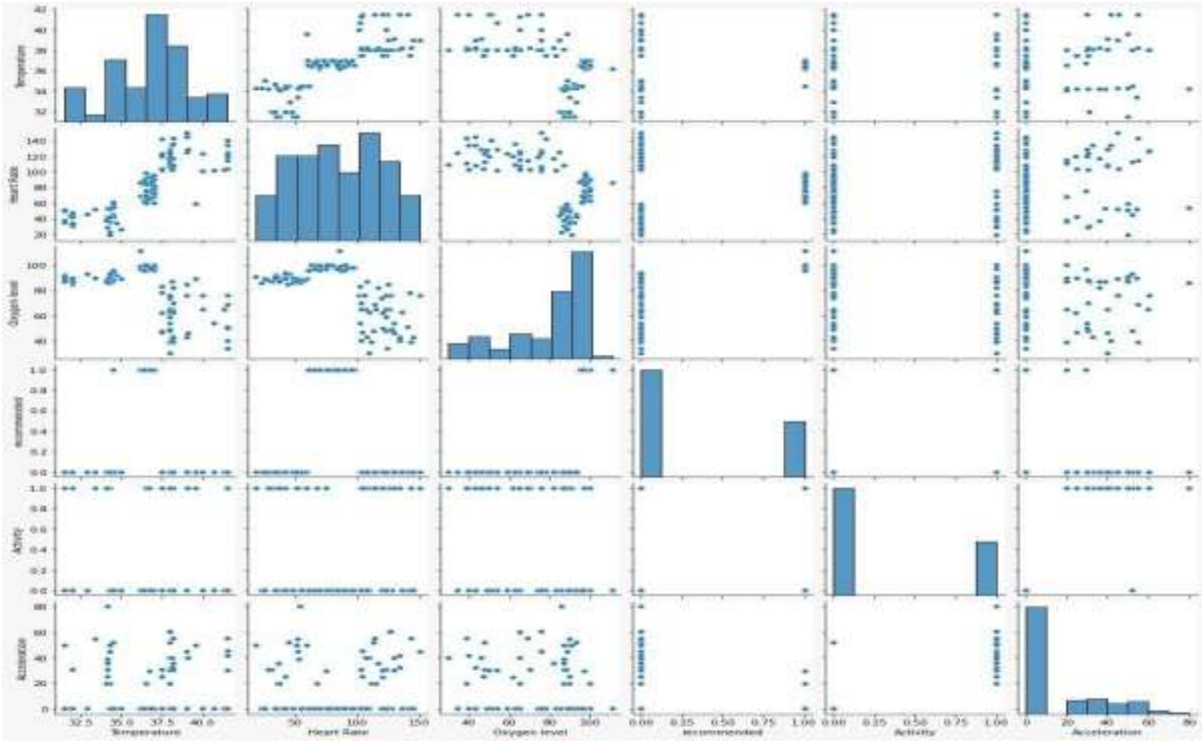



**Figure 22: Show details of dataset trained**

## 5.3 RESULTS

The system consists of two parts: the hardware and the IoT platform. Both parts are essential for the system, and users can obtain notification concerning results from both. In the display of the system the heart rate results, blood oxygen level, even body temperature are shown below.

### 5.3.2 Results displayed on LCD


**Figure 23: Show the results displayed on LCD**

### 5.3.3 Cloud platform dashboard and visualization

The sensor data was captured by a microcontroller and sent to Things speak via Raspberry Pi utilizing Wi-Fi technology. The following outputs were acquired over time after data from 109 persons was collected and transferred to the cloud.

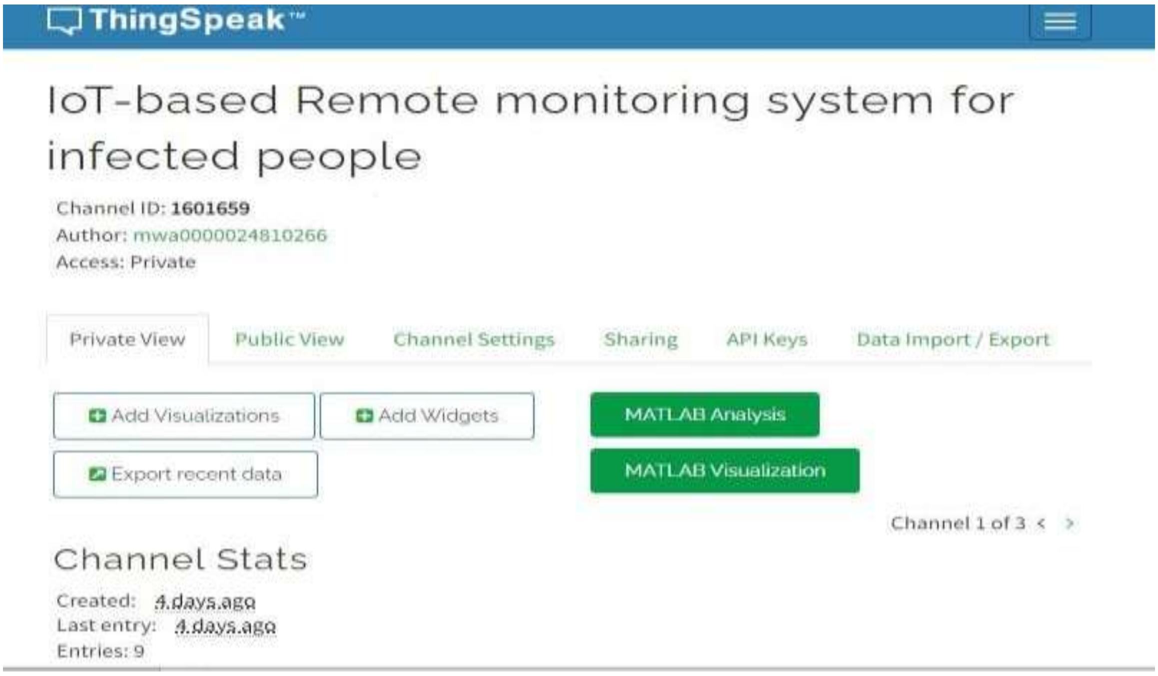



**Figure 24: Show infected people vital signs the channel dashboard**

### 5.3.4 Results displayed on cloud platform dashboard

This section presents particularly the results for any collected data sensors according to the data analysis made. The following graphs allow us to review the output displayed on the dash.

❖ Heart rate results

This dashboard shows the output after analyzing the data sensor, the results of heart rate help the doctor to know the status of infected people. The measures are sequential becausehuman health state.

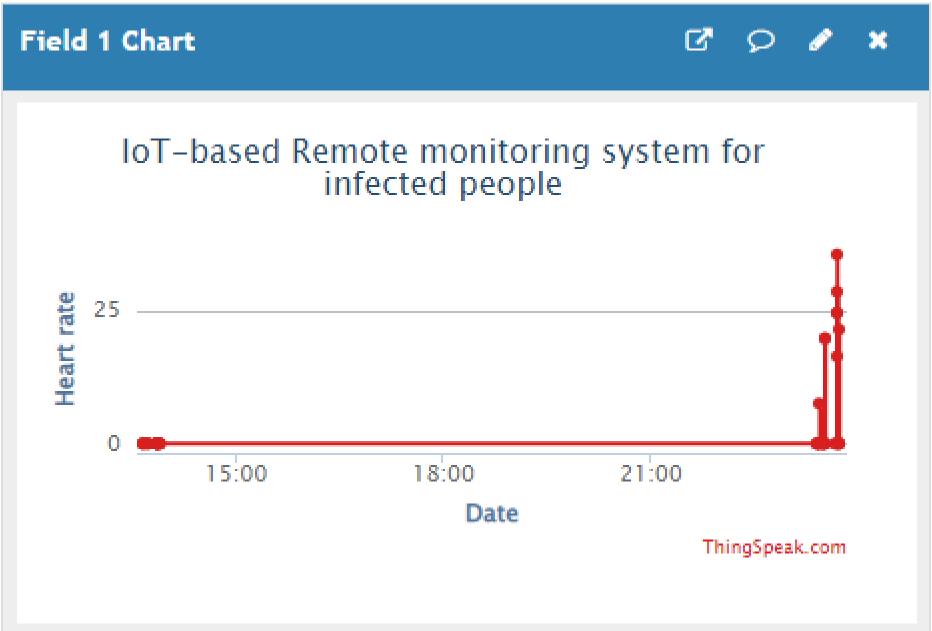



**Figure 25: Graph shows the hate rate results**

❖ Blood oxygen level result

This result determines how well-infected people's body receives oxygen. The results show if the patient has low oxygen in the blood that is a severe symptom. The results canbe obtained in a sequential line caused by the health state.

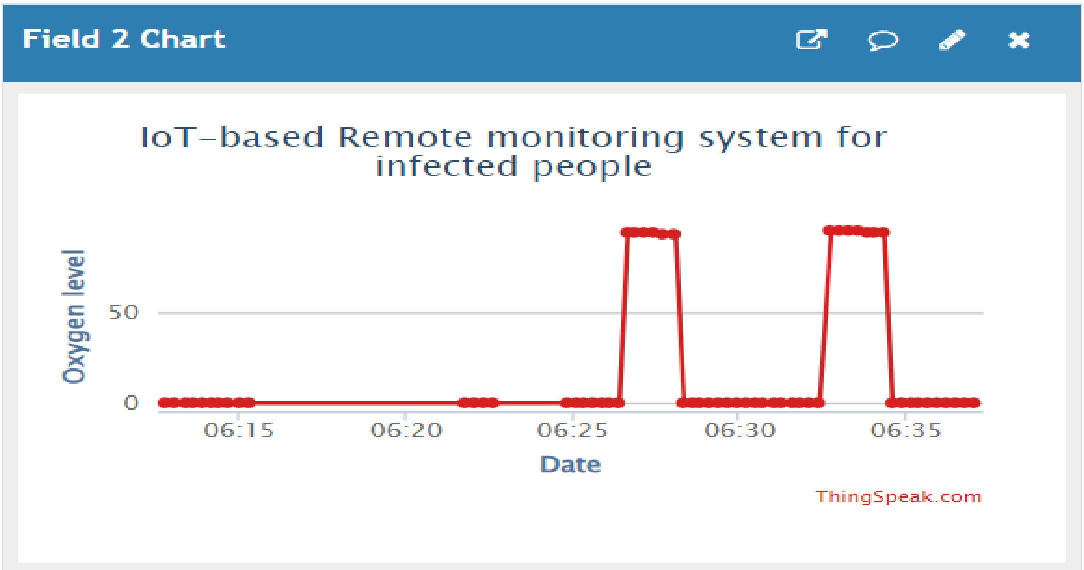



**Figure 26: Graph shows the blood oxygen level results**

❖ Temperature result

This graph shows the temperature result of infected people that changes time by time according to the health state.

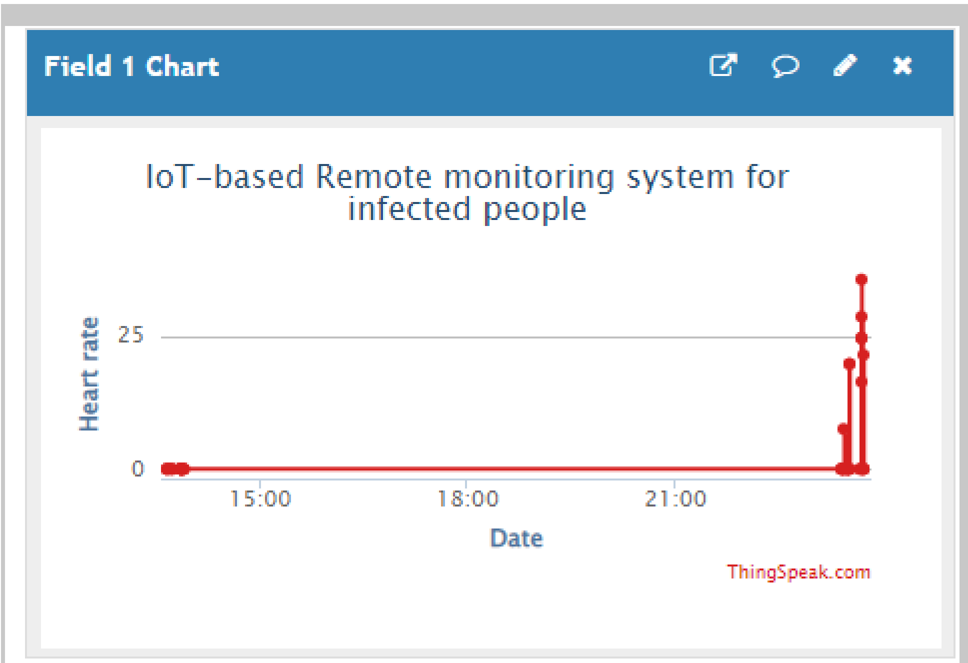



**Figure 27: Graph shows the temperature results**

### 5.3.4 Covid-19 infected people health status notification

The cloud platform was set in a way that whenever the body temperature, heart rate, blood oxygen level of the expectant patient exceeds 38 $^{0}$C, 101%, and 100bpm refers to the respective parameters, a health alert has to be sent automatically to the doctor, to the patient, caregiver, and admin via email. This is also applied to below 35 $^{0}$C, 60%, and 95bpm, the system shows the health status of the covid-19 infected people and the health workers should make immediate support. The image processed must be sent to the doctor's email through a web application.

#### 5.3.4.1 Health alerts

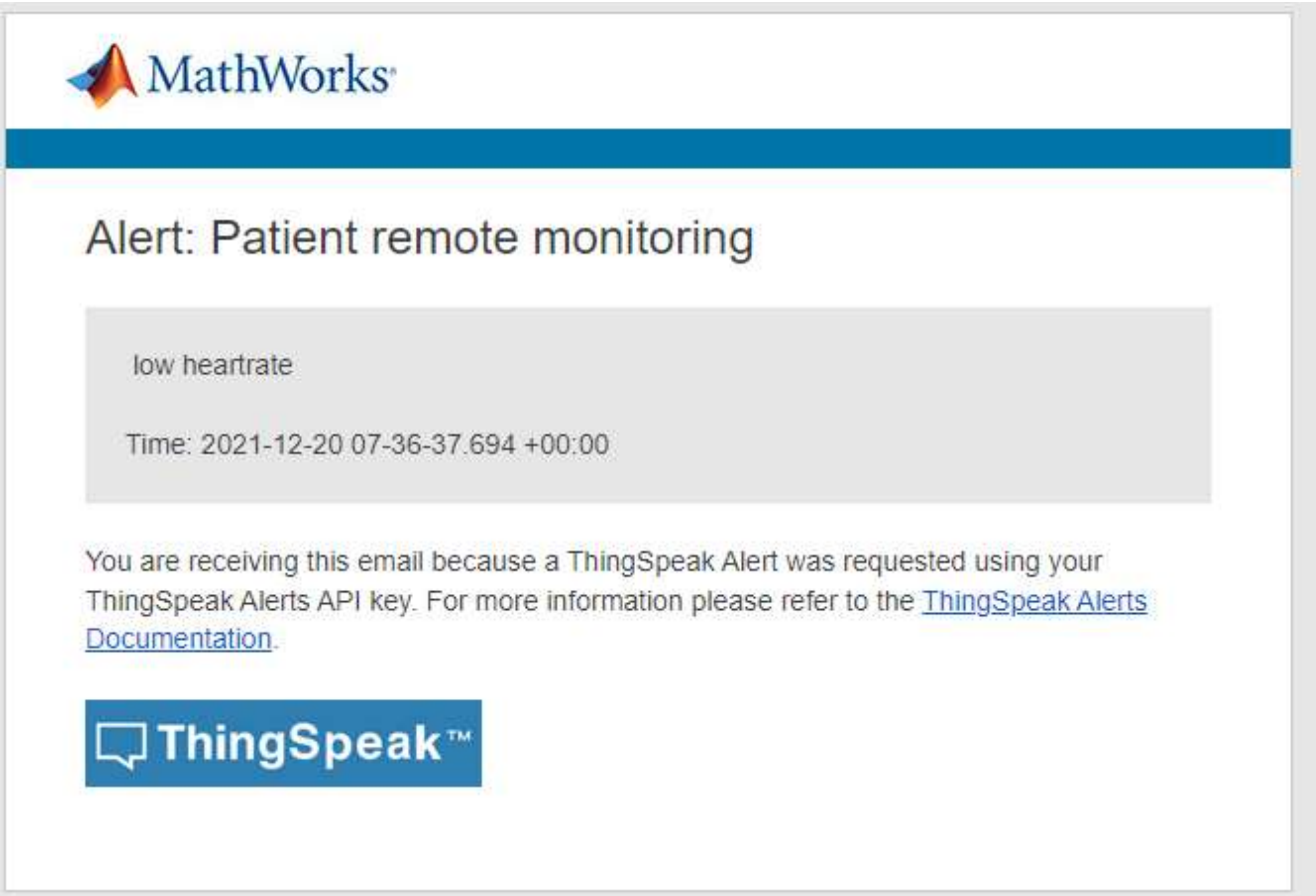



**Figure 28: heart rate alert**

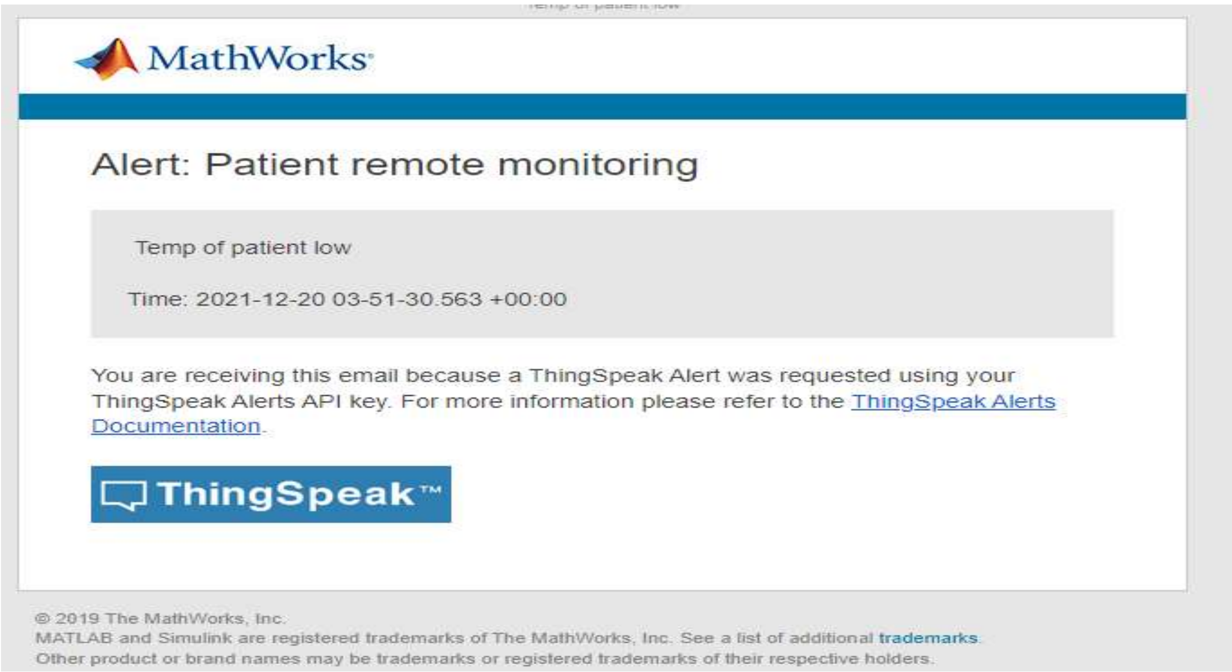



**Figure 29: Low-temperature alert**

# CHAPTER SIX: CONCLUSION AND RECOMMENDATION

## 6.1 Conclusion

This thesis research showed that a wearable sensor network and camera-based human activity have the potential to monitor covid-19 infected people while staying in the home. This project provides efficient healthcare services, particularly for coronavirus pandemic (covid-19) self-isolation. The essential strategy is to monitor covid-19 infected people while remaining in a domestic home as well as evaluate the vital signs and human behavior for infection control. As coronavirus mutation, which increases mortality rate, remote health monitoring based on covid-19 vital signs and human behavior might play an important role. The implementation of this project will lead to a reduction of death, even the large number to be admitted to the hospital, and prevent the risk of infection transmission or evacuation delay in case of clinical deterioration.

## 6.2 Recommendation

In the implementation, there is a need for IoT architecture integrated into image processing. The study recommends an IoT integration architecture with five layers namely data acquisition, transportation layer, the integration layer, application layer, and business layer.

Future research should investigate different gastrointestinal symptoms that might affect the health status of covid-19 infected people who stayed in the home. These were found as the factors of severe complications linked to covid-19 that might be diagnosed and monitored in real-time to prevent dehydration.

Due to limited mobile network availability, continuous data transmission maybe only possible in a few circumstances. Significant delays in data transfer and, in some cases, complete loss of transmission should be reported, particularly in places with only a 2G network. If the patient's home has a canal box or 4G network, wireless communication will be most effective.

## REFERENCES


[1] R. Karthickraja, R. Kumar, S. Kirubakaran, L. Jegan Antony Marcelin, and R. Manikandan, "COVID-19 prediction and symptom analysis using wearable sensors and IoT," *Int. J. Pervasive Compute. Common.*, 2020, DOI: 10.1108/IJPCC-09-2020-0146.

[2] K. N. Swaroop, K. Chandu, R. Garapata, and S. Deb, "A health monitoring system forvital signs using IoT," *Internet of Things (Netherlands)*, vol. 5, pp. 116–129, 2019, DOI: 10.1016/j.iot.2019.01.004.

[3] N. Al Bassam, S. A. Hussain, A. Al Arguli, J. Khan, E. P. Sumesh, and V. Lavanya,"IoT based wearable device to monitor the signs of quarantined remote patients of COVID-19," *Informatics Med. Unlocked*, vol. 24, pp. 10–11, 2021, DOI: 10.1016/j.imu.2021.100588.

[4] M. Talal *et al.*, "Smart Home-based IoT for Real-time and Secure Remote Health Monitoring of Triage and Priority System using Body Sensors: Multi-driven SystematicReview," *J. Med. Syst.*, vol. 43, no. 3, pp. 1–2, 2019, DOI: 10.1007/s10916-019-1158-z.

[5] R. Priam Bodo and T. M. Katarina, "Monitoring Self-isolation Patient of COVID-19 with the Internet of Things," *2020 IEEE Int. Conf. Common. Networks Satell. Contest2020 - Proc.*, pp. 87–91, 2020, DOI: 10.1109/Comnetsat50391.2020.9328953.

[6] S. Gayathri, N. Rajkumar, and V. Vinothkumar, "Human Health Monitoring System Using Wearable Sensors," *Int. Res. J. Eng. Technol.*, pp. 2395–56, 2015.

[7] J. Zhang, S. Garrett, and J. Sun, "Gastrointestinal symptoms, pathophysiology, and treatment in COVID-19," *Genes Dis.*, vol. 8, no. 4, pp. 385–400, 2021, DOI: 10.1016/j.gendis.2020.08.013.

[8] B. Armocida, B. Furmenty, S. Es[1]say, F. Palestra, and E. Missoni, "The Italian health system and the COVID-19 challenge," *Lancet Public Heal.*, vol. 5, no. 5, p. e253, 2020, DOI: 10.1016/S2468-2667(20)30074-8.

[9] A. Boscolo, "Outcomes of COVID-19 patients intubated after the failure of non-invasive ventilation: a multicenter observational study," pp. 1–19.

[10] D. R. Seshadri *et al.*, "Wearable Sensors for COVID-19: A Call to Action to Harness Our Digital Infrastructure for Remote Patient Monitoring and Virtual Assessments," *Front. Digit. Heal.*, vol. 2, 2020, DOI: 10.3389/fdgth.2020.00008.

[11] C. Gizzards *et al.*, “Association between antithrombin and mortality in patients with COVID-19. A possible link with obesity,” *Nutra. Meta. Cardiovasc. Dis.*, vol. 30, no. 11, pp. 1914–1919, 2020, DOI: 10.1016/j.numecd.2020.07.040.

[12] N. Arun Pradeep, G. Niranjana, and G. Suseela, “Smart healthcare monitoring system using IoT,” *Int. J. Adv. Sci. Technol.*, vol. 29, no. 6, pp. 2788–2796, 2020, DOI: 10.22214/ijraset.2020.5101.

[13] M. L. Hoang, M. Cerrato, V. Paciello, and A. Pietro Santo, “Body temperature—indoor condition monitor and activity recognition by mems accelerometer based on IoT-alert system for people in quarantine due to COVID-19,” *Sensors,* vol. 21, no. 7, pp. 1–2, 2021, DOI: 10.3390/s21072313.

[14] A. I. Paganelli *et al.*, “A conceptual IoT-based early-warning architecture for remote monitoring of COVID-19 patients inwards and at home,” *Internet of Things*, p. 100399, 2021, DOI: 10.1016/j.iot.2021.100399.

[15] E. Dirikgil *et al.*, “Home monitoring reduced short-stay admissions in suspected COVID-19 patients: COVID-box project,” *Eur. Respir. J.*, vol. 58, no. 2, pp. 1–8, 2021,DOI: 10.1183/13993003.00636-2021.

[16] D. M. El-Din, A. E. Hassanein, E. E. Hasaean, and W. M. E. Hussein, “E-quarantine:A smart health system for monitoring coronavirus patients for remote quarantine,” *J. Syst. Manag. Sci.*, vol. 10, no. 4, pp. 102–124, 2020, DOI: 10.33168/JSMS.2020.0407.

[17] M. M. Islam, S. Mahmud, L. J. Muhammad, M. R. Islam, S. Nooruddin, and S. I. Ayon, “Wearable Technology to Assist the Patients Infected with Novel Coronavirus (COVID-19),” *SN Compute. Sci.*, vol. 1, no. 6, pp. 1–2, 2020, DOI: 10.1007/s42979-020-00335-4.

[18] J. A. Behar *et al.*, “Remote health diagnosis and monitoring in the time of COVID-19,” *Physiol. Meas.*, vol. 41, no. 10, 2020, DOI: 10.1088/1361-6579/abba0a.

[19] M. Nasajpour, S. Pouriyeh, R. M. Parizi, M. Dorodchi, M. Valero, and H. R. Arabnia, “Internet of Things for Current COVID-19 and Future Pandemics: An Exploratory Study,” *J. Healthc. Informatics Res.*, vol. 4, no. 4, pp. 325–364, 2020, DOI: 10.1007/s41666-020-00080-6.

[20] G. Biagetti, P. Crippa, L. Fianchetti, S. Oricon, and C. Turchetti, “Human activity monitoring system based on wearable Smeg and accelerometer wireless sensor nodes,” *Biomed. Eng. Online*, vol. 17, pp. 1–25, 2018, DOI: 10.1186/s12938-018-0567-4.

[21] Y. Shang *et al.*, “Management of critically ill patients with COVID-19 in ICU: a statement from front-line intensive care experts in Wuhan, China,” *Ann. Intensive Care*,vol. 10, no. 1, pp. 1–54, 2020, DOI: 10.1186/s13613-020-00689-1.

[22] D. R. Beddiar, B. Nini, M. Saporous, and A. Hadid, *Vision-based human activity recognition: a survey*, vol. 79, no. 41–42. 2020.

[23] D. Wurzer *et al.*, “Remote monitoring of COVID-19 positive high-risk patients in domestic isolation: A feasibility study,” *Plops ONE*, vol. 16, no. 9 September. 2021, DOI: 10.1371/journal.pone.0257095.

[24] M. D. Santos *et al.*, “A Real-Time Wearable System for Monitoring Vital Signs of COVID-19 Patients in a Hospital Setting,” *Front. Digit. Heal.*, vol. 3, 2021, DOI: 10.3389/fdgth.2021.630273.

[25] R. Yan, Y. Zhang, Y. Li, L. Xia, Y. Guo, and Q. Zhou, “Structural basis for the recognition of SARS-CoV-2 by full-length human ACE2,” *Science (80- ).*, vol. 367, no.6485, pp. 1444–1448, 2020, DOI: 10.1126/science. abb2762.

[26] D. J. Miller *et al.*, “Analyzing changes in respiratory rate to predict the risk of COVID-19 infections,” *Plops One*, vol. 15, no. 12 December, pp. 28–29, 2020, DOI: 10.1371/journal.pone.0243693.

[27] E. Fridriksdottir and A. G. Bonomi, “Accelerometer-based human activity recognition for patient monitoring using a deep neural network,” *Sensors (Switzerland)*, vol. 20, no.22, pp. 1–13, 2020, DOI: 10.3390/s20226424.

[28] N. Al Bassam, S. A. Hussain, A. Al Arguli, J. Khan, E. P. Sumesh, and V. Lavanya,“IoT based wearable device to monitor the signs of quarantined remote patients of COVID-19,” *Informatics Med. Unlocked*, vol. 24, pp. 1–2, 2021, DOI: 10.1016/j.imu.2021.100588.

[29] D. S. Dahiya, A. Kilolo, M. Alberta, S. Paged, and F. Wani, “Gastrointestinal implications in COVID-19,” *J. Investing. Med.*, vol. 68, no. 8, pp. 1397–1401, 2020, DOI:10.1136/Jim-2020-001559.

[30] P. Yi *et al.*, “Risk factors and clinical features of deterioration in COVID-19 patients in

Zhejiang, China: a single-center, retrospective study," *BMC Infect. Dis.*, vol. 20, no. 1, pp. 1–15, 2020, DOI: 10.1186/s12879-020-05682-4.

[31] S. Lyra *et al.*, "A deep learning-based camera approach for vital sign monitoring using thermography images for ICU patients," *Sensors*, vol. 21, no. 4, pp. 1–18, 2021, DOI: 10.3390/s21041495.