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

DESIGN OF A SMART SCALE WITH INTEGRATED DIGITAL SPHYGMOMANOMETER AND
BMI CALCULATION.

By:

NYIRANSENGIMANA Jacqueline

Reference Number: 221030752

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.

Supervised by:

Prof. Ph.D, KETUL C.POPAT

and


Dr. Frederic NZANYWAYINGOMA

DECLARATION

This dissertation," DESIGN OF A SMART SCALE WITH INTEGRATED DIGITAL SPHYGMOMANOMETER AND BMI CALCULATION," is my original work based on research and a prototype, and it hasn't been submitted for any other degree or professional qualification, I, NYIRANSENGIMANA Jacqueline, declare.

Student Name: NYIRANSENGIMANA Jacqueline

Reg.NO: 221030752

Student Signature:  __

Date: __7th October 2024

CERTIFICATE

This is to confirm that NYIRANSENGIMANA Jacqueline (Reg.No:221030752), a Biomedical Engineering MSc student, is the author of the project "Design A Smart Scale with an Integrated Digital Sphygmomanometer for Health Monitoring Based on IoT".

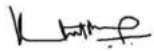
This work has been submitted under the guidance of

Main Supervisor:

Co-Supervisor:

Prof. Ph.D, KETUL C.POPAT and

Dr. Frederic NZANYWAYINGOMA



Signature

Signature.....

Date14TH April2024

Date ...18TH April 2024

Biomedical Engineering Master’s Program Coordinator

Name: Dr. Gerard RUSHINGABIGWI

Signature:

Date:

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ABSTRACT

Hypertension, also known as high blood pressure, is a prevalent global health issue affecting over one billion individuals worldwide[1]. It serves as a major risk factor for cardiovascular diseases, including heart attacks, strokes, and kidney failure[2]. In many regions, especially rural and underserved areas there are challenges associated with monitoring and managing non-communicable diseases(NCDs) including regular check-ups and consultations with healthcare professionals. Traditionally, individuals would have to use separate devices to measure their weight and blood pressure, which can be cumbersome and time consuming. This thesis presents the design of a smart scale equipped with an integrated sphygmomanometer based on the Internet of Things (IoT) for hypertension monitoring and risk assessment. The proposed system combines weight and blood pressure data collected by the smart scale to effectively monitor and track hypertension progress. Early detection and management of hypertension are essential for preventing these complications. In designing a smart scale with integrated sphygmomanometer based on IOT develop a smart scale that can measure weight, height and blood pressure, it stores and transmits data to a cloud platform, it generates personalized hypertension monitoring status, and provides real – time hypertension risk assessment. The smart scale utilizes a load cell sensor for weight measurement, a blood pressure cuff for blood pressure measurement, and ultrasonic sensor for height measurement. These sensors are connected to a microcontroller unit (MCU) to collect, process it and to send the processed data to the cloud server, a cloud server to store the user's data and make it accessible to authorized medical professionals. This project allows for the monitoring of patients' health in remote or rural areas without access to medical care. A smart scale with an integrated digital sphygmomanometer based on IoT could be a valuable tool for preventing and managing hypertension in rural areas. This device would allow people to monitor their blood pressure and weight at home, and to share this data with their healthcare provider remotely. The development of this smart scale was carried out over a period of two years. The research involved extensive literature review, system design, prototype development, testing, and evaluation.

Key Words: Smart scale, sphygmomanometer, Internet of Things (IoT), remote monitoring, NCD.

LIST OF ACRONYMS

ABP: Arterial Blood Pressure

BMI: Body Mass Index

BP: Blood Pressure

BCG: Ballistocardiogram

DBP: Diastolic Blood Pressure

ECG: electrocardiogram

IoT: Internet of Things

LCD : Liquid Crystal Display

LED: Light Emitting Diode

NCD: Non-Communicable Diseases

PPG: photoplethysmogram

PPW: Pressure Pulse Wave

PTT: Pulse transit time

SBP: Systolic Blood Pressure

WHO: World Health Organization

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CHAPTER 1. GENERAL INTRODUCTION

1.1.Introduction

The two greatest causes of death globally, heart disease and stroke, now have systemic hypertension as one of their main risk factors. It is projected that by 2025, hypertension would affect over 1.56 billion people [3]. High blood pressure (BP), or hypertension, is a common, long-term health condition, particularly among older adults. Untreated or ineffectively treated hypertension leads to increased cardiovascular morbidity and mortality in individuals, increased consumption of health care resources, high financial and human costs to society.

According to the data from the World Health Organizations Global Health Observatory, non-communicable conditions account for 36 percent of deaths in Rwanda, of which cardiovascular diseases account for 13%, cancers account for 7%, diabetes accounts for 2%, chronic respiratory diseases account for 1%, and other NCDs account for 12% [4].

Several government agencies and health professional associations have created different BP management standards. The etiology of the hypertension, its severity, and the existence or absence of concurrent conditions all play a significant role in the treatment plan selection. Lifestyle and behavior modification (e.g., quitting smoking, consuming alcohol in moderation, restricting salt intake and other foods, exercising regularly, and losing weight if obese) are recommended management strategies for blood pressure control [5]. These strategies are typically used in conjunction with antihypertensive medication. Research has demonstrated that maintaining adequate blood pressure can reduce the risk of stroke by 35-40%, myocardial infarction by 20-25%, and heart failure by more than 50% [2]. Rwanda has made significant strides in tackling hypertension, but challenges remain, particularly in rural areas, often have fewer healthcare facilities compared to urban areas, making it difficult and time-consuming for residents to travel for regular check-ups and blood pressure monitoring. Strategies being implemented or proposed to reduce the risk of progression is to expand access to early detection and diagnosis.

To track crucial health parameters like blood pressure, heart rate, glucose level, rate of respiration, body mass, room and body temperature, etc., a remote monitoring and recording system for healthcare is used. This system is primarily based on the Internet of Things [6]. A Smart Scale with an Integrated Digital

Sphygmomanometer for Health Monitoring Based On IoT plays a crucial role in remote monitoring of BMI and blood pressure for hypertension management while the system relies on two main types of devices: a digital scale for BMI measurement and a digital blood pressure monitor. These devices are equipped with sensors and electronic components necessary to accurately measure weight, height (for BMI calculation), and blood pressure. Patients use the digital scale and blood pressure monitor to measure their BMI and blood pressure respectively. The devices are user-friendly, requiring minimal setup and interaction. After measurements are taken, the data is transmitted to a central storage system through Wi-Fi. The received data is processed and stored in a secure cloud-based. The system ensures that patient data is protected and accessible only to authorized individuals, such as the patient and their healthcare provider. Patients can access their recorded BMI and blood pressure data through a dedicated web-based platform. The system provides tools for visualizing the data in the form of numerical values this allows patients to track their health metrics over time and Patients can receive personalized feedback and recommendations remotely based on their health status and intervene as needed, such as adjusting medication dosages or scheduling follow-up consultations.

IoT-enabled systems for monitoring BMI and blood pressure leverage sensor technology, wireless connectivity, centralized data processing, and user-friendly interfaces to facilitate remote hypertension management, enabling patients to stay connected with their healthcare providers and receive timely interventions, even when they are away from the doctor's office

1.2. Problem statement

In rural areas, access to consistent and affordable healthcare can be limited, making it difficult for individuals to monitor key health metrics like Body Mass Index (BMI) and blood pressure. Traditional standalone devices for these measurements might be unavailable or cumbersome. The project aims to design a low-cost, user-friendly smart scale with an integrated digital sphygmomanometer (blood pressure monitor) for use in resource-limited rural settings. This Internet of Things (IoT) enabled device will empower individuals to proactively monitor their health and share data with healthcare providers remotely.

1.3. Research Questions

- i. Does the developed system accurately measure weight and blood pressure compared to standard clinical measurements?
- ii. Can the IoT platform successfully transmit health data from the microcontroller to the remote healthcare provider?
- iii. Does the system able to display the status of patient's health parameters?

1.4. Objectives

1.4.1 General Objective

To design of a smart scale with integrated digital sphygmomanometer and BMI calculation this improve healthcare access and encourage lifestyle changes in rural areas for aims of reducing hypertension.

1.4.2 Specific Objectives

- i. To design a smart scale that can precisely measure body weight, body height and body mass index (BMI) using Embedded system design.
- ii. To integrate the smart scale with a digital sphygmomanometer for blood pressure measurement
- iii. To develop an Internet of Things based platform that can securely transfer all health data including blood pressure, weight and body composition to a cloud database.
- iv. To create a database accessible to the healthcare providers for analyzing the transmitted data and providing feedback to the patient using Database management system(MYSQL).

1.5. Study Scope

This project involves designing a physical device that combines a smart scale for measuring weight and height with a digital sphygmomanometer for measuring blood pressure. Its primary purpose is to offer users a comprehensive health monitoring solution, it combines hardware and software to provide real-time health data and monitoring capabilities. This system is more useful in rural where there were a big challenges of healthcare Monitoring system. The system uses Arduino IDE microcontroller which is crucial because their boards are more user-friendly, localhost data-base using Database management system(MYSQL) for storing the patient's data and enabling the access for health provider and Proteus software for drawing a circuit.

1.6. Significance of the Study

The development and application of a blood pressure sensor-equipped smart scale in Rwanda, particularly in rural areas, would benefit the following people and organizations. Healthcare professionals would benefit from having access to information on patients' blood pressure in rural areas in order to identify and treat hypertension early and potentially prevent serious health issues like heart disease, stroke, and kidney failure. People with hypertension who live in rural areas would benefit from having a mechanism to track their blood pressure and provide information to medical specialists for remote monitoring. As a result, they would be in a better position to oversee the treatment of their patients and promptly identify and treat hypertension. Rwandan government would benefit from the design and implementation of a smart scale with blood pressure sensors for hypertension prediction in rural areas by reducing the cost of healthcare and improving the overall health of the Rwandan people, Researchers would benefit from the data collected by the smart scale to conduct research on the prevalence and risk factors for hypertension in Rwanda. This research could be used to develop more effective strategies for preventing and treating hypertension.

1.7. Organization

This paper is structured as follows: Chapter 1 comprises of the introduction, problem statement, aims and objectives of the research. Chapter 2 presents the literature review, Chapter 3 describes the methodology applied, system and hardware requirements, description of components, Chapter 4 presents the system design and development, discusses the results and system test; Chapter 5 summarizes conclusion and the recommendations

1.8 Summary

Weight and blood pressure metrics allows for a more comprehensive assessment of cardiovascular health and hypertension risk. Analyzing trends in both weight and blood pressure can potentially reveal connections, like weight gain leading to increased blood pressure, or vice versa. This information can guide individuals and healthcare professionals in tailoring management strategies. Consulting with a healthcare professional is crucial for interpreting health data and making informed decisions about your health. They can provide personalized guidance on weight management, blood pressure monitoring, and potential interventions for hypertension prevention or control.

CHAPTER 2. RECENTLY RELATED LITERATURE

2.1 Literature Review

IoT based devices are increasingly used in the healthcare sector due their ability to monitor and analyze health conditions. This chapter focus on reviewing state of the art related to IoT in healthcare with respect to BMI and blood pressure. It aims at increasing an understanding of what has been done, strengths and weaknesses of the existing literature.

2.2. Related Studies

In [7] Carek,A.M.,Jung,H.,&Iran,O.T. were developed a weighting –scale- based methodology for estimating PTT and blood pressure. In a Reflective Photoplethysmogram Array and Channel Selection Algorithm for Weighing Scale Based Blood Pressure Measurement the group was based on two key components: (1) the photoplethysmogram (PPG) signal was used as the distal timing reference, and (2) the ballistocardiogram (BCG) signal was used as the proximal time reference. A foot strap was placed across the foot to detect the arrival of the distal pulse. The study presents an array of PPG sensors on a weighing scale platform, allowing for easy distal pulse detection. The sensors emit light and measure blood volume pulses at the bottom of the foot and cardiogenic body movements. The system calculates PTT (Positive Blood Pressure) using the time interval between proximal and distal timings. The device allows subjects to remain motionless on the scale, requiring less initial setup. The proximal time reference is obtained by measuring the BCG signal using a high-bandwidth force plate. A channel selection algorithm analyzes signals from all sensors to select the most reliable and informative signal for blood pressure estimation. This study indicates the feasibility and potential effectiveness of this approach for blood pressure monitoring.

The study presents a method to track changes in blood pressure, but has limitations. It only includes young, healthy subjects, and older subjects may struggle with standing balance. Age also increases arterial stiffness, potentially affecting PPG measurements. However, non-specific estimate models and the need for several calibrations constrain PTT-based techniques for blood pressure estimation, the study contains high amount of sensors.

M. A. Nematollahi *et al.*,In [8] study titled "Body composition predicts hypertension using machine learning methods: a cohort study" investigates the relationship between body composition and hypertension risk. It utilizes a cohort study design, tracking a group of individuals over time to observe

changes in their health status. The study employs a device equipped with tools for assessing body composition metrics such as BMI, body fat percentage, and muscle mass. Additionally, the device incorporates equipment for monitoring blood pressure, a key indicator of hypertension. Data from these measurements are securely stored and associated with individual participants in the cohort. Machine learning algorithms are utilized to analyze the collected data, identifying patterns or correlations between body composition metrics and the likelihood of developing hypertension. Real-time feedback may be provided to participants based on their body composition measurements and predicted hypertension risk. Longitudinal monitoring is essential for tracking changes in body composition and blood pressure over time. Machine learning methods achieved acceptable accuracy in predicting hypertension (up to 90% with specific techniques), body composition indices derived from BIA (like total and regional fat percentage) were important factors for the prediction.

Potential limitations of the study include body composition metrics which may require more sophisticated measurement techniques and equipment, as it was using bioelectrical impedance analysis may also be subject to greater variability and error. The study doesn't mention how long participants were followed, making it difficult to assess how well the predictions hold up over time. The study population was limited to a specific age range (35-70 years), so the results may not be generalizable to younger or older individuals.

In [11]The Digital Blood Pressure Height Weight BMI Machine Coin Operated is a self-service medical device that measures height, weight, blood pressure, and body mass index (BMI). It is commonly used in public health settings, such as gyms, schools, and clinics.

In this system users need to insert coins or tokens to initiate the measurement process. The machine may prompt the user to input basic information, such as age, gender. The user is usually asked to stand on a platform equipped with ultrasonic sensor for height measurement. Select the measurement you want to take (height, weight, blood pressure, or BMI). Follow the voice instructions for each measurement. The results will be displayed on the screen and printed on the thermal printer.

This system is not accurate because the coin slot is designed to accept coins of a specific size and thickness. If a coin is too large, too small, or too thick, it might not fit properly into the slot and trigger the activation mechanism. The device is calibrated to recognize coins based on their weight and density. If a coin is too light or too heavy, it might not register the correct weight and fail to activate the machine.

The coin slot is designed to detect coins made from specific materials, typically metal alloys. If a coin is made from a different material, such as plastic or composite, it might not be detected by the sensor and fail to activate the machine. If a coin is damaged or bent, it might not fit properly into the slot or trigger the activation mechanism. Additionally, if the coin's surface is heavily worn or corroded, it might not be detected by the sensor. If a coin is heavily soiled or covered in debris, it might not be detected by the sensor. The data from this system however cannot be shared with health professionals as its not cloud-based.

F. Landi *et al.*, In [12] The Longevity Check-Up 7+ Study investigates the correlation between Body Mass Index (BMI) and hypertension, focusing on participants aged 7 and older. It employs several key components to explore this relationship thoroughly. Firstly, BMI is calculated for each participant using weight Measurement measured by using calibrated weighing scales and height measurement measured by using a standardized stadiometer, a device with a vertical scale to measure standing height. Secondly, blood pressure readings, including systolic and diastolic measurements, are obtained using standardized techniques. Participants are then categorized into hypertensive or non-hypertensive groups based on established blood pressure thresholds. Traditional methods involving calibrated weighing scales and standardized stadiometers that may prone to human errors.

C. F. Chung *et al.* In [13] The study focused on implementing a new kiosk technology for blood pressure management in a family medicine clinic affiliated with the WWAMI Region Practice and Research Network. The researchers introduced this innovative technology with the aim of improving blood pressure monitoring within the clinic setting. The study likely involved assessing the feasibility and effectiveness of integrating the kiosk technology into routine clinic operations. This technology was likely designed to streamline the process of blood pressure measurement and data recording. The study likely evaluated patient and healthcare provider perceptions of the new kiosk technology. Researchers may have monitored patient engagement with the kiosk and its impact on clinic workflow. Additionally, the study might have examined the accuracy of blood pressure readings obtained from the kiosk compared to traditional methods. The results likely showed positive findings regarding the feasibility and acceptability of the kiosk technology in the family medicine clinic. Patients may have found the kiosk user-friendly and convenient, leading to increased engagement in blood pressure management. Healthcare providers may have reported improved efficiency in managing blood pressure-related tasks.

Moreover, the study may have observed improved patient outcomes, such as better blood pressure control rates, associated with the use of the kiosk technology. Overall, the study suggests that integrating new kiosk technology for blood pressure management in family medicine clinics holds promise for enhancing patient care and clinic efficiency within the WWAMI Region Practice and Research Network. Integrating kiosk data with electronic health records for better BP management might require additional work not explored in this research.

J. Mae, E. Oey, and F. S. Kristiady,[14] Using a real-time database, an Internet of Things-based body weight tracking system for obese adults in Indonesia may efficiently track weight fluctuations and encourage weight control among those who struggle with obesity. The user precisely measures their weight by stepping on a modified digital weight scale. The scale wirelessly communicates the weight measurement to the Internet of Things module. The weight measurement is digitally formatted by the IoT module, which then transmits it to the cloud-based real-time database for storage and makes it available to the smartphone application. The most recent weight measurement is periodically retrieved by the smartphone application from the real-time database[14]. The user can monitor their progress by viewing the weight measurement and updating their weight history through the smartphone application. During the initial setup process when the user first registers or creates their profile, the system can prompt them to manually enter their height. This information can then be stored in the real-time database for future BMI calculation. The manual entry of heights is a major drawback as it slows the process and is prone to errors.

D. Gupta, A. Parikh, and R. Swarnalatha, In[10] Cuffless blood pressure measurement with smartwatches primarily relies on three physiological signals: **Photo plethysmography (PPG)**: PPG measures changes in blood volume in the capillaries of the skin using optical sensors. These changes in blood volume are related to the pulsatile nature of blood flow, which is influenced by blood pressure. **Electrocardiogram (ECG)**: ECG records the electrical activity of the heart. The timing of the ECG signal can be used to estimate the pulse arrival time (PAT), which is the time it takes for the blood pressure wave to travel from the heart to the peripheral arteries. **Seismocardiography (SCG)**: SCG measures vibrations caused by the heart's contractions. The smartwatch's accelerometer detects these vibrations, which can be used to extract. This device is not accurate because of Physiological characteristics such as age, skin

pigmentation, and vascular health can affect the accuracy of blood pressure estimates. Movement during measurement can interfere with the acquisition of reliable physiological signals and Temperature and ambient light can affect the performance of optical sensors.

E. Edwan, M. Abu-Musameh, and A. Alsabah, In [15], The Blood Pressure Monitoring System using Arduino-Android platform is a project designed to measure and monitor blood pressure using readily available hardware and software components. It utilizes an Arduino microcontroller to interface with a blood pressure sensor and then communicates the measured data to an Android smartphone via Bluetooth. The Android app is responsible for displaying the blood pressure readings in a user-friendly interface and potentially logging the data for further analysis or tracking. This system provides a convenient and accessible means for individuals to monitor their blood pressure levels at home without the need for expensive medical equipment. It can be particularly beneficial for individuals with hypertension or other cardiovascular conditions who require regular monitoring of their blood pressure. As it is real time monitoring health professional didn't capture all data which will be facilitate him to take decision.

2.3. SUMMARY AND GAPS IDENTIFIED

The review of the state of the work proves that sensing technologies can be used to capture real time data and calculate the BMI and blood pressure of a person automatically. Likewise, studies have showed that use of Digital Blood Pressure Height Weight BMI Machine Coin Operated is used to monitor BMI and hypertension simultaneously is achieved. However, this research has found that, some of the existing BMI and blood pressure system utilize manual entry of data leading to poor accuracy and consuming more time, other systems lack a real time cloud storage and monitoring however data cannot be shared with health professionals. Other systems are quite expensive, while others require high level of expertise. Therefore, this research implements an IoT-based BMI and hypertension system that is accurate, easy to use with real time storage and monitoring, low-cost and a better accuracy. The proposed system does not replace the healthcare systems put in place but rather acts as a support tool for healthcare.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Research Design and Tools

A mixed research design approach involving both qualitative and quantitative research was used for better understanding the existing hypertension monitoring systems and provide complete evidence for integration of IoT in hypertension monitoring in developing countries. Data was collected from people in Rwanda from Rwamagana District. Physiological data such as body mass index(BMI), blood pressure (BP) were collected. Observation, interview questions, documentation analysis guides were used as the main tools for collecting data.

The selection of those tools was guided by nature of the data to be collected, time available as well as by the objectives of the study.

The Observation Method: During the observation, the research data findings were based on seeing the way of monitoring health of people was being done in Rwanda.

Therefore, the research made indicates that the majority of adult utilize primary healthcare facility for their health needs, Patient visit medical center to see professional medical, Adults people with long term illness, to access the healthcare services is challenge, sometimes they spend whole day to see medical professional when they visit health center. They use traditional method to monitor health of people.

A qualitative approach was taken to learn about the difficulties health professionals encountered when gathering blood pressure readings for patients from rural areas, as well as their suggestions for system enhancements. In this method, interviews were used to collect data from Rwamagana level two teaching hospital, Saint Therese clinic and Saint Simon clinic and beneficiaries located in rural area at Rwamagana District.

No of question	Questions	Number of responding "yes"	Number of responding "No"	Percentages "Yes" %
Q1.	What are the most common challenges patients face when monitoring their health at home?	5	3	62.5
Q2.	How many of your patients require regular blood pressure monitoring at home?	6	3	66.7
Q3.	Do you use a device which monitor your weight at home?	68	21	76.4
Q4.	Have you ever used a blood pressure monitor?	63	24	72.4
Q5.	Do you face any challenges, in monitoring your health at home?	23	78	22.8
Q6.	Would you be interested in a device that combines a scale and blood pressure monitor?	81	13	86.2
Q7.	How comfortable are you using new technology?	76	21	78.4
Q8.	Would you be interested in a device that could share your health data with your doctor?	78	2	97.5
Q9.	Is there a reliable internet access in your area?	67	17	79.8

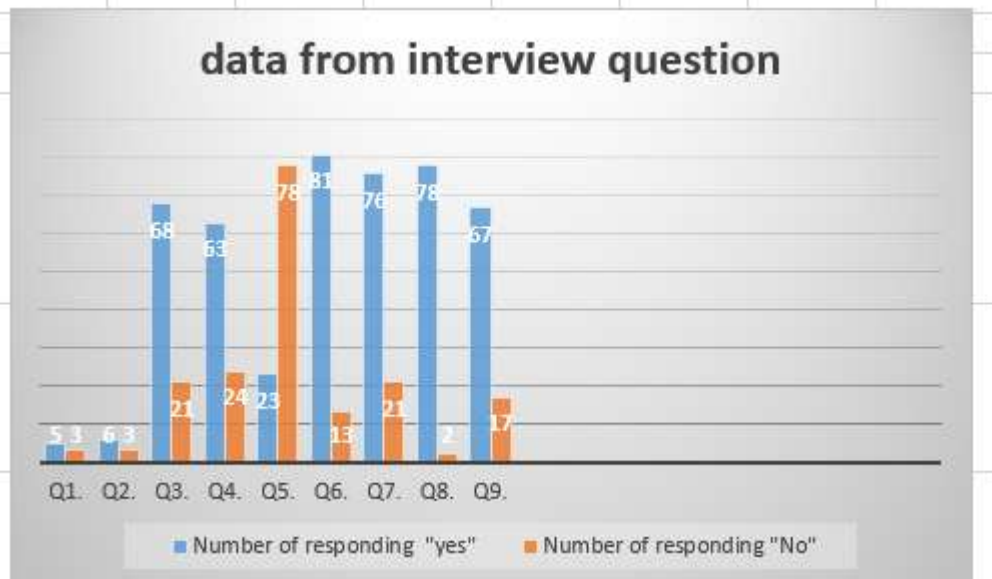


Figure:3. 1: data analysis from questionnaire

Healthcare providers for each healthcare service were asked and they suggested the system that will help them to access and analyze the patient’s data remotely which is time consuming and low costly. Beneficiaries located in rural areas were asked, they prefer a combination and remote monitoring device that provides better patient care, enabling doctors to take timely action and access real-time data. It also reduces hospital visits and treatment costs, empowering patients to make informed decisions about their lifestyle, diet, and exercise habits, ultimately leading to better health outcomes.

3.2 Embedded System Design

In this section the embedded system level design is presented; First research process, system architecture is outlined followed by the system design. The system components, system flow chart and Use case diagrams are presented.

3.2.1. Research Process

The notion that started the study process led to a thorough review of the relevant literature. The process began with developing the study subject in light of the gaps found in the literature review. A write-up of the research proposal was then submitted to the university for approval. After a research proposal was approved, the next sequential stages were as shown in figure 2.

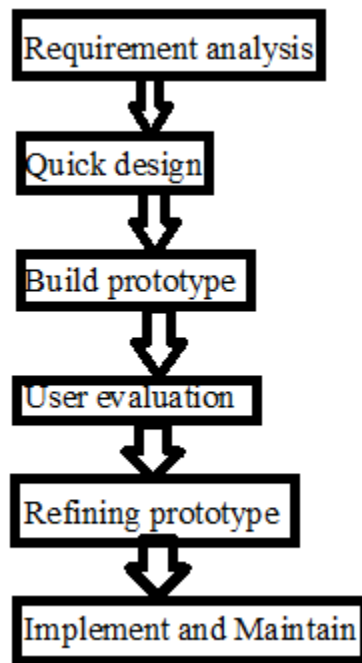


Figure:3. 2:Development of system process

Requirement and analysis: In this stage, the prerequisites of the system were defined. We interviewed health practitioners from those hospitals to get their pain points of the traditional methods they were using and get their views on how they would want the proposed system function.

Quick design: In this stage a quick design of the system was created. This incorporated the structural design of the proposed system which gave a brief idea of the system framework to the user.

Build prototype: In this stage an actual prototype was build dependent on the data assembled from quick design. This stage incorporated all the system requirements gathered and the expectations of the user.

User evaluation: In this stage we presented the proposed framework to the end user for an initial evaluation. This stage helped in discovering the strengths and weaknesses of the proposed system and areas of the framework which needed improvement.

Refining prototype: In this stage we incorporated the changes made by end user into the system until the end user was happy with the system. This was in terms of system accuracy, ease of use, reliability, and time efficiency of the system.

Implement and maintain: This was the last stage in which the system was fully tested and rolled out to be used among the residents of RWAMAGANA District. The system was maintained to prevent any system failure.

3.2.2. System Architecture

Figure 3. Give the system architecture. The main components of the architecture include sensing unit, the microcontroller connects to internet gateway, an open cloud server.

The sensing unit is made by Load cell sensor, Ultrasonic sensor and blood pressure sensor connected to the microcontroller. These sensors collect data for the different parameters. NodeMCU transfers the data to the cloud server for storage, analysis and processing. The processed data is sent to the caregiver platform and doctor platform and display on the LCD.

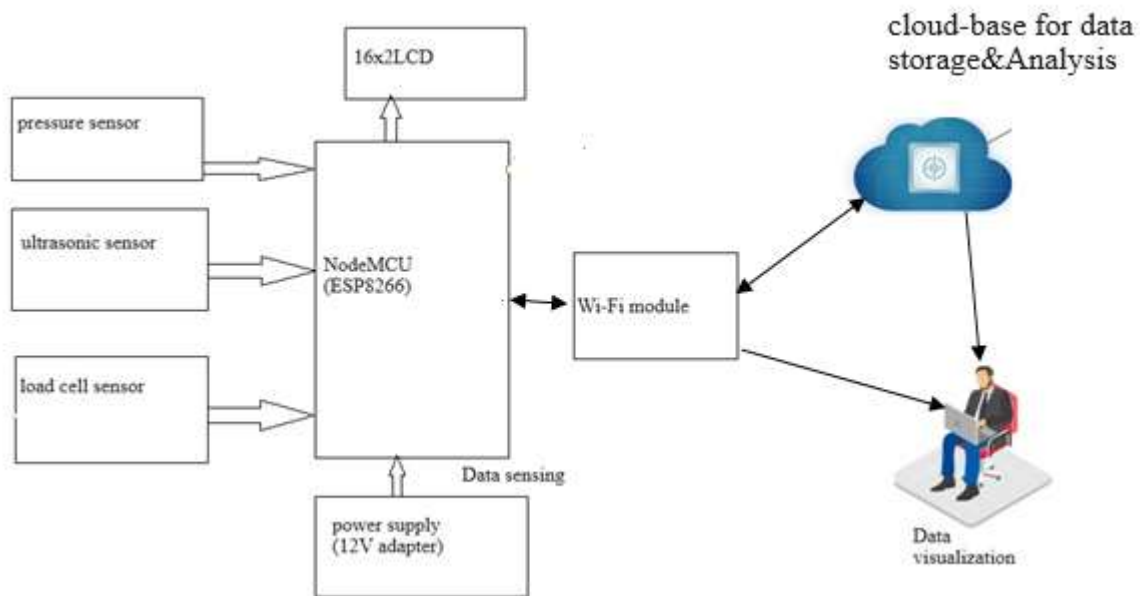


Figure:3. 3: System architectural of smart scale with integrated sphygmomanometer.

The architecture has three main parts perception, network, and application layer.

- Perception Part: is a physical part which has sensors for sensing and gathering data. This part comprises of ultrasonic sensor, load cell sensors for capturing height and weight data of a person and blood pressure sensor for monitoring blood pressure
- The network component: this is used to send and interpret sensor data as well as to connect to other smart devices and network devices. Through a network, the Internet of Things devices are linked to one another and to the cloud.
- Application component: utilized to provide the user with services unique to the application. Cloud-stored data, recommendations, and estimated health status are provided via telephone or email applications.

3.2.3. SYSTEM REQUIREMENTS

Designing a smart scale with an integrated sphygmomanometer and IoT connectivity requires careful consideration of various hardware, software, and network components.

3.2.3.1. Hardware:

- ❖ **Microcontroller unit (MCU):** This brains the operation, processing data from sensors, running ML algorithms, and handling communication with other components. Consider MCUs with low power consumption, adequate processing power for your chosen ML models, and built-in connectivity options like Bluetooth or Wi-Fi.
- ❖ **Weight sensor:** A high-precision load cell is crucial for accurate weight measurement. Choose one with the desired capacity and consider factors like temperature stability and resistance to overload.
- ❖ **Blood pressure sensor:** An inflatable cuff and pressure sensor are needed for sphygmomanometer functionality. Ensure accuracy and compliance with medical device regulations.
- ❖ **Display:** An LCD or OLED display is essential for presenting weight, blood pressure readings, and other health insights to the user. Choose one with good visibility and appropriate size for the device form factor.
- ❖ **Connectivity modules:** Wi-Fi modules enable data transfer to smartphones, cloud platforms, or other IoT devices.
- ❖ **Power supply:** Depending on desired portability and battery life, a power adapter is used.

3.2.3.2. Software:

- ❖ **Real-time operating system (RTOS):** This manages hardware resources, sensor data acquisition, and communication tasks efficiently.
- ❖ **Embedded firmware:** Code running on the MCU to control sensor readings, data processing, and display updates.
- ❖ **Mobile app or web interface:** A user-friendly interface for visualizing health data, tracking trends, and providing actionable insights. Consider compatibility with various operating systems and accessibility features.

- ❖ **Cloud platform (optional):** For advanced data analysis, storage, and remote monitoring, consider cloud integration with secure data transfer protocols.

3.2.3.3. Network:

- ❖ **Internet connectivity (optional):** Depending on your chosen features and functionalities, you may need internet access for cloud communication, software updates, or remote data access.

3.2.4. System Components

3.2.4.1. HARDWARE DESIGN

The development of an IoT based A Smart Scale with an Integrated Digital Sphygmomanometer for Health Monitoring system consists of Load cell sensor, Ultrasonic sensor, HX711 amplifier, blood pressure sensor and NodeMCU microcontroller. The ultrasonic sensor, load cell sensor, blood pressure sensor sent the data into the microcontroller which does the computations and sends the computed data to the LCD.

1. LOAD CELL SENSORS

Load cell is a type of transducer, specifically a force transducer. It converts an input mechanical force such as load, weight, tension, compression or pressure into another physical variable, in this case, into an electrical output signal that can be measured, converted and standardized[16], [17]. It arranged in a Wheatstone bridge configuration to measure the weight. A Wheatstone bridge is a configuration of four resistors with a known voltage applied as shown in figure

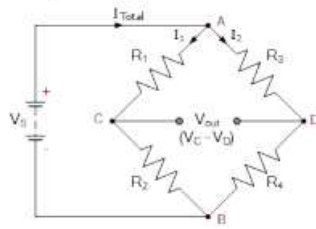


Figure:3. 4: wheatstone bridge circuit

When force (**tension** or **compression**) is applied, the metal body acts as a “spring” and is slightly deformed, and unless it is overloaded, it returns to its original shape. As the flexure deforms, the strain gage also changes its shape and consequently its electrical resistance, which creates a differential voltage variation through a **Wheatstone Bridge circuit**[18][17]. Thus, the change in voltage is proportional to the physical force applied to the flexure, which can be calculated via the load cell circuit voltage output.[18]

With a known constant voltage, V_s , V_{out} is measured. V_{out} is 0 if $R1/R2 = R3/R4$. A change in any of the resistors means a change in V_{out} [18][16]. This is governed by the Ohm's law as shown in equation.

$$V_{out} = \left[\left(\frac{R3}{R3+R4} - \frac{R2}{R1+R2} \right) \right] * V_{in}$$

If we replace the Wheatstone bridge resistors with a strain gauge which has Metal foil strain gage is a sensor whose electrical resistance varies with applied force, V_{out} can easily be measured which intern will help assess the amount of force applied. The electrical resistance of the Wheatstone bridge changes on the direct application of a force on the load cell and thus generates electrical output in millivolts (mV). The HX711 amplifier, then amplifies the small electrical signal generated by the load cell into 24-bit changes in voltage (0-5V). This allows the microcontroller to resolve the weight changes and get a measurable data out of the load cell.

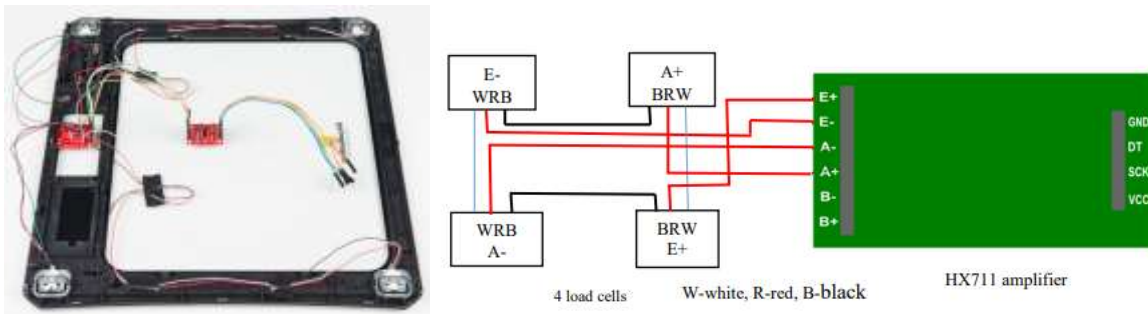


Figure:3. 5: four load sensors arranged in a Wheatstone bridge configuration with HX711 amplifier

2. NODEMCU

NodeMCU is a low-cost, open-source IoT platform that combines firmware and hardware to make it easy to develop and prototype projects that connect to the internet. It's based on the ESP8266 Wi-Fi SoC chip, which is made by Espressif Systems. The processor supports real time operation system (RTOS) operating at a clock frequency of between 80MHz and 160 MHz. It has 128 KB RAM and 4MB of Flash memory for data and program storage[19][20]. It has a high processing power and deep sleep operating feature that's makes it perfect for IoT applications

NodeMCU hardware is based on ESP-12E module, and the firmware runs on ESP8266 Wi-Fi SoC. Wi-Fi module connect to internet to upload or fetch data. The input and output pins have a different mapping on NodeMCU. Unlike other Arduino boards that are powered with 5Volts, ESP8266 chip requires 3.3V power supply voltage. However, NodeMCU ESP-12E development board can be connected to 5V using micro-USB connector or Vin pin available on board. In this project we made a 5 V regulated power supply for NodeMCU Esp8266 so that it can be easily powered using a 12 V adaptor, a solar panel, a 12 V battery, or any dc voltage source. The input voltage should be less than 35 Volts and greater than 5 Volts as we are using a 7805-voltage regulator

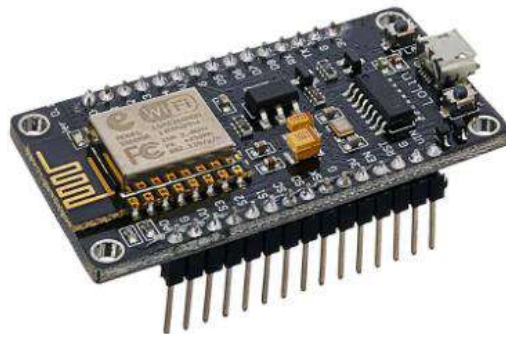


Figure:3. 6: ESP8266 NodeMCU Pinout

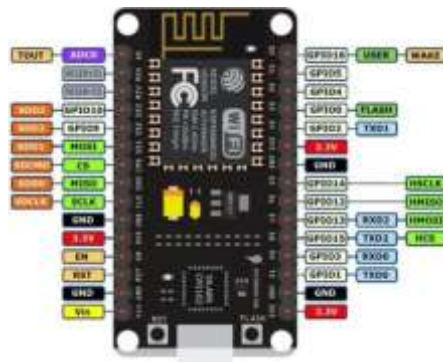


Figure:3. 7: ESP8266 NodeMCU

J1 is the female dc socket where you can connect a 12v adaptor or a 12v battery or a 9v battery. The power supply as you can see is based on the LM7805 voltage regulator. Two 470uf capacitors are connected at the input and output of the voltage regulator. A 330-ohm resistor is connected in series with the 2.5v led. This is a current limiting resistor. to power, up the Nodemcu module, we simply connect the output of the voltage regulator with the Vin pin of the Nodemcu module and connect the ground with the ground pin of the Nodemcu module. these SV1 and SV2 are female headers that can be used for interfacing with other electronic circuits.

3. ULTRASONIC SENSOR

The ultrasonic sensor is a piezoelectric transducer, which is able to convert an electrical signal into mechanical vibrations, and mechanical vibrations into an electrical signal[21]. Ultrasonic sensor is an electronic device that emit sound waves at a high frequency of 40 KHz at regular intervals. Ultrasonic sensor has a transmitter which emits the sound waves and the receiver which receives the reflected sound

waves. To measure the distance of an object, the sensor measures the time it takes between the emission and reception of the sound waves[10], and it's calculated as

$$distance = \frac{T \text{ Round Trip} * V \text{ Sound}}{2}$$

The HC-SR04 ultrasonic sensor is used in this project because it can measure distance from 2cm to 450cm with a accuracy of 3mm.

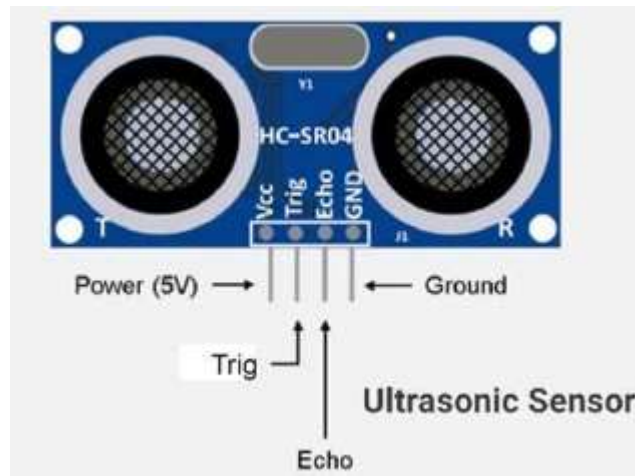


Figure:3. 8: Ultrasonic Sensor

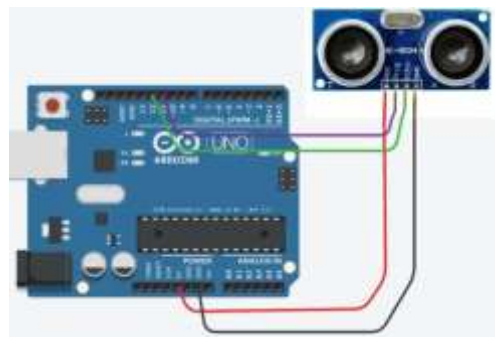


Figure:3. 9: Ultrasonic Sensor Pin Configuration.

4. BLOOD PRESSURE SENSOR

Blood Pressure Sensor (MPS20N0040D-DMP) is used to measure the blood pressure using the non-invasive method. In this project pressure cuff linked to a blood pressure sensor is used to measure the blood pressure. Here, we use a motor pump to pump the pressure inside the cuff to increase the pressure on the artery, automatically a pressure sensor detects the pressure in the artery and give output. This output is then translated into an electrical signal processed by microcontroller which record results and display them on LCD. This sensor has well-proven sensing technology that offers excellent performance, accuracy, and dependability. It makes use of a specific piezoresistive micromachined sensing element. A Wheatstone bridge is formed by the four active piezoresistors found in each sensor. Pressure causes the resistance to vary, and the sensor responds by producing an output millivolt that is proportionate to the input pressure.

The continuous PPW signals extracted from the radial artery by a piezoelectric sensor directly reveals the arterial behaviors of expansion and contraction. The beat-to-beat pressure change was obtained by the pressure sensitivity of the piezoelectric sensor (2 mV/mmHg)[22][23]. In order to linearly convert the electrical signals to pressure signals by pressure sensitivity, the tested signals must stay within the pressure range of the sensor in the specification. The ranges of SBP and DBP are, respectively, from 70/40 mmHg and 190/100 mmHg, including categories of hypotension, normal blood pressure, and hypertension. Systolic pressure: Arterial Pressure recorded during maximum contraction of the heart. Diastolic pressure: Arterial Pressure recorded during maximum relaxation of the heart.

We used a piezoelectric sensor with a pressure range of $-50-3000$ mmHg works with 5V to ensure the system operation in the linear region..[24][25]



Figure:3. 10: Interfacing blood pressure to Node MCU

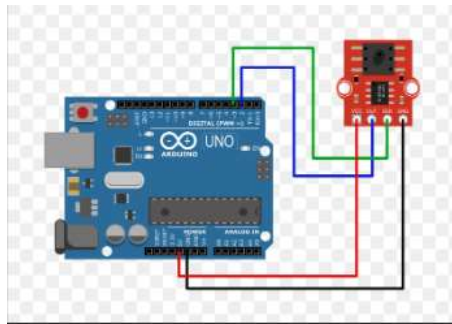


Figure:3. 11: MPS20N0040D-D blood pressure sensor

The additional electronics on the small PCB consist of a 24-bit ADC (HX710B) and a few passive components that go along with it. The HX710B similar to the HX711 is an ADC that is most commonly used for scale sensors but is a great pick here too since the pressure sensor as resistor network. This also means that the sensor is rather easy to use with an Arduino.

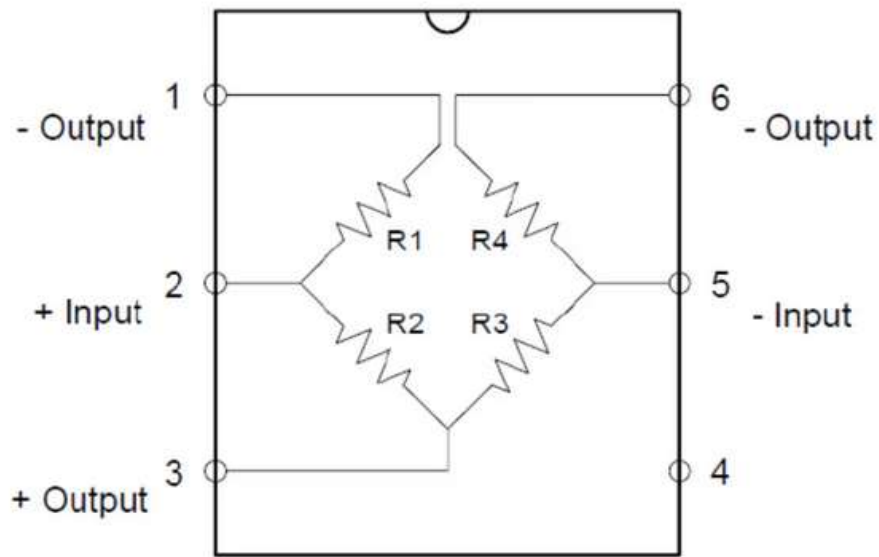


Figure:3. 12: bridge of pressure sensor

5. I2C LCD

Characters and symbols are shown on a 16x2 LCD (Liquid Crystal Display) device. It comprises 2 rows and 16 columns. It is affordable, readily available, and simple to program. BMI, Systolic and diastolic blood pressure values, are shown on a 16x2 LCD.



Figure:3. 13: LCD Display

6. POWER SUPPLY

This project uses a regulated DC power source since it is a more environmentally friendly option than using batteries. Additional hardware utilized in the project included of wires, wooden plates, bolts, and nuts.



Figure:3. 14: Jump wire

7. Circuit Diagram

Interfacing Load Cells, Blood Pressure Sensor, and Ultrasonic Sensor with NodeMCU ESP8266

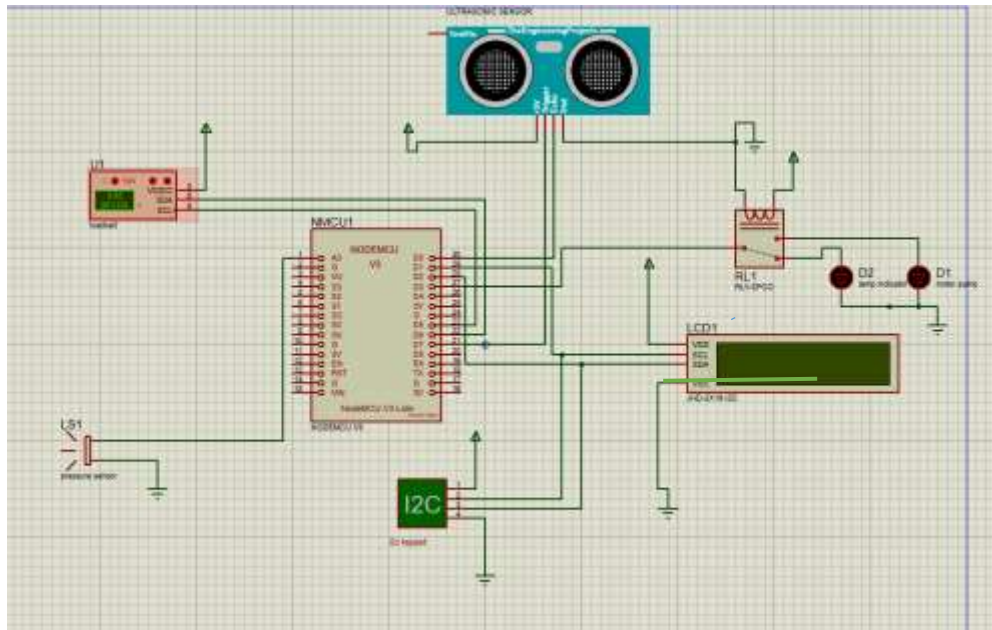


Figure:3. 15: Interfacing loadcells sensor, ultrasonic sensor,pressure sensor to NodeMCU

LCD pins GND, VDD, SDA and SCL were connected to pin number GND, Vin, D1, and D2 of NodeMCU respectively. HX711 Module's DT and SCK pins are directly connected with pin D5 and D6 respectively. Ultrasonic sensor trig pin and echo pin are connected to D7 and D0 respectively. One push button for sending data to the cloud was connected to D0 while the other for resetting the scale was connected to D7 and one push button for resetting pump. The NodeMCU Vin pin and Ground pin were extended to a board to support more devices.

Working principle

3.2.4.2. SOFTWARE DESIGN

In this part the installation of Arduino IDE from Arduino.cc is involved, ESP8266 board manager, HX711 library, thingspeak library, cloud-data base, Liquid Crystal I2C library, I2C Keypad and coding. Arduino IDE programming: Most microcontroller systems are limited to Windows but Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Arduino Software (IDE) provides easy programming software, which is open source and extensible [10]. The language can be expanded through C++ libraries. The programs developed are installed in the Arduino ESP8266 Microcontroller through digital and analog pins provided.

IoT system: The software is stored on the Cloud and is accessed by web browser sensor.com, on which all the data is stored for each patient. The web browser can be accessed from anywhere. The web browser also allows the doctor to provide a feedback to the enrolled patient.

We turned on the system and took any measurement off the device first. Then patient stand on the scale and put his/her left arm in the cuff for blood pressure measurement. Once the readings started, we used the serial monitor to communicate the device of a known set measurement that was placed on the device in order to determine the calibration factor. With the calibration factor in hand, we could simulate up to 200 kg of weight. Later on, the main code made use of the calibration factor.

An ultrasonic sensor was mounted at a known height of two meters from the weight sensor in order to measure a person's height. The letters H and D stand for a person's height and ultrasonic distance, respectively. $H=2m-D$ was the formula used to determine H. we could also simulate up 120mmhg for normal systolic pressure and 80 normal diastolic pressure. Later on, the main code made use of the calibration factor.

From our code, the system was able to display BMI according to the height and weight measured and blood pressure with systolic and diastolic pressure on a 16x2 LCD. With a press of a push button the computed data was send to the cloud-data base for storage and analysis.

3.2.5. system structure

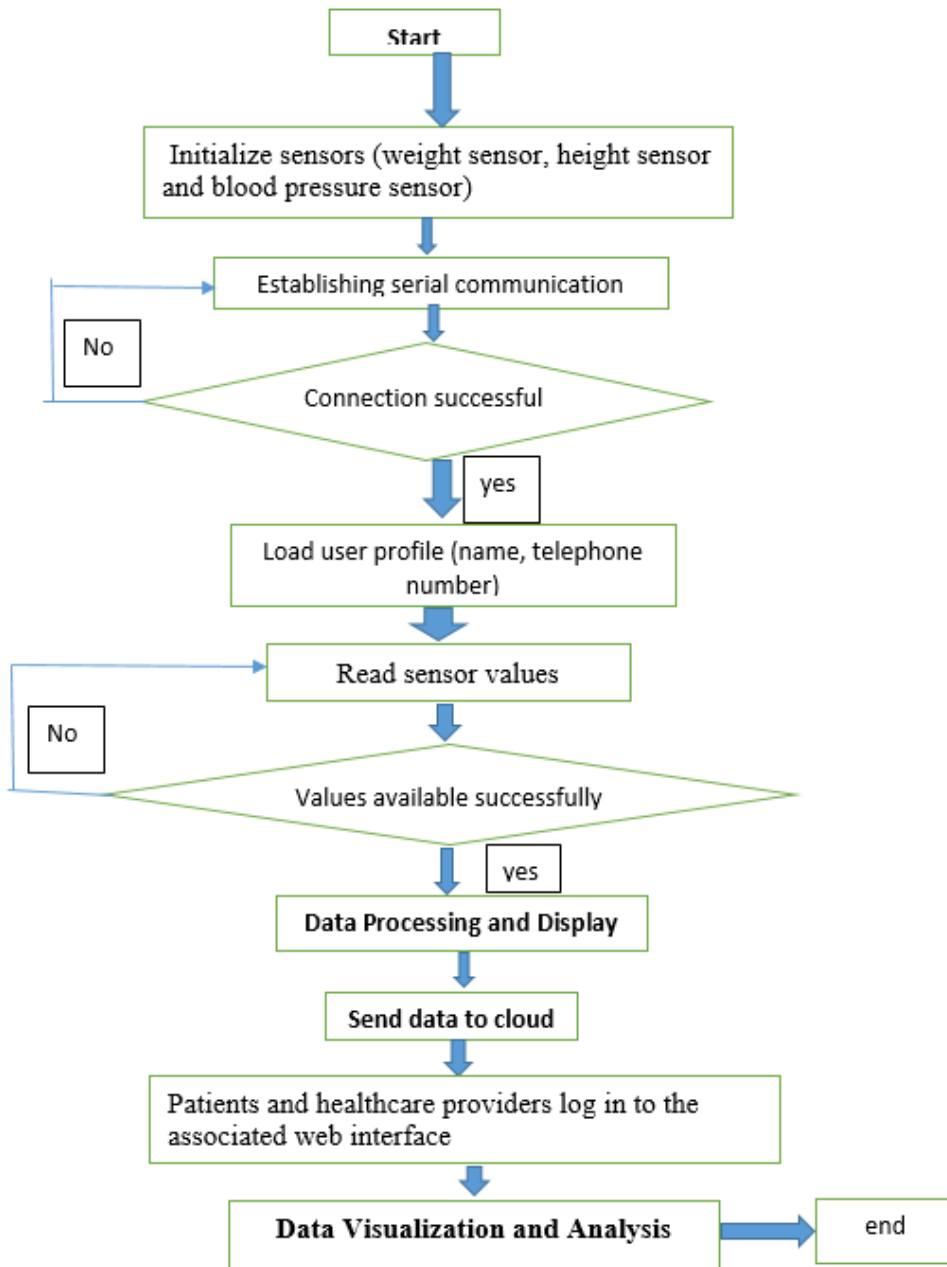


Figure:3. 16: flowchart

Iot-Based Smart Scale With Integrated Syphygmanometer Structural Design

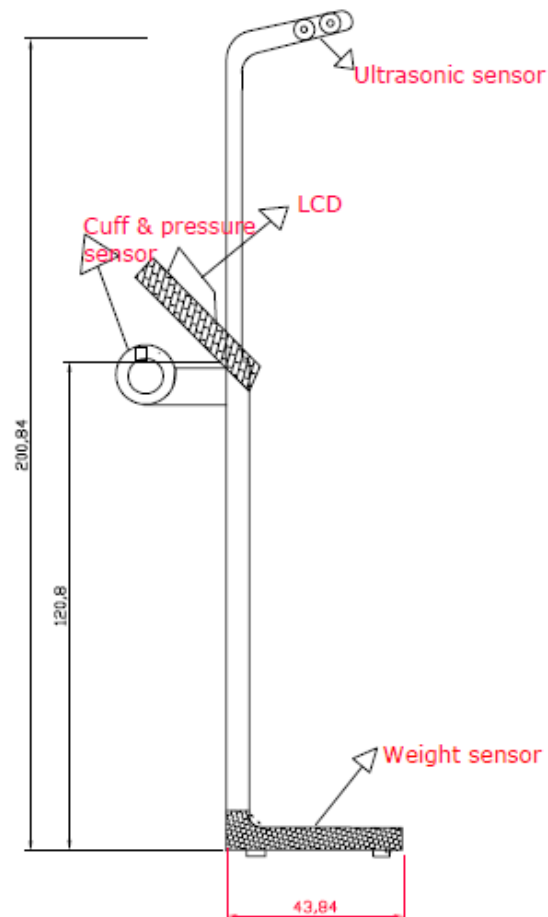


Figure:3. 17: smart scale with sphygmomanometer structure design

The structural design of the system was made up of Wooden pole. The load cell sensors were mounted on a 0.30x0.30m x 0.025m wooden surface and then mounted on top of wood base. The height sensor was fixed a height of 2m from the weight sensor, pressure sensor and LCD mounted on 1.2m from base. The wood base carrying the weight sensor was 0.43m long. The overall system weighed 3.6kg which is portable compared to other existing system.

3.3. Summary

Based on different findings in literature review indicates that in the developing countries especially in Sub-Saharan Africa, we are still having the gaps on real time monitoring of the health of people of rural area by measuring different parameters like body mass index, blood pressure and tracking their location and also to notify the caregiver or doctor about the health status of these people in order to take decision accordingly anywhere anytime, and there is a gap of skilled and knowledgeable people in the new technology like Internet of Things(IoT). So that, the goal of designing and implementing an IoT system to monitor health of people of rural area helps to overcome those challenges by helping people from rural area to get health status on real time and medicines anywhere; thus improve their quality of live, Helping Caregivers and Doctors to monitor these people remotely; Reducing consultation time and related healthcare costs.

CHAPTER 4. THE PROJECT RESULTS FROM IMPLEMENTATION

This section describes step by step the system analysis and the results obtained. The system was designed and working prototype was developed using the different hardware components and data sent to the cloud platform

4.1. SYSTEM PROCESSING

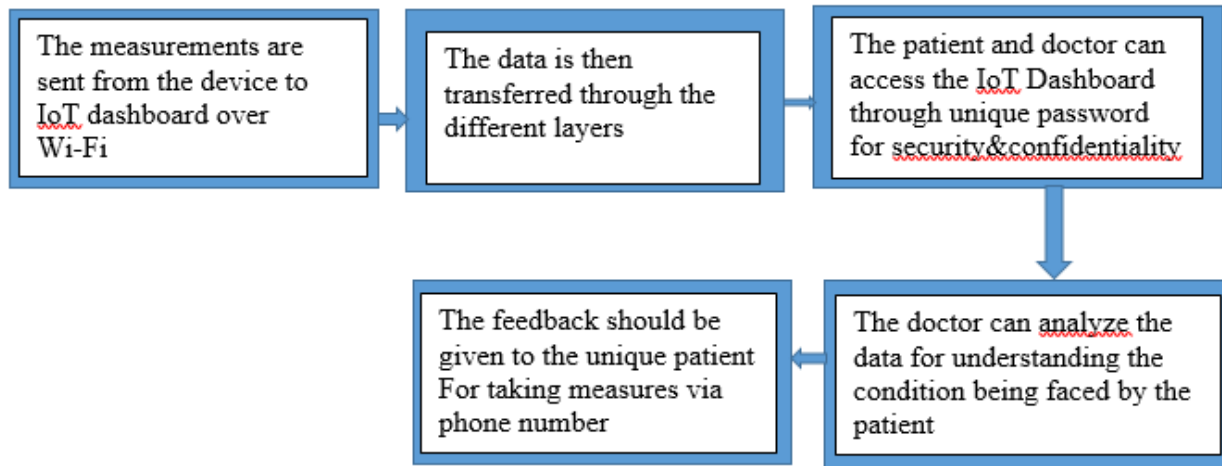


Figure:4. 1: Software processing of measurements

After developing, testing and verification of the implemented system, the results are shown on dashboard IoT cloud where the results are stored, analyzed and visualized as shown in the figures below. The figure 4.2. shows that we have an account in localhost/blood.com cloud platform and monitoring dashboard was created.

FRONT END VIEWER OF THE SYSTEM

Referring to the homepage below, the horizontal navigation bar is used to develop the blood monitoring system; four menus are in the home page the system: home, users, doctor and client.

Home shows who is logging in the system, users display the system users, Doctor and client shows the login form with a sign up for those who is going to use the system at the first time

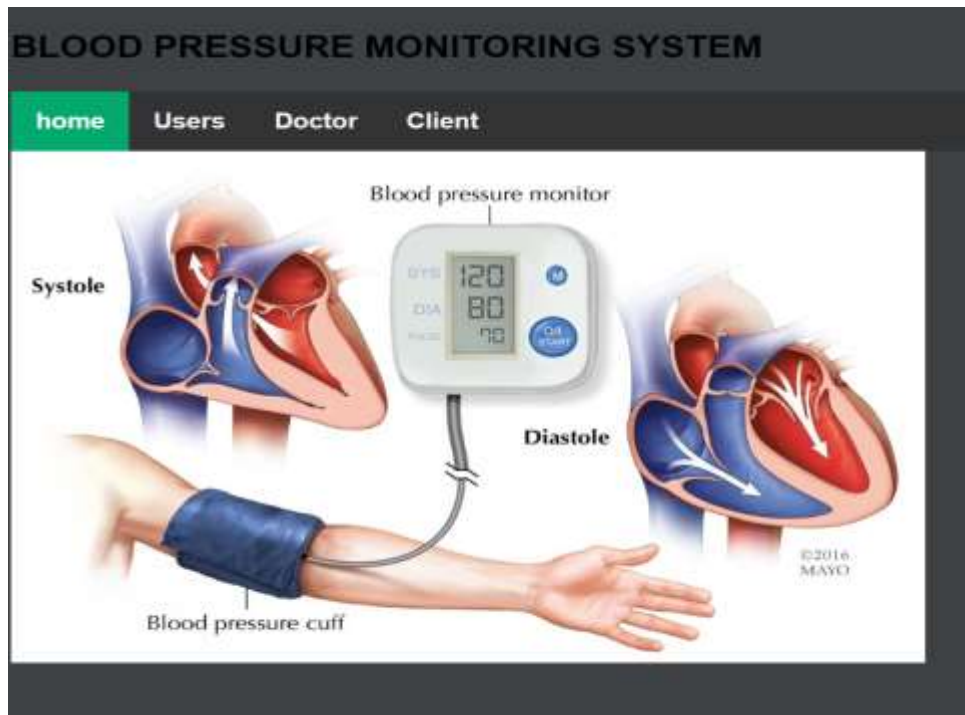


Figure:4. 2: FRONT END VIEWER OF THE SYSTEM

4.2. RESULTS

This part outlines vital signs results of people collected by the sensor. The system consists of two parts: Hardware and IoT cloud dashboard platform Both parts are essential for the system, and users can obtain result notification from both.

4.2.1. System prototype

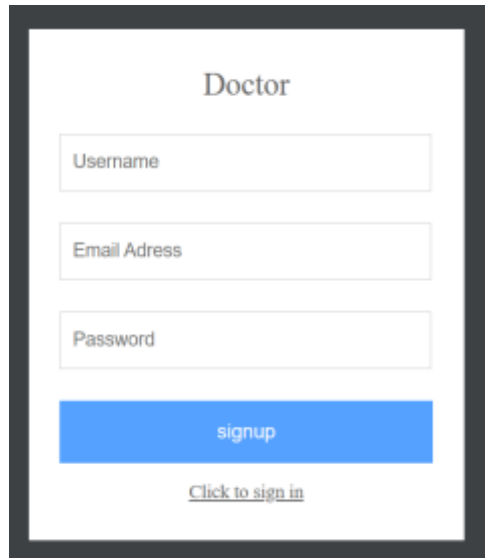
To obtain actual results, a system prototype was designed as follow



Figure:4. 3: system prototype

Each component associated with the PCB was tested to verify if it was working correctly with no short circuits. As a result, the reliability of the microcontroller-based unit was confirmed.

With this technology, patients with hypertension can be monitored and data can be stored for numerous patients' medical analyses. The sensors function only when the device is linked to a wireless network. After measurements are obtained and delivered to the IoT dashboard, Figure 4.4. illustrates the processing that occurs.



Doctor

Username

Email Address

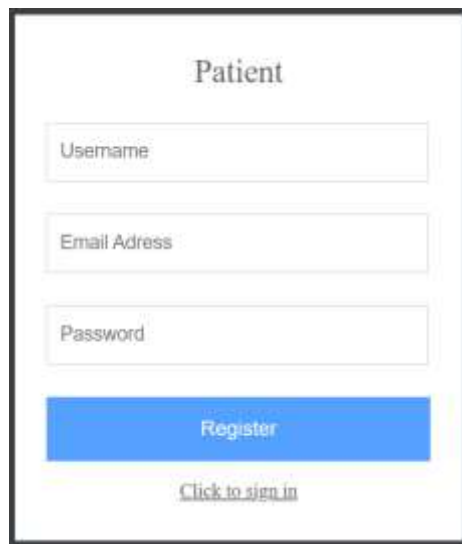
Password

signup

[Click to sign in](#)

The image shows a login form for a doctor. It has a title 'Doctor' at the top. Below the title are three input fields: 'Username', 'Email Address', and 'Password'. Below these fields is a blue button labeled 'signup'. At the bottom of the form is a link that says 'Click to sign in'.

Figure:4. 4: Login form for Doctor



Patient

Username

Email Address

Password

Register

[Click to sign in](#)

The image shows a login form for a patient. It has a title 'Patient' at the top. Below the title are three input fields: 'Username', 'Email Address', and 'Password'. Below these fields is a blue button labeled 'Register'. At the bottom of the form is a link that says 'Click to sign in'.

Figure:4. 5: Login form for patient

4.2. DATASET DISCOVERY

A. Making a database for cloud-base

We chose cloud-base because is an open-source IoT platform specifically designed for collecting, analyzing, and visualizing data from internet-connected devices at no cost and share it among multiple users. Send sensor data from the devices to the cloud data base using Application Programming Interface (API). It retrieves updates from your database automatically in almost real-time as they happen and for retrieve for the long time.

B. DATASET EXPLORATION

Your medical professionals can make more informed and effective decisions about your care by using statistical graphs, patterns, and trends generated from the data that has been gathered and stored in the cloud. It can readily exchange data with your medical advisors, enabling them to counsel and advise you on appropriate health care.

4.2.1. Description of Database tables

From back end side, the blood pressure monitoring system comprises three tables: Admin, sensor, and users table. The credentials for managing the system on behalf of administration is scripted in this table that is only accessed by the system administrators. The sensor table is directly interfaced with embedded system for the purpose of receiving the measured values. Users table contains the system user who got accessed/login in the system. All of the aforementioned tables are in database called **blood**

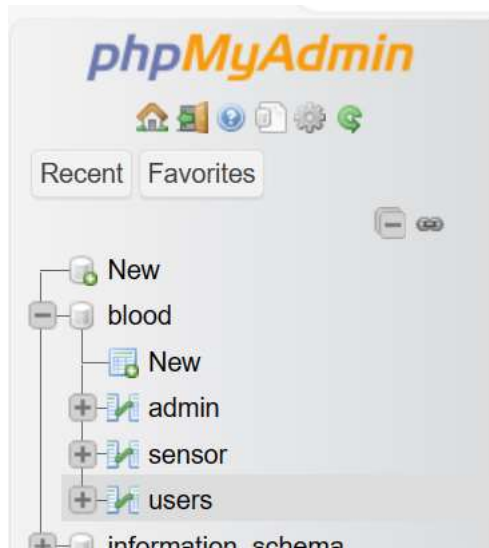


Figure:4. 6: Database table

4.2.2. Sensor table

This is the core table of system as it is interfaced with the hardware. Thus, it is made by the hereunder rows arranged as follows: id, name , phone number, BMI, systolic pressure, diastolic pressure and date.

The Hypertension and BMI dataset used was an open-source dataset from sensor.com. The dataset of 7 columns situated in this table is accessed over the website.

id	name	phone_no	BMI	Systolic_pressure	Diastolic_pressure	Date
1	JACKY	0788972115	22.5	120	80	2024-03-01 14:03:18
2	YVONNE	0784030462	18.7	130	90	2024-03-02 14:04:55
3	FIDELE	0780146881	23.6	128	88	2024-03-02 14:04:55
4	EMELYNE	0784396338	22.1	119.6	79.5	2024-03-07 14:08:38
5	KALISA	0788915277	23.6	127.2	87.7	2024-03-08 14:08:38

Table: 4. 1: Readings of multiple patient on dashboard

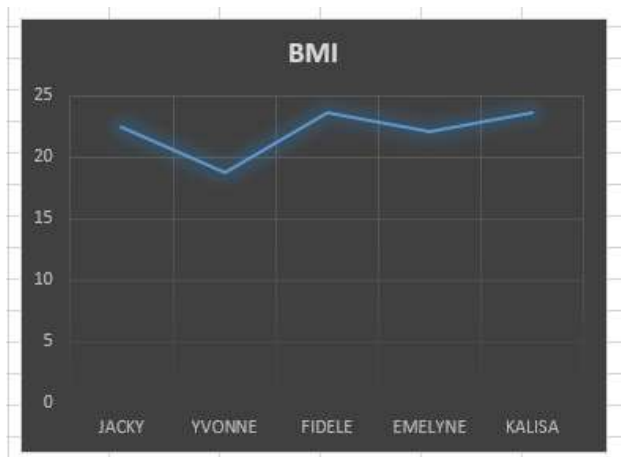


Figure:4. 7: Body mass index

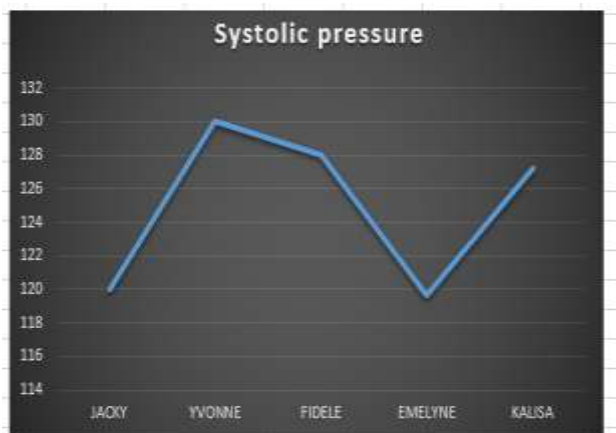


Figure:4. 8: Systolic blood pressure

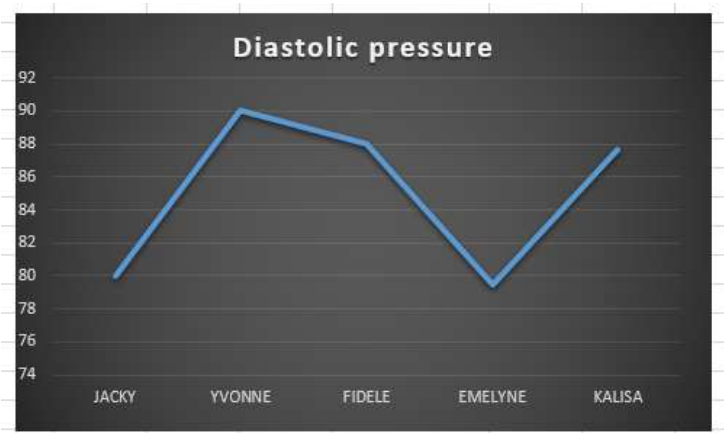


Figure:4. 9: Diastolic blood pressure

Blood pressure is the force that a person’s blood exerts against the walls of their blood vessels. This pressure depends on the resistance of the blood vessels and how hard the heart has to work.

The systolic reading of 130 mm Hg refers to the pressure as the heart pumps blood around the body. The diastolic reading of 80 mm Hg refers to the pressure as the heart relaxes and refills with blood [2]–[4] [26][27]

	Systolic (mm Hg)	Diastolic (mm Hg)
Normal blood pressure	less than 120	less than 80
Elevated blood pressure	120–129	less than 80
Grade 1 hypertension	130–139	80–89
Grade 2 hypertension	140 and over	90 and over

Table 4. 1:Blood pressure range given by AHA

4.2.3. DATA ANALYSIS

1. Based on the data JACKY provided a BMI of 22.5 falls within the normal weight range (18.5-24.9). This is a positive indicator of her overall health. Systolic pressure of 120mmHg and diastolic pressure of 80mmHg is considered normal blood pressure (<120/80mmHg). Maintaining a healthy weight and lifestyle habits can help you keep your blood pressure in check.

4. Based on data YVONNE provided a BMI of 18.7 and blood pressure of 130/90mmHg

A blood pressure reading of 130/90mmHg falls into the category of Stage 1 hypertension according to the latest guidelines from the American Heart Association (AHA)[27]. This indicates that her blood pressure is slightly elevated but not yet in the severe range.

➤ Lifestyle modifications are often the first line of defense in managing Stage 1 hypertension. [2].

A BMI of 18.7 falls within the normal weight range (18.5-24.9). This is positive as maintaining a healthy weight can help reduce your risk of developing hypertension and other chronic diseases.

5. Based on the data FIDELE provided a BMI of 23.6 falls within the normal weight range (18.5-24.9). This is a positive indicator of your overall health. Your blood pressure reading of

128/88mmHg is considered borderline normal according to the latest guidelines from the American Heart Association (AHA). While technically not in the hypertensive range, it's on the higher end of what's considered optimal (<120/80mmHg) [27].

6. Based on the data provided by EMELYNE, a BMI of 22.1 falls within the normal weight range (18.5-24.9). This is a positive indicator of your overall health. Your blood pressure reading of 119.6/79.5mmHg is considered optimal according to the latest guidelines from the American Heart Association (AHA). This is excellent and indicates that your blood pressure is in a healthy range. You seem to be doing a great job with your health.
7. Based on the data KALISA provided, a BMI of 23.6 falls within the normal weight range (18.5-24.9). This is a positive indicator of your overall health. Your blood pressure reading of 127.2/87.7mmHg is considered borderline normal according to the latest guidelines from the American Heart Association (AHA). While technically not in the hypertensive range, it's on the higher end of what's considered optimal (<120/80mmHg) [27].

4.3. DISCUSSION

In case the patient takes a measurement, then the values displayed on the IoT interface. A smart scale provides a precisely measurement of body weight, body height, and body mass index (BMI) at 98%. The system Integrate the smart scale with a digital sphygmomanometer that measures blood pressure accurately, providing ± 6 mmHg for both systolic and diastolic. When the patients were regular checkup BMI and hypertension status were measured using this device, and their values were subsequently stored on the cloud platform. Healthcare provider through the analysis of parameters can get a better understanding of the medical condition and potential medical threats that the patient might face. The values for a given measurement were integrated together and a graph indicating the patient's health trend was developed, to provide a statistical analysis. Finally, the healthcare professional can continuously remotely monitor the status of hypertension for any disturbance in the patient's health conditions, to prevent a potential catastrophe.

CHAPTER 5. CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

The study provides a suitable device for daily analysis of health parameters to monitor hypertension. The prototype is a fully functioning device, to measure the body weight, height for calculation body mass index (BMI) and blood pressure parameters. This device is efficient, user friendly. Therefore, this device is of a suitable use for regular tracking of hypertension conditions and also allows the doctor to provide feedback regularly to the patient. The patient and the doctor can analyze their historical medical data on the IoT server, which will help them keep track of their health condition on a daily basis.

5.2. RECOMMENDATION and FUTURE WORK

5.2.1. Recommendation

The results from the previous sections prove our hypothesis that an IoT based system can be used to monitor hypertension status and body weights were calculated for the certain persons. We recommended the future work to design smart scale capable to measure BMI for people who weigh more than 200 kg, the created method is not appropriate as it can only measure up to 200 kg, for disability affecting the left arm and leg is not well served by the system. We also recommend future researchers to think about using machine learning which will help in the prediction of the hypertension stage based on the characteristics examined in this study and to show potential hazards or problems to individuals with hypertension.

5.2.2. FUTURE WORK

The project prototype that was developed indicates that there are some limitations; there is accurate issue of the systems' hardware to be thought about and resolved in the future work.

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APPENDICES

Appendix 1: Interviews questions.

Example of questionnaire

Interviews questions included the following.

From hospitals

1. What are the most common challenges patients face when monitoring their health at home?
 - a) Interpreting health data
 - b) Storing health data
 - c) Lacking support from healthcare providers
2. How many of your patients require regular blood pressure monitoring at home?
 - a. Below 70% patients
 - b. Above 70% patients

From patients

1. Do you use a device to monitor your weight at home?
 - a. Yes
 - b. No
2. Have you ever used a blood pressure monitor?
 - a. Yes
 - b. No
3. What challenges do you face in monitoring your health at home?
 - a. Interpreting health data
 - b. Storing health data
 - c. Lacking support from healthcare providers
4. Would you be interested in a device that combines a scale and blood pressure monitor?
 - a. Yes
 - b. No
5. How are you comfortable while using new technology?
 - a. Good
 - b. Bad

6. Would you be interested in a device that could share your health data with your doctor?
 - a. Yes
 - b. No
7. Is there a reliable internet access in your area?
 - a. Yes
 - b. No

Appendix 2: The Utilized Codes

```
#ifdef ESP32
  #include <WiFi.h>
  #include <HTTPClient.h>
#else
  #include <ESP8266WiFi.h>
  #include <ESP8266HTTPClient.h>
  #include <WiFiClient.h>
#endif
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include "HX711.h"

LiquidCrystal_I2C lcd(0x27,20,4); // set the LCD address to 0x27 for a 16 chars and 2
line display
int echopin=D0;
int trigpin=D7;
float distance;
float reading;
float duration;
const int LOADCELL_DOUT_PIN = D6;
const int LOADCELL_SCK_PIN = D5;
float weight1=0;
int piezosensor=A0;
float sensorreading=0;
HX711 scale;
const char* ssid = "TECNO SPARK 10C";
const char* password = "fideli123@";
WiFiClient client;
float objectdistance=2;
float senseddistance=0;
float BMI=0;

int pumpflowrate=5;
int diastolic=0;
int systolic=0;
// REPLACE with your Domain name and URL path or IP address with path
const char* serverName = "http://192.168.141.175/sensordata/post-esp-
data.php";//192.168.197.175
String apiKeyValue = "0788972115";
String number="0788972115";
```

```

String name1="JACKY";
void setup()
{
  lcd.init();           // initialize the lcd
  lcd.init();
  // Print a message to the LCD.
  lcd.backlight();
  lcd.setCursor(0,0);
  lcd.print("BLOOD PRESSURE ");
  lcd.setCursor(0,1);
  lcd.print(" ,MONITOR ");
  delay(3000);
  lcd.clear();
  pinMode(trigpin,OUTPUT);
  pinMode(echopin,INPUT);
  Serial.begin(9600);
  scale.begin(LOADCELL_DOUT_PIN, LOADCELL_SCK_PIN);
  //cale.set_scale();           //for calibration
  //cale.set_scale(5178000);//red scale factor
  //cale.tare();
  WiFi.begin(ssid, password);
  Serial.println("Connecting");
  while(WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.print("Connected to WiFi network with IP Address: ");
  Serial.println(WiFi.localIP());
}

void loop()
{
  length1();
  weight();
  BMI=-(weight1/(senseddistance*senseddistance));
  pressure();
  display1();
  if(WiFi.status()== WL_CONNECTED){
    HTTPClient http;

```

```

// Your Domain name with URL path or IP address with path
http.begin(client,serverName);

// Specify content-type header
http.addHeader("Content-Type", "application/x-www-form-urlencoded");
//http.addHeader("Content-Type", "text/plain");

// Prepare your HTTP POST request data
String httpRequestData
="&api_key="+apiKeyValue+"&name="+name1+"&phone_no="+number+"&BMI="+BMI+"&Systolic_pre
ssure="+systolic+"&Diastolic_pressure="+diastolic+"";
Serial.print("httpRequestData: ");
Serial.println(httpRequestData);

// You can comment the httpRequestData variable above
// then, use the httpRequestData variable below (for testing purposes without the
BME280 sensor)
//String httpRequestData =
"api_key=tPmAT5Ab3j7F9&sensor=BME280&location=Office&value1=24.75&value2=49.54&value3=
1005.14";
// Send HTTP POST request
int httpResponseCode = http.POST(httpRequestData);

// If you need an HTTP request with a content type: text/plain
//http.addHeader("Content-Type", "text/plain");
//int httpResponseCode = http.POST("Hello, World!");

// If you need an HTTP request with a content type: application/json, use the
following:
//http.addHeader("Content-Type", "application/json");
//int httpResponseCode =
http.POST("{\"value1\":\"19\",\"value2\":\"67\",\"value3\":\"78\"}");
if (httpResponseCode>0) {
    Serial.print("HTTP Response code: ");
    Serial.println(httpResponseCode);
}
else {
    Serial.print("Error code: ");
    Serial.println(httpResponseCode);
}
// Free resources
http.end();
}

```

```

else {
    Serial.println("WiFi Disconnected");
}
//Send an HTTP POST request every 15 seconds
delay(1500);
}

void length1(){
    delayMicroseconds(2);
    digitalWrite(trigpin,LOW);
    delayMicroseconds(10);
    digitalWrite(trigpin,HIGH);
    delayMicroseconds(10);
    digitalWrite(trigpin,LOW);
    delayMicroseconds(10);
    duration=pulseIn(echopin,HIGH);
    distance=(duration*0.34)/2;

    if(distance>=2000){
        distance=2000/1000;
        senseddistance=(2000-distance)/1000;
        Serial.print("length:");
        Serial.print(senseddistance);
        Serial.println("m ");
    }
    else{
        senseddistance=(2000-distance)/1000;
        Serial.print("length:");
        Serial.print( senseddistance);
        Serial.println("m ");
    }
}

void weight(){
    if (scale.is_ready()) {
        //reading== scale.get_units(10);
        reading = scale.read();
        weight1=((reading/10000)-51.7);
    } else {
        Serial.println("HX711 not found.");
    }
}

delay(100);

```

```

}
void pressure(){
  sensorreading=analogRead(A0)*5/1023;
  Serial.println(sensorreading);

  if(sensorreading<=0){
    systolic=0;
    diastolic=0;
  }
  else{
    diastolic=pumpflowrate*(sensorreading*14);
    systolic=pumpflowrate*(sensorreading*22);
  }
}
void display1(){
  lcd.setCursor(0,0);
  lcd.print("BMI:");
  lcd.print(BMI,1);
  lcd.print(" ");
  lcd.setCursor(0,1);
  lcd.print("SP:");
  lcd.print(systolic);
  lcd.print(" ");
  lcd.setCursor(8,1);
  lcd.print("DP:");
  lcd.print(diastolic);}

```

Appendix 3: PHP scripts that run the blood pressure monitoring

```
<?php
include('connection.php')
?>

<!DOCTYPE html>
<html lang="en">
<head>
  <meta http-equiv="refresh" content="5" >
  <link rel="stylesheet" type="text/css" href="style.css" media="screen"/>

<title>BLOOD PRESSURE MONITORING SYSTEM </title>
<meta charset="UTF-8">
<meta name="viewport" content="width=device-width, initial-scale=1">
<style>
body {
  font-family: Arial, Helvetica, sans-serif;
}
.topnav {
  background-color: #333;
  overflow: hidden;
}

/* Style the links inside the navigation bar */
.topnav a {
  float: left;
  color: #f2f2f2;
  text-align: center;
  padding: 14px 16px;
  text-decoration: none;
  font-size: 17px;
}

/* Change the color of links on hover */
.topnav a:hover {
  background-color: #ddd;
  color: black;
}

/* Add a color to the active/current link */
.topnav a.active {
  background-color: #04AA6D;
  color: white;
}
```

```
}
.image1-1{
  width:600px;
}
</style>
</head>
<body>
  <div class="title"><h2> BLOOD PRESSURE MONITORING SYSTEM<h1><div>
<div class="topnav">
  <a class="active" href="dashboard.php">home</a>
  <a href="user.php">Users</a>
  <a href="registration.php">Doctor</a>
  <a href="patient.php">Client</a>

</div>

<div class="image">

  
</div>
</body>
</html>
```

Appendix 4: Budget

Name of components	Cost per unit (FRW)	Quantity	Total cost(Frw)
Pressure sensor	12000	1	12000
Load cell sensor	29000	4	116000
Ultrasonic sensor	12000	1	12000
Microcontroller (Arduino IDE)	15000	1	15000
I2C LCD Display	22950	1	22950
I2C Keypad	15000	1	15000
pump	12000	1	12000
Bread board	2000		2000
Jumper wires	3000		3000
Internet (4G)	30000		30000
Wires	3000		3000
transports	100000		100000
TOTAL			325950

Table 5. 1: Budget