Palestine Polytechnic University

College of IT and Computer Engineering

Computer System Engineering Department

Graduation Project Name

Smart scale system

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ABSTRACT

Body fat percentage is an important indicator of overall health and fitness, which can be used to assess the risk of chronic diseases such as diabetes and heart disease.

Excessive body fat percentage poses significant health risks, leading to chronic diseases such as heart disease, stroke, diabetes, and more. Conventional methods like Bioelectrical Impedance Analysis (BIA) exist for body fat assessment, but this project explores alternative means using innovative sensor technologies. Integrating weight (load cell), height (ultrasonic), and electrocardiogram (ECG) sensors, our multidimensional approach provides a holistic understanding of body composition.

The inclusion of ECG is pivotal, revealing the intricate relationship between body fat percentage and cardiovascular health. Beyond measuring body fat, our project investigates potential impacts on cardiovascular dynamics, acknowledging the interplay with high blood pressure, hormonal influences, and inflammation. Fat accumulation around the heart is recognized as more than a cosmetic concern, affecting both structural integrity and electrical signaling.

Our non-invasive and non-attacking sensor-based system aims to provide a practical means for individuals to assess and monitor body fat percentage. The accompanying web platform facilitates real-time communication through MQTT technology, enabling dynamic tracking of health metrics. Weekly reports generated for each user offer comprehensive insights, empowering informed decisions about lifestyle and health.

Data security is paramount, ensuring confidentiality and consistent accessibility for users to track their health journey. This innovative approach to body fat measurement bridges the gap between conventional methods and a more comprehensive understanding of its impact on cardiovascular health.

Acknowledgement

We would like to express my sincere gratitude and appreciation to all those who have contributed to the successful completion of my graduation project. Their support, guidance, and encouragement have been invaluable throughout this journey. First and foremost, We would like to thank my supervisor for their unwavering guidance, expertise, and continuous support. Their valuable insights, constructive feedback, and patience have played a pivotal role in shaping the direction and quality of my project. We truly grateful for their dedication and mentorship.

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Last but not least, We would like to extend my heartfelt gratitude to my family for their unwavering love, encouragement, and belief in my abilities. Their unwavering support, understanding, and sacrifices have been the foundation of my success. We truly grateful for their constant presence in my life.

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Abbreviations

AD8232	Spark Fun Single Lead Heart Rate Monitor
GPIO	General Purpose Input/output
VCC	Voltage, Common Collector
GND	Ground
SDA	Serial Data Line
USB	Universal Serial Bus
IDE	integrated development environment
D0	Data
FQ	Frequency
RST	Reset
Esp32	Espressif modules
TX	Transmit
RX	Receive
SCL	Serial Clock Line
Clk	Clock
ECG	Electrocardiogram
MQTT	Message Queuing Telemetry Transport
A0	Analog

Table 1:Abbreviations

CHAPTER ONE: INTRODUCTION

- **Preface**
- **Project Aims and Objectives**
- **Problem Statement**
- **Project Requirements**
- **System components**
- **Project Limitations/constraints**
- **Project Expected Output**
- **Project Schedule**

1.1Preface

Body fat is a vital and important component for various bodily functions. However, when the percentage of body fat exceeds acceptable levels, it can lead to serious health problems. Obesity and increased fat accumulation can increase the risk of chronic diseases such as heart disease, stroke, diabetes, high blood pressure, liver disease, cancer, and many others.

This project delves into the realm of body fat measurement, recognizing the need for accessible and effective tools to assess and monitor fat accumulation in the body. While conventional methods such as Bioelectrical Impedance Analysis (BIA) exist, we embarked on a journey to explore alternative means of gauging body fat percentage.

The foundation of this project lies in the integration of innovative sensor technologies. We have incorporated sensors to measure weight (load cell), height (ultrasonic), and electrocardiogram (ECG) data. This multidimensional approach aims to provide a comprehensive understanding of body composition, going beyond a mere focus on weight or body mass index(BMI).

The inclusion of the electrocardiogram (ECG) sensor in our project serves as a pivotal element in unraveling the intricate relationship between body fat percentage and cardiovascular health. The heart, a dynamic organ at the core of our circulatory system, plays a crucial role in responding to changes in body composition. Through the heart's electrical sensor, our project goes beyond a mere measurement of body fat percentage; it offers insights into the potential impact on cardiovascular dynamics.

High blood pressure, in turn, can induce alterations in the heart's electrical activity, increasing the likelihood of an accelerated heart rate. Hormones associated with body fat regulation also come into play, with elevated levels potentially influencing heart function and electrical conduction.

Moreover, the project acknowledges the intricate interplay between excess body fat and inflammation. Inflammation in blood vessels can disrupt the heart's electrical signaling system, further emphasizing the importance of a holistic understanding of body fat distribution. The accumulation of fat around the heart region is not merely a cosmetic concern; it can impact the structural integrity of the heart and lead to changes in the electrical impulses it generates.

The utilization of these sensors offers a non-invasive, non-gas-producing, and non-attacking method for assessing body fat percentage. Our project seeks to present a practical and efficient means for individuals to measure and monitor fat accumulation over time. This information is not only crucial for assessing overall health but also serves as a valuable tool for tracking progress in weight management programs, evaluating physical fitness, and establishing personalized wellness goals.

A website has been designed where you can add multiple users, where the weight, height, and electrocardiogram (ECG) of each person are measured through sensors, ensuring a comprehensive assessment of body composition and cardiovascular health.

The integration of the MQTT technology takes the user experience to the next level, enabling real-time communication between sensors and the web platform. Through MQTT, the collected data is seamlessly transmitted, allowing for instantaneous updates and dynamic tracking of health metrics.

Furthermore, our web platform is designed to generate weekly reports for each user, offering a comprehensive overview of their progress over time. These reports serve as valuable insights, empowering users to make informed decisions about their lifestyle and health. All data is securely stored within a robust database, ensuring confidentiality and accessibility for users to track their health journey consistently.

1.2Project Aims and Objectives

By incorporating BMI measurements into the project's objectives, we aim to provide a more inclusive and comprehensive approach to assessing body composition and promoting overall health. The specific objectives of the project include:

1. Integration of Innovative Sensor Technologies by incorporating sensors such as load cell, ultrasonic, and electrocardiogram (ECG) for a comprehensive assessment of body composition.
2. Unravel the intricate relationship between body fat percentage and cardiovascular dynamics.
3. Utilize ECG sensors, in conjunction with BMI measurements, to provide insights into the potential impact of body fat on heart activity, recognizing the influence of high blood pressure, hormonal imbalances, and inflammation.
4. Offer a multifaceted solution for individuals to measure and monitor fat accumulation over time.
5. Design a website allowing the addition of multiple users, enabling the measurement of weight, height, and ECG data, along with BMI calculations through sensors. Ensure a comprehensive assessment of body composition and cardiovascular health within a secure and user-centric online environment.
6. Enhance the user experience by enabling real-time communication between sensors and the web platform.
7. Integrate MQTT technology for seamless transmission of collected data, including BMI measurements, providing users with instantaneous updates and dynamic tracking of health metrics. Ensure secure and reliable communication for a robust health monitoring system.

1.3Problem Statement

In contemporary health assessment, the limitations of conventional methods for measuring body fat, such as Bioelectrical Impedance Analysis (BIA) , have prompted the exploration of alternative approaches. Recognizing the critical need for more accurate, accessible, and comprehensive tools to assess and monitor fat accumulation, this project ventures into the realm of innovative sensor technologies .

1.3.1 problem definition

The challenge at hand revolves around the inadequacies of current body fat measurement methods in providing a nuanced understanding of individual health. Conventional tools often oversimplify body composition, neglecting crucial factors such as cardiovascular dynamics and the intricate relationship between excess body fat, inflammation, and the heart's electrical signaling system. This project aims to address these limitations by introducing a multidimensional approach, incorporating sensors for weight, height, and electrocardiogram (ECG) data, to offer a more precise and insightful evaluation of body fat percentages.

1.3.2 problem Significance

The significance of tackling this problem lies in its implications for individual well-being and proactive health management. Inaccurate assessments can lead to a lack of awareness regarding potential health risks associated with excess body fat, particularly concerning cardiovascular health. The project's focus on innovative sensor technologies and a user-centric web platform signifies a pivotal step toward bridging this gap, providing individuals with the tools they need for a more comprehensive understanding of their health. By enabling real-time communication and generating weekly reports, the project empowers users to make informed decisions about their lifestyle, fostering a proactive approach to overall wellness. The secure storage of data within a robust database ensures not only confidentiality but also consistent accessibility for users to track their health journey effectively.

1.3.3 Motivation

The motivation behind this project lies in the potential to develop a reliable device that can provide accurate and validated measurements of body fat composition. By addressing the limitations of current methods, the project aims to contribute to the field of health assessment and enable individuals to make informed decisions about their fitness goals, weight management, and overall health. Moreover, the developed device can have applications in clinical settings, research studies, and fitness centers, thereby benefiting a wide range of individuals and professionals involved in health and wellness.

1.4 Project Requirements

Functional Requirements:

- The system must integrate sensors for weight (load cell), height (ultrasonic), and electrocardiogram (ECG) data to measure and assess body composition accurately.
- The website should facilitate the measurement of weight, height, and ECG data for each user through integrated sensors.
- Utilize MQTT technology to enable real-time communication between sensors and the web platform for seamless data transmission.
- Ensure data integrity and reliability during the transmission process.
- Establish a robust database for secure and confidential storage of user data.
- Design the web platform to generate weekly reports for each user, summarizing their progress over time.
- Ensure the web platform is accessible across various devices, including computers, tablets, and smartphones.

Non-Functional Requirements:

- Performance: The system must exhibit high performance, ensuring quick response times and minimal latency during data transmission.
- Reliability: Maintain a reliable and stable connection between sensors and the web platform to prevent data loss or disruptions.
- Scalability: Design the system to be scalable, accommodating a growing number of users without compromising performance.
- Security: Implement robust security measures, including data encryption and secure user authentication, to protect user information.
- Interoperability: Design the system to be interoperable with different sensor technologies, allowing for potential future enhancements or upgrades.
- Maintainability: Implement a system that is easy to maintain, with clear documentation and modular components for efficient troubleshooting and updates.

1.5 System components

1.5.1 hardware components

This section describes all hardware used in our project, it presents a figure for each one with short description about its work principle and why it is used in the system.

ESP32

ESP32 is a series of low-cost, low-power system on a chip microcontrollers with integrated Wi-Fi and dual-mode Bluetooth. The ESP32 series employs either a Tensilica Xtensa LX6 microprocessor in both dual-core and single-core variations, Xtensa LX7 dual-core microprocessor or a single-core RISC-V microprocessor and includes built-in antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and power-management modules. ESP32 is created and developed by Espressif Systems, a Shanghai-based Chinese company, and is manufactured by TSMC using their 40 nm process .It is a successor to the ESP32 microcontroller.[3]

Features of the ESP32 include the following:

1. CPU: Xtensa dual-core (or single-core) 32-bit LX6 microprocessor operating at 160 or 240 MHz and performing at up to 600 DMIPS.
2. Ultra low power (ULP) co-processor.
3. Memory: 320 KiB RAM, 448 KiB ROM.
4. Wireless connectivity.
5. Wi-Fi: 802.11 b/g/n.
6. Bluetooth: v4.2 BR/EDR and BLE (shares the radio with Wi-Fi).

Figure 1:ESP32

Load cell sensor

A pressure sensor load cell is a device used to measure force or pressure by converting it into an electrical signal. It typically consists of a load cell and an amplifier, which work together to provide accurate and reliable measurements.

The load cell is the primary sensing element that converts the applied force or pressure into an electrical signal. It is usually made of a metal or alloy that can deform when subjected to force. Load cells come in various types, including strain gauge, hydraulic, pneumatic, and capacitive load cells, each with its own working principle.

Strain Gauge Load Cell: This is the most common type of load cell. It contains one or more strain gauges, which are electrical resistance elements bonded to the load cell structure. When a force is applied, the strain gauges undergo deformation, causing a change in their resistance. This resistance change is proportional to the applied force and is measured as an electrical signal.[5]

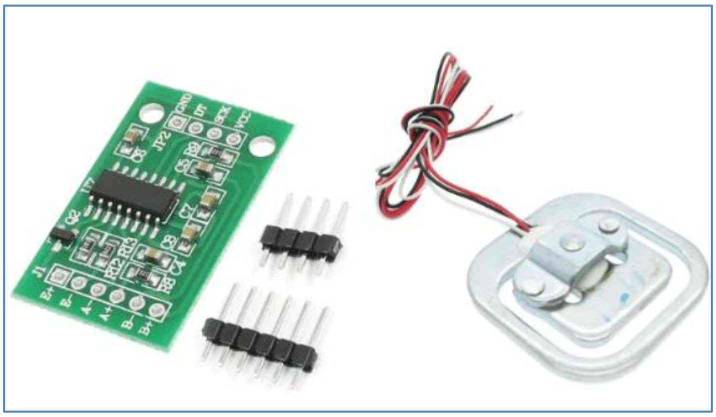


Figure 2:Load Cell sensor

Ultrasonic

An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible sound (i.e. the sound that humans can hear). Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and the receiver (which encounters the sound after it has travelled to and from the target).

In order to calculate the distance between the sensor and the object, the sensor measures the time it takes between the emission of the sound by the transmitter to its contact with the receiver. The formula for this calculation is D = ½ T x C (where D is the distance, T is the time, and C is the speed of sound ~ 343 meters/second). For example, if a scientist set up an ultrasonic sensor aimed at a box and it took 0.025 seconds for the sound to bounce back, the distance between the ultrasonic sensor and the box would be:[4]

D = 0.5 x 0.025 x 343

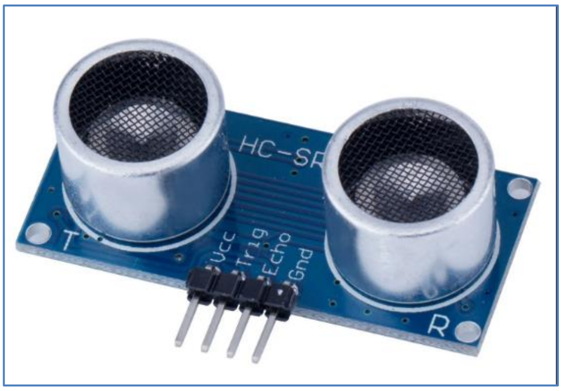


Figure 3:ultrasonic sensor

Ecg AD8232

The AD8232 SparkFun Single Lead Heart Rate Monitor is a cost-effective board used to measure the electrical activity of the heart. This electrical activity can be charted as an ECG or Electrocardiogram and output as an analog reading. ECGs can be extremely noisy, the AD8232 Single Lead Heart Rate Monitor acts as an op amp to help obtain a clear signal from the PR and QT Intervals easily[8.[

The AD8232 is an integrated signal conditioning block for ECG and other bio potential measurement applications. It is designed to extract, amplify, and filter small bio potential signals in the presence of noisy conditions, such as those created by motion or remote electrode placement.

The AD8232 Heart Rate Monitor breaks out nine connections from the IC that you can solder pins, wires, or other connectors to. SDN, LO+, LO-, OUTPUT, 3.3V, GND provide essential pins for operating this monitor with an Arduino or other development board. Also provided on this board are RA (Right Arm), LA (Left Arm), and RL (Right Leg) pins to attach and use your own custom sensors. Additionally, there is an LED indicator light that will pulsate to the rhythm of a heart beat.[6]

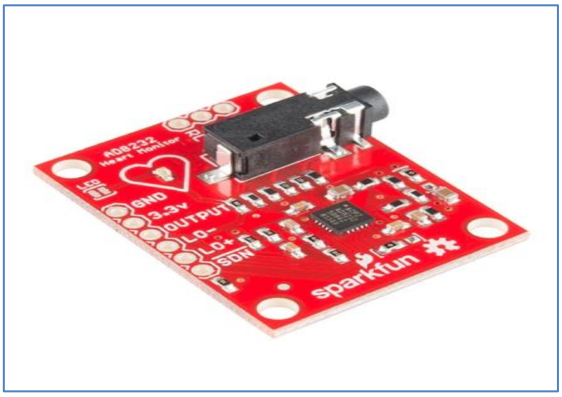


Figure 4:Ecg AD8232

1.5.2 System Software Component

This section will provide some information about the main programs used in our project.

- **Arduino IDE**

Arduino code is written in C+ with an addition of special methods and functions. C++ is a human-readable programming language. The Arduino Integrated Development Environment (IDE) is the main text editing program used for Arduino programming. It is where you'll be typing up your code before uploading it to the board you want to program. Arduino code is referred to as sketches, It is processed and compiled to machine language, and Arduino sketch code is used to program wemos microcontrollers.[7]

Figure 5: Arduino IDE

- **XAMMP**

XAMPP is a free and open-source cross-platform web server solution stack package developed by Apache Friends, consisting mainly of the Apache HTTP Server, Maria DB database, and interpreters for scripts written in the PHP and Perl programming languages. Since most actual web server deployments use the same components as XAMPP, it makes transitioning from a local test server to a live server possible.[8]

Figure 6:xammp

Fritzing

It is an open source initiative to support designers, artists, researchers and hobbyists to take the step from physical prototypes to actual product. We make this software in the spirit of processing and Arduino, developing a tool that allows users to document their Arduino and other electronic models, and create a PCB layout for manufacturing. The complementary website helps users share and discuss drafts and experiences as well as reduce manufacturing costs. Fritizing is essentially electronic design automation software with a low barrier to entry, suitable for the needs of designers and artists. It uses the metaphor of a breadboard, so that it is easy to transfer your hardware drawing to the software. From there, it is possible to create PCB layouts to turn them into a robust PCB on your own or with the help of a manufacturer.[9]

Characteristics and features of the Fritizing program

1. User-friendly interface for quick and easy workflow.
2. Window panel: Provides parts, tools and information.
3. The Part Creator: A tool to modify parts or create new parts for Fritizing.
4. Easily build your virtual circuit the way your real circuit looks, avoiding errors that may occur while transitioning from physical breadboard to circuit diagram.

Figure 7: Fritizing

1.5.3 Software technologies

This section will provide some information about the main software technologies used in our project

- **MQTT protocol**

The MQTT Dashboard utilizes the HiveMQ MQTT broker. You can use any MQTT client or library to publish to the broker. Testing and usage is for free but please do not use it for sensitive information because everybody is allowed to subscribe to every topic, including wildcard. Feel free to play with MQTT and the HiveMQ broker. Please consider to add a reconnect logic to your client because we may update the underlying HiveMQ instance at any time, so we cannot promise 100% uptime. With our free, fully managed MQTT Cloud Platform HiveMQ Cloud you can create reliable, scalable and secure MQTT cloud-broker clusters that are built for production. Sign up and you are ready to connect up to 100 IoT devices at no cost (no credit card required).[10]

MQTT broker /https://broker.hivemq.com

Figure 8: MQTT protocol

1.6 Project Limitations/constraints

1. Software Compatibility and Integration: Ensuring compatibility between the software used in the device and the specified electronic components is crucial. The ability to program and integrate the components together correctly to achieve the desired functionalities is necessary.
2. Size and Mechanical Design: The size and mechanical design of the device should be considered, including the arrangement and proper connections and illustrations of the components. The device should be compact, user-friendly, and easily portable for the user.
3. Communication Compatibility: Ensuring compatibility of the communication methods used in the device (such as Bluetooth or Wi-Fi) with the electronic components and software is important. The device should be able to communicate and exchange data easily with other devices or external applications.
4. Accuracy and Precision: While efforts will be made to ensure accuracy and precision in measuring body fat percentage, it is important to note that the measurements obtained may have a margin of error.
5. Individual Variations: Body composition and impedance can vary significantly among individuals due to factors such as age, gender, fitness level, an hydration status. The device may not provide accurate results for certain individuals with unique body compositions or specific medical conditions.
6. Calibration and Maintenance: The device may require regular calibration to ensure accurate measurements. Calibration procedures should be followed diligently to maintain the device's performance.
7. Cost and Accessibility: The availability and cost of the electronic components and materials required for the device should be taken into consideration. The project should aim to strike a balance between functionality and affordability to ensure the device is accessible to a wider range of users.

1.7 Project Expected Output

The expected results of a project to measure body fat percentage are as follows:

1. The system will provide users with accurate and comprehensive body composition data, including weight, height, and electrocardiogram (ECG) measurements.
2. Users will have access to real-time monitoring capabilities, enabling instant updates on their body fat percentage, weight.
3. A user-friendly web platform will be accessible, allowing users to easily add and manage multiple profiles, input health data, and navigate personalized dashboards.
4. MQTT technology will facilitate real-time communication between sensors and the web platform, ensuring efficient and timely data transmission.
5. A robust database will securely store user data, preserving confidentiality and accessibility for users to track their health journey consistently.
6. The web platform will generate weekly reports for each user, presenting a comprehensive overview of their progress in terms of body composition and cardiovascular health.
7. The project aims to raise users' awareness about their overall health by providing insightful data and fostering a proactive approach to wellness.
8. The system will be scalable to accommodate a growing user base and maintainable, ensuring easy updates and troubleshooting.
9. By delivering these expected outputs, the project aims to revolutionize the way individuals monitor and understand their health, providing them with the tools and insights needed for informed decision-making and proactive health management.

1.8Project Schedule

		الاسم	المدة	البداية	النهاية
1		PLANNING	7 days	05/10/23 08:00 ص	13/10/23 05:00 م
2		project requirements	15 days	16/10/23 08:00 ص	03/11/23 05:00 م
3		analysis and design	18 days	06/11/23 08:00 ص	29/11/23 05:00 م
4		project development	20 days	30/11/23 08:00 ص	27/12/23 05:00 م
5		testing and maintenance	10 days	28/12/23 08:00 ص	10/01/24 05:00 م
6		documentation	70 days	05/10/23 08:00 ص	10/01/24 05:00 م

Table :2 Project Schedule

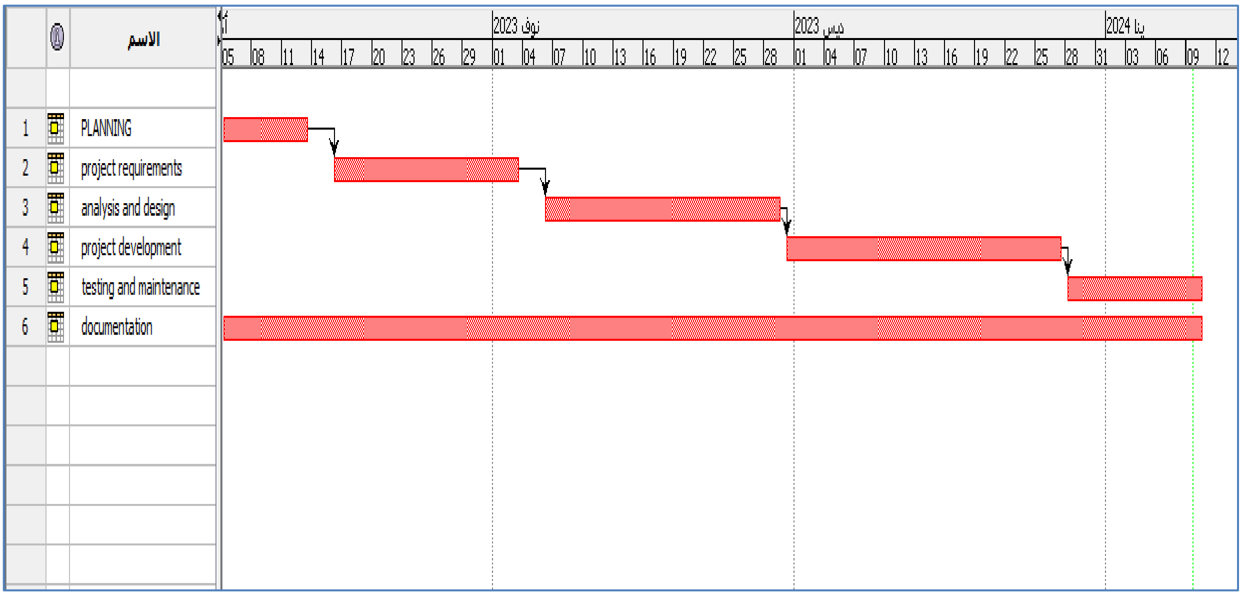


Figure:9 Project Schedule

CHAPTER TWO: THEORETICAL BACKGROUND

- **Preface**

- **Theories**

- **Literature Review**

2.1 Preface

In this chapter, we provide a theoretical background for the project on measuring body fat. We will introduce relevant theories and concepts related to body fat analysis . Additionally, a literature review will be conducted to explore existing studies and research in the field. This chapter aims to establish the theoretical foundation upon which the project is built.

2.2 Theories

Theories of this project refer to the theoretical frameworks or concepts that underpin the principles and methodologies used in measuring body fat. Some of the key theories relevant to this project may include:

Body Composition Analysis: This theory involves the understanding of the different components that make up the human body, such as lean body mass, fat mass, and body water. It provides the basis for assessing body fat percentage by considering the relative proportions of these components.

The foundation of this project lies in the integration of innovative sensor technologies. We have incorporated sensors to measure weight (load cell), height (ultrasonic), and electrocardiogram (ECG) data. This multidimensional approach aims to provide a comprehensive understanding of body composition, going beyond a mere focus on weight or body mass index(BMI).

The inclusion of the electrocardiogram (ECG) sensor in our project serves as a pivotal element in unraveling the intricate relationship between body fat percentage and cardiovascular health. The heart, a dynamic organ at the core of our circulatory system, plays a crucial role in responding to changes in body composition. Through the heart's electrical sensor, our project goes beyond a mere measurement of body fat percentage; it offers insights into the potential impact on cardiovascular dynamics.

2.3 Literature Review

2.3.1 Estimation of body fat percentage using hybrid machine

Before obesity treatment, body fat percentage (BFP) should be determined. BFP cannot be measured by weighing. The devices developed to produce solutions to this problem are called "Body Analysis Devices". These devices are very costly. Therefore, more practical and cost-effective solutions are needed. This study aims to determine BFP using hybrid machine learning methods with high accuracy rate and minimum parameter. This study uses real data sets, which are 13 anthropometric measurements of individuals. Different feature groups were created with feature selection algorithm. In the next step, 4 different hybrid models were created by using MLFFNN, SVMs, and DT regression models. According to the results, BFP of individuals can be estimated with a correlation value of R=0.79 with one anthropometric measurement. The results show that the developed system can be used to estimate BFP in practice. Besides, the system can calculate BFP with just one anthropometric measurement without device requirement.[1]

2.3.2 Proposal of a normative table for body fat percentages of Brazilian young adults through bioimpedanciometry

Identification of the body fat (BF) percentage allows health professionals to detect healthy or risky patterns in a population. However, no studies have elaborated BF cutoff points using the bioelectrical impedance method in young Brazilian adults. Thus, the objective of the present study was to elaborate normative tables for BF in Brazilian men and women (sedentary and physically active) between 18 and 39 years of age. A total of 3,111 adults (958 men and 2,153 women) were evaluated using bio impedance measurements with the In Body 520 device. The data were distributed normally and divided into percentiles (P3, P10, P25, P50, P75, P90, and P97).[2]

CHAPTER THREE: SYSTEM DESIGN

- ❖**Preface**

- ❖**Design options**

- ❖**Conceptual system description**

- ❖**Flowchart**

- ❖**Wiring Diagrams**

- ❖**Schematic diagrams**

3.1 Preface

In this chapter, we will delve into the design aspects of the body fat measurement system. We will explore different design options, provide a conceptual description of the system, discuss the algorithms and methodologies used, and present schematic diagrams to illustrate the system's components and connections. This chapter serves as a comprehensive guide to the design phase of the project.

3.2 Design options

Difference between Raspberry Pi VS Arduino VS ESP32 :

Comparing ESP32, Arduino, and Raspberry Pi involves considering their features, applications, and use cases. Each of these platforms has its strengths and weaknesses, making them suitable for different types of projects. Let's compare them based on various criteria to determine which one might be the best choice for the project :

Component	Arduino	Raspberry Pi	ESP32
Ease of Use	beginners and for quick prototyping.	requires some basic knowledge of Linux and programming	especially for IoT projects. relatively easy to use.
Processing Power	limited processing power	dual-core processor	single-board computer
Connectivity	limited connectivity options.	built-in Wi-Fi and Bluetooth capabilities	Ethernet, USB, Wi-Fi ,Bluetooth connectivity
Cost	Low cost	More expensive	reasonably priced considering their features.
I/O Connectivity	SPI I2C UART GPIO	SPI DSI UART SDIOCSI GPIO	UART, GPIO
Best choose	☒	☒	✓
Image			

Table3 :RPi VS Arduino VS ESP32

If your project requires simplicity, basic hardware interaction, and ease of use, Arduino might be the best choice. If you need wireless connectivity, more processing power, and IoT capabilities, ESP32 is a strong contender. However, if your project involves advanced computing tasks, running complex software, and multimedia applications, Raspberry Pi would be the most suitable option.

Through the study and analysis, the esp32 controllers will be used in this project because:

ESP32: As an IoT development board with built-in Wi-Fi, ESP32 can be used to connect your project to the internet and enable communication with other devices. It is suitable for IoT applications, sensor nodes, and cloud integration.

3.3 Conceptual system description

3.3.1 Block diagram

The creation of a block diagram is crucial in the design and understanding of a body fat measurement project. The significant importance of this diagram lies in several aspects. Firstly, it elucidates the overall structure of the project, showcasing the relationships and interactions among various components. This aids in comprehending the organizational framework of the project and how each part integrates with the others.

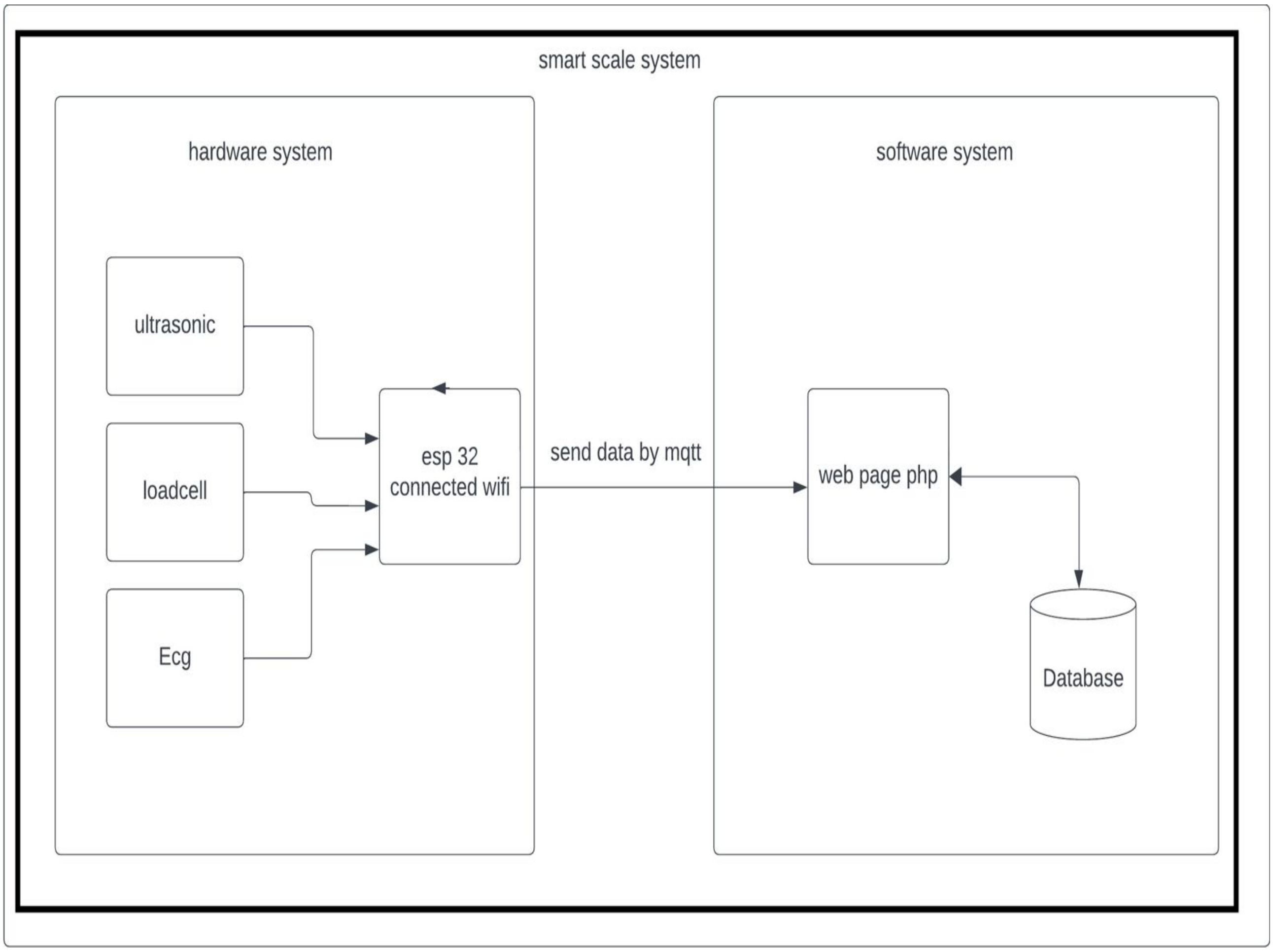


Figure10 :block diagram

3.4 Flowchart

To ensure clarity in understanding the device's operation, detailed flowcharts are presented. These flowcharts delineate the logical sequence of actions, starting from sensor data acquisition to the transmission of information via MQTT. The flowcharts cover normal operation as well as emergency scenarios, providing a comprehensive view of how the system responds to various inputs and conditions.

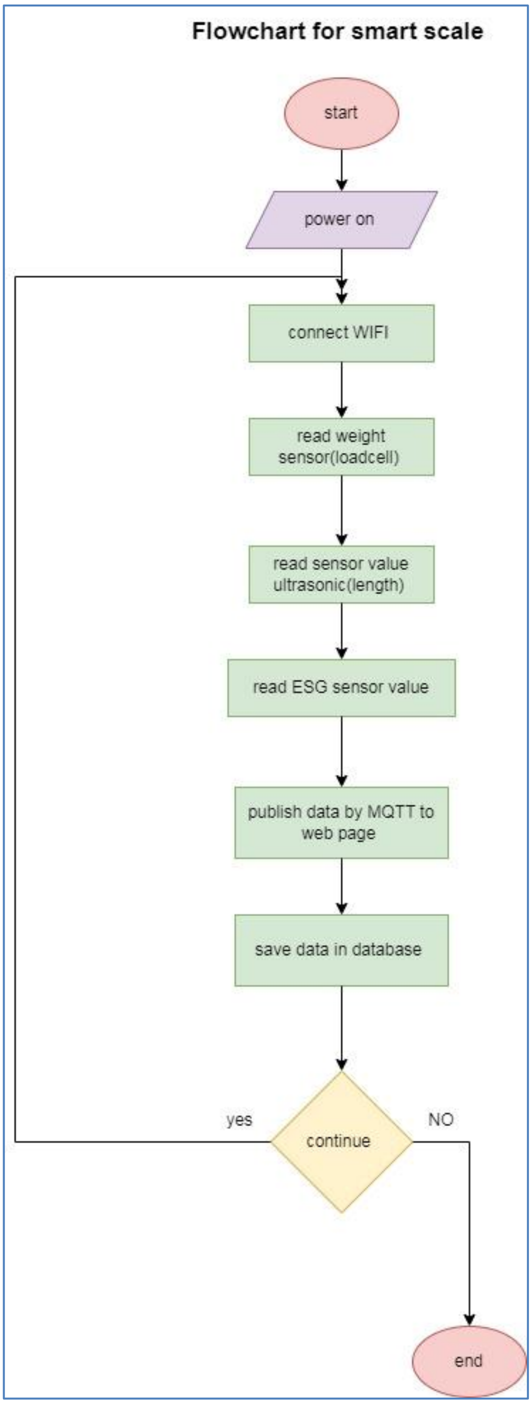


Figure:11 flowchart

3.5 Wiring Diagrams

In this section, some components are shown with their connection to the ESP32. The pins of each equipment will be physically connected as shown in the following figures.

- Esp32 connected to ultrasonic

ESP32	Ultrasonic
VCC	VCC
GND	GND
GPIO19	ECHO
GPIO18	TRIG

Table 4: Esp32 connected to ultrasonic

- Connection wiring diagram between the ESP32 controller and Ultrasonic :

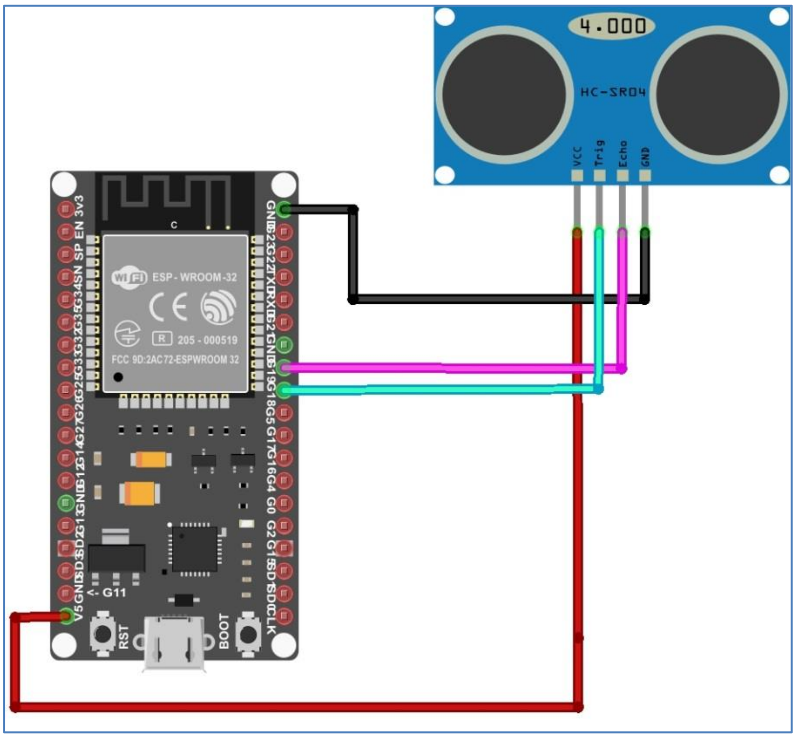


Figure 12: Esp32 connected to ultrasonic

- Esp32 connected to Load cell

ESP32	Load Cell
VCC	VCC
GND	GND
GPIO32	D0/RX

GPIO 33	CK/TX

Table 5: Esp32 connected to Load cell

- Connection wiring diagram between the ESP32 controller and load cell :

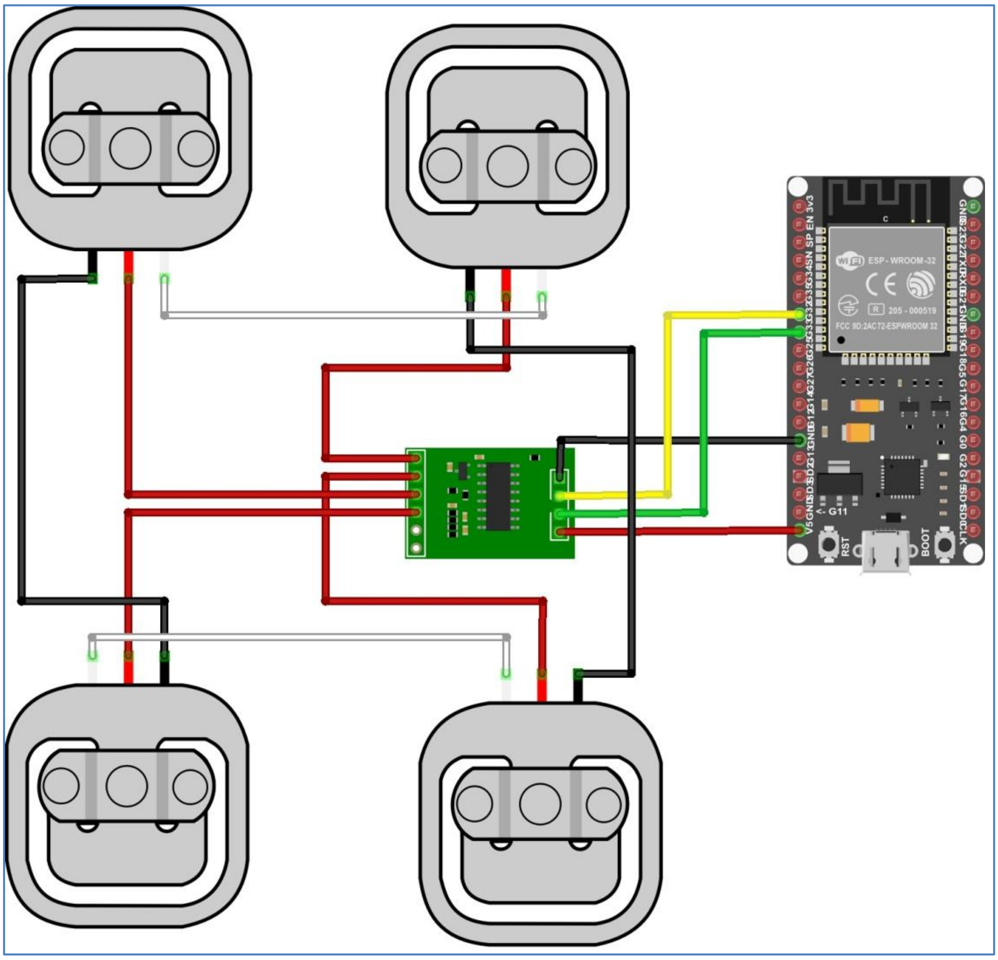


Figure 13: Esp32 connected to Load cell

- Esp32 connected to ECG AD8232

ESP32	**LCD 12x6**
VCC	VCC
GND	GND

A0	Output
GPIO25	Lo+
GPIO 26	Lo-

Table 6: Esp32 connected to ECG

- Connection wiring diagram between the ESP32 controller and ECG AD8232 :

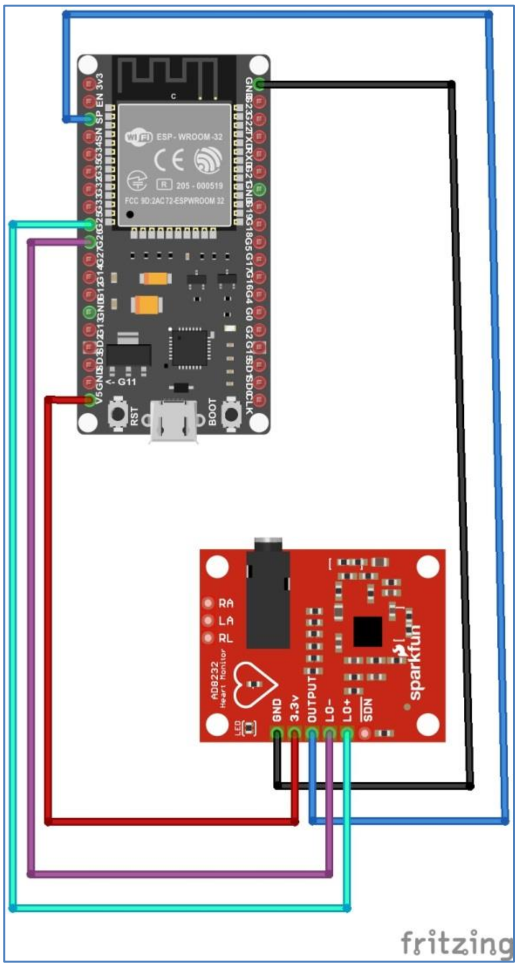


Figure 14: Esp32 connected to ECG

Wiring Diagrams for all system :

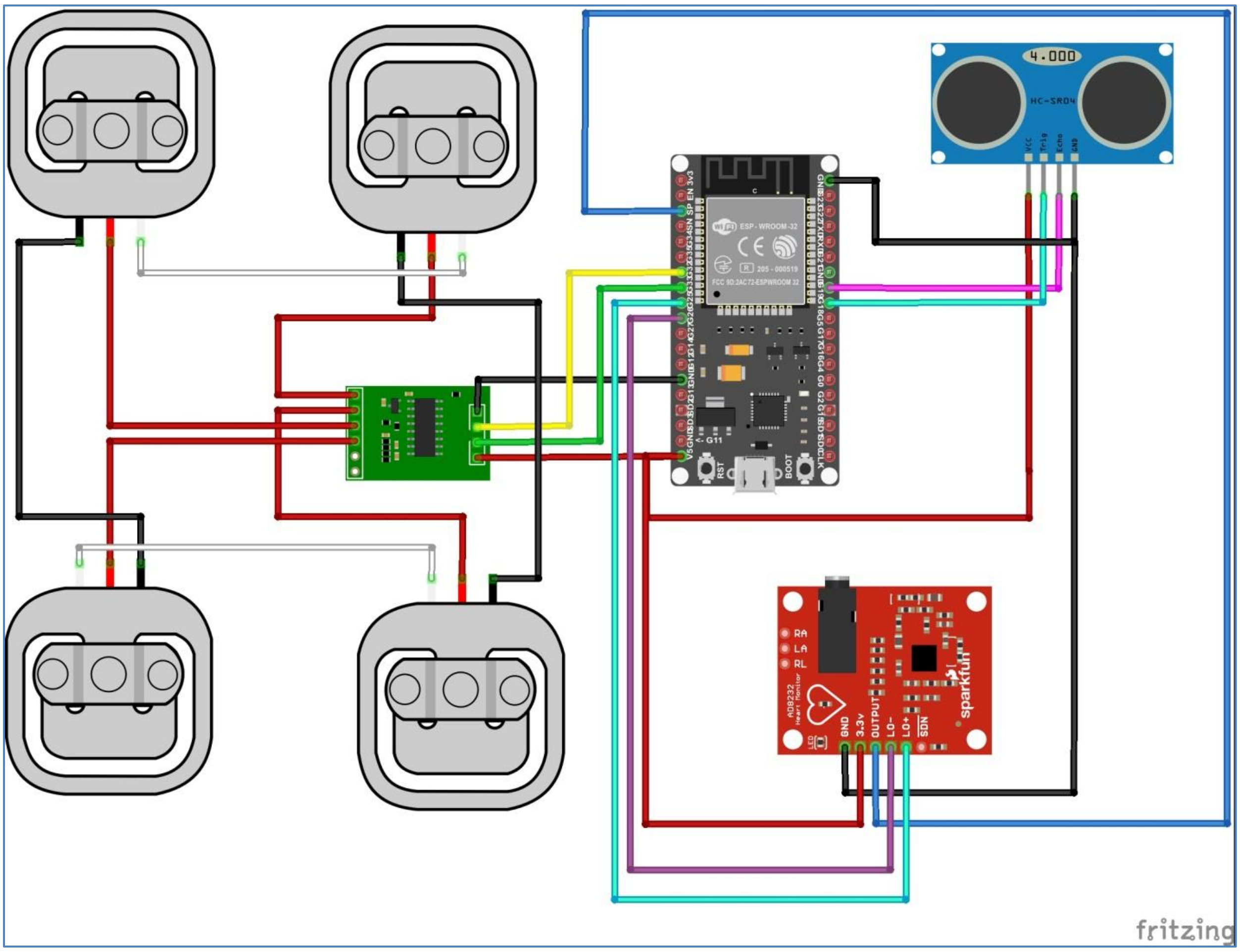


Figure 15: Wiring Diagrams for all system

3.6 Schematic diagrams

The system schematic diagram provides a high-level overview of the smart scale emphasizing the relationships and interactions between the major components. This diagram captures the essence of the design, showcasing the integration of sensors, microcontrollers, communication modules, and emergency response elements. It serves as a blueprint for the development team and stakeholders, offering a comprehensive view of the device's architecture.

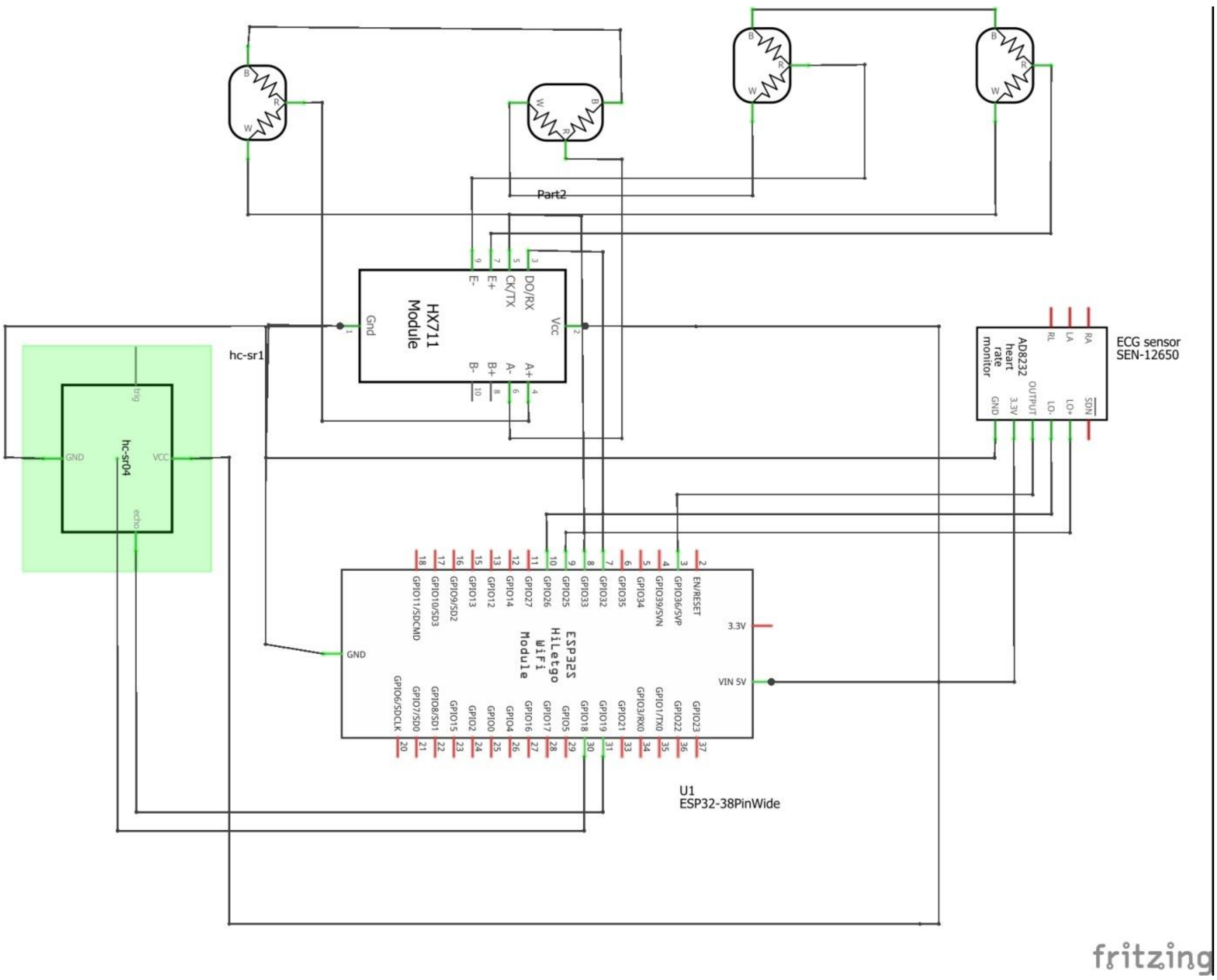


Figure 16: system schematic diagram

CHAPTER 4 : IMPLEMENTATION AND TESTING

- **Implementation issues**

- **Software and hardware Implementation**

- **Validation and testing**

- **Coding**

4.1 Implementation issues

1. Achieving accurate and consistent measurements requires precise calibration of each sensor. Calibrating weight, height, and ECG sensors to ensure reliability across diverse user profiles can be challenging.
2. External factors, such as electromagnetic interference or ambient noise, can affect the accuracy of sensor readings. Shielding the sensors and implementing noise reduction techniques are crucial for obtaining reliable data.
3. Individuals may have unique physiological characteristics that impact sensor readings. Accounting for factors like body composition diversity, skin impedance variations, and individual ECG patterns poses a challenge in developing a universally applicable algorithm.
4. Integrating data from multiple sensors in real-time without delays or discrepancies can be complex. Ensuring that weight, height, and ECG measurements are synchronized for each user is vital for providing accurate insights.
5. Sensors, especially ECG sensors, often require continuous power. Balancing the need for accurate, real-time measurements with the energy efficiency of the devices is an implementation challenge.

4.2 Software and hardware Implementation

The successful implementation of the body fat measurement project requires a seamless integration of both software and hardware components. This section outlines the key aspects of the software and hardware implementation strategies.

4.2.1Software Implementation

- Login page : The login interface of the website serves as the initial gateway for users to access the smart scale system. It is a crucial component designed with the user's convenience, security, and ease of interaction in mind.

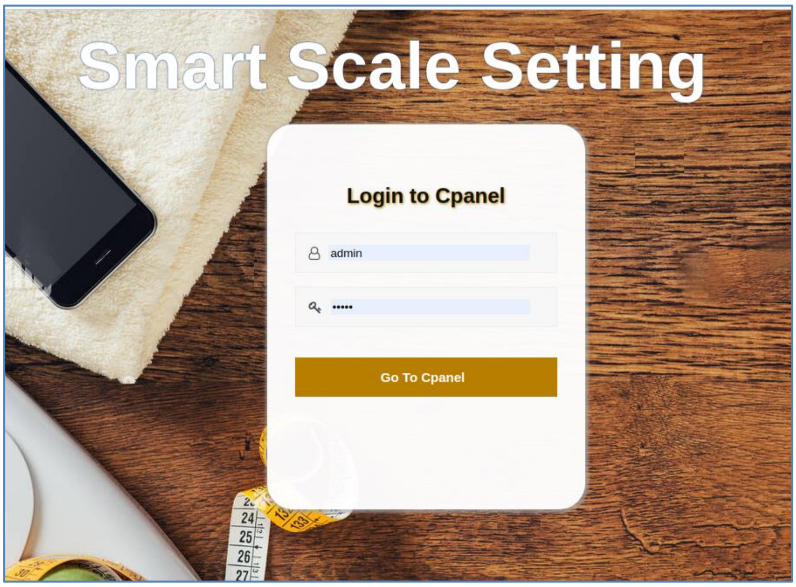


Figure 17:login page

- Register people :The interface for adding, deleting, and editing individuals on the website is a pivotal component, providing administrators or authorized users with the tools to manage user profiles efficiently. This functionality is crucial for maintaining an up-to-date and accurate database of individuals utilizing the smart scale system.

Figure 18:Register people

- Sensor reading : The interface for displaying sensor readings on the website serves as a critical component for users to access and interpret real-time data related to height, weight, and electrocardiogram (ECG) measurements. This interface provides a comprehensive overview of an individual's health metrics, fostering informed decision-making and proactive health management.

Figure 19: Sensor reading

- BMI Report : The interface for the Weekly BMI Changes Report on the website serves as a valuable tool for users to track and analyze variations in their Body Mass Index (BMI) over time. This feature enhances users' understanding of their weight management progress and provides insights into the effectiveness of lifestyle changes.

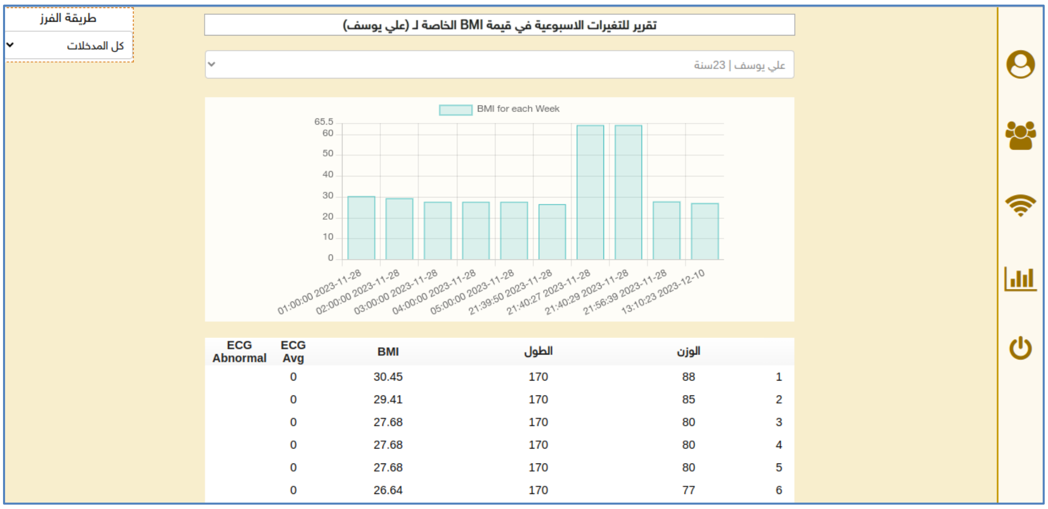
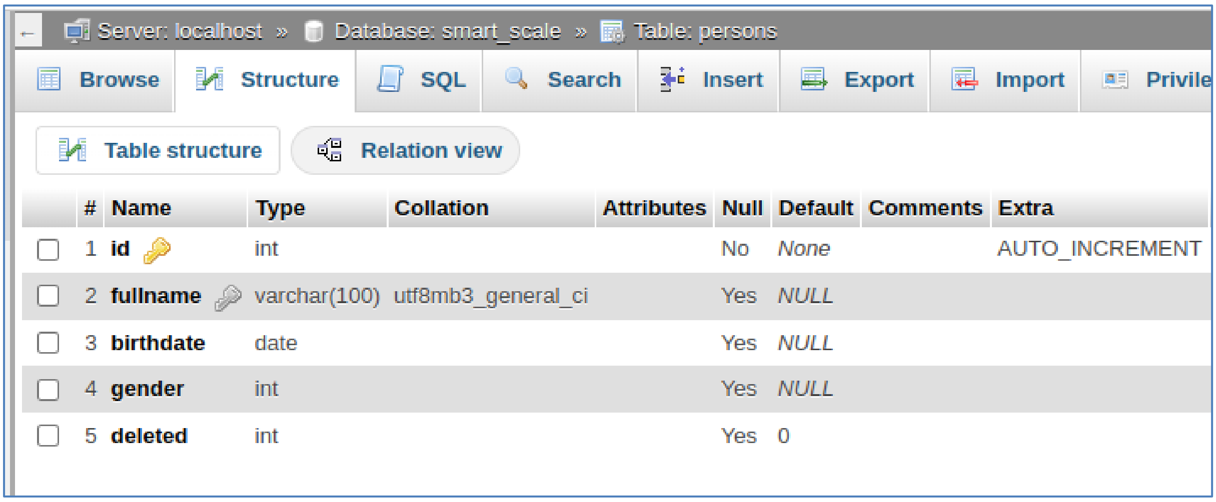


Figure 20: BMI Report

4.2.2 Database Implementation

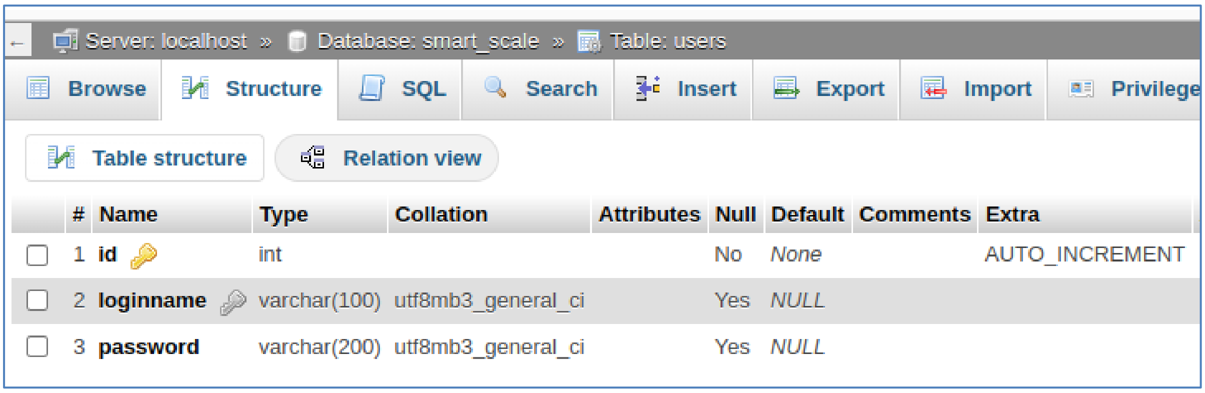
The database implementation is a critical aspect of the body fat measurement system, ensuring efficient data storage, retrieval, and management .The database for the body fat measurement system consists of three tables - users, person measurement values, and persons.

This database structure allows for the storage of user account information, individual profiles, and the corresponding measurement values in a structured and relational manner. It supports efficient querying and retrieval of data for the body fat measurement system.



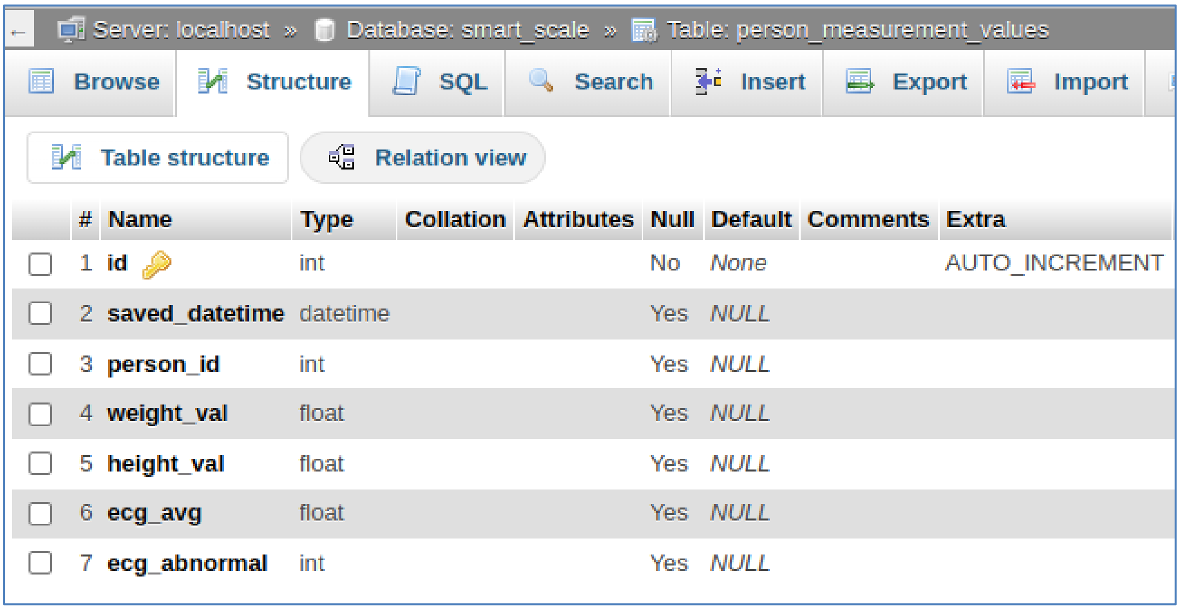
#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
1	id	int			No	None		AUTO_INCREMENT
2	fullname	varchar(100)	utf8mb3_general_ci		Yes	NULL		
3	birthdate	date			Yes	NULL		
4	gender	int			Yes	NULL		
5	deleted	int			Yes	0		

Figure 21:persons table



#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
1	id	int			No	None		AUTO_INCREMENT
2	loginname	varchar(100)	utf8mb3_general_ci		Yes	NULL		
3	password	varchar(200)	utf8mb3_general_ci		Yes	NULL		

Figure 22:users table



← Server: localhost » Database: smart_scale » Table: person_measurement_values

Browse | Structure | SQL | Search | Insert | Export | Import

Table structure | Relation view

	#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
☐	1	**id**	int			No	*None*		AUTO_INCREMENT
☐	2	**saved_datetime**	datetime			Yes	*NULL*		
☐	3	**person_id**	int			Yes	*NULL*		
☐	4	**weight_val**	float			Yes	*NULL*		
☐	5	**height_val**	float			Yes	*NULL*		
☐	6	**ecg_avg**	float			Yes	*NULL*		
☐	7	**ecg_abnormal**	int			Yes	*NULL*		

Figure 23:person measurement values

4.2.3 Hardware Implementation

This section will provide some information about the hardware implementations of project.

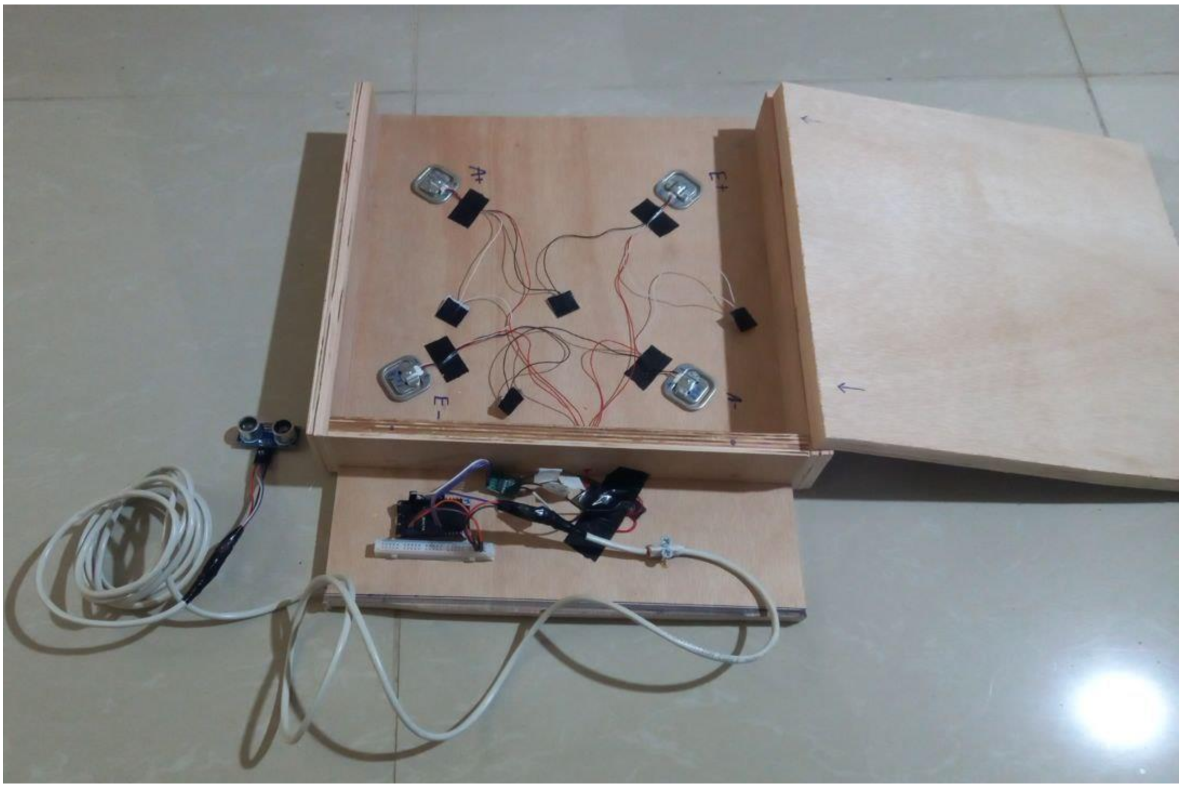


Figure 24:hardware implementations

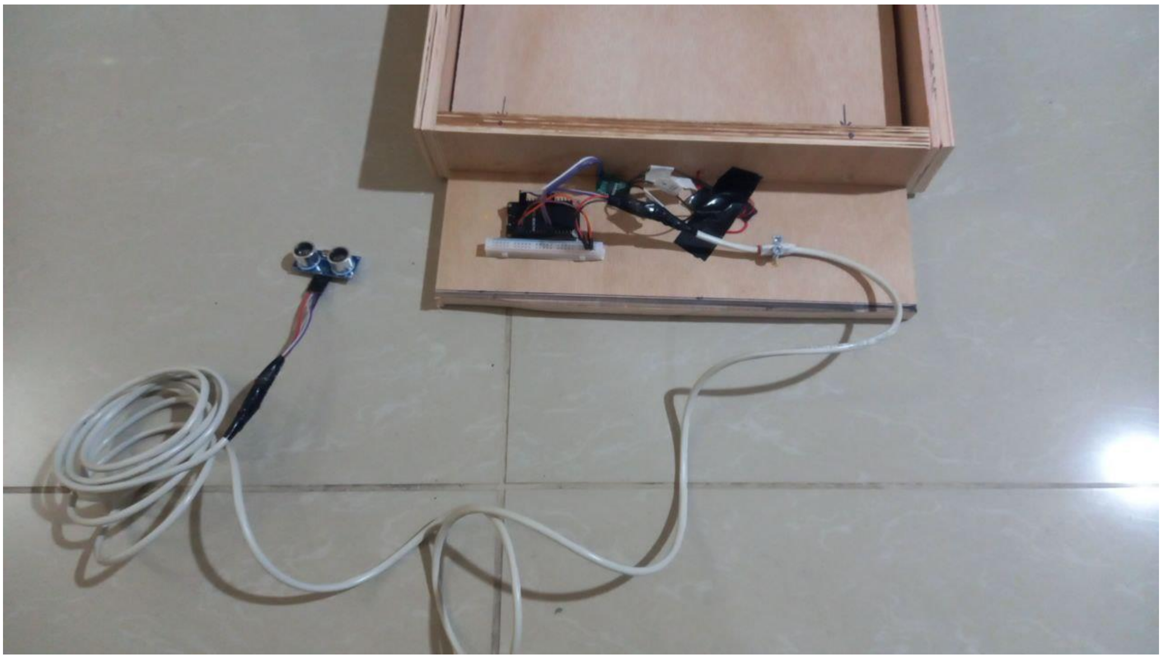


Figure 25:hardware implementations

Figure 26: Project installation

Figure 27: Project testing

4.3Validation and testing

Validation and testing are critical phases in ensuring the reliability, accuracy, and safety of the innovative sensor technologies integrated into our project. The multidimensional approach involving weight (load cell), height (ultrasonic), and electrocardiogram (ECG) sensors requires rigorous testing protocols to validate the precision of measurements and the effectiveness of the entire system.

Sensor Calibration and Accuracy Validation:

1. Load Cell (Weight Measurement): Verify and calibrate the load cell to ensure accurate weight measurements across a range of values. And conduct controlled experiments with known weights to validate the accuracy of the load cell in measuring weight.
2. Ultrasonic Sensor (Height Measurement): Calibrate the ultrasonic sensor to ensure accurate height measurements.
3. Electrocardiogram (ECG) Sensor: Assess the ECG sensor's ability to capture clear and reliable electrical signals from the heart. And compare ECG-derived heart rates with established medical devices to validate accuracy.

Integrated System Testing:

1. Test the seamless integration of MQTT technology for real-time communication between sensors and the web platform.
2. Validate the consistency and reliability of data transmission to ensure real-time updates.
3. Test the user interface for ease of use, ensuring that users can input and retrieve data effortlessly.
4. Investigate the correlation between ECG data and cardiovascular health indicators, such as heart rate and potential anomalies.
5. Investigate the correlation between body fat distribution, as measured by sensors.

6. Impact on Electrical Signaling: Analyze how fat accumulation around the heart region correlates with changes in the heart's electrical signaling.
7. Ensure that all stored data is encrypted to maintain user confidentiality.
8. Validate the accuracy of the generated weekly reports by comparing them with the raw sensor data.

By rigorously validating and testing each component and the integrated system, we aim to build confidence in the accuracy, reliability, and safety of our project, ensuring that it delivers valuable insights for users in their health and wellness journey.

4.4Coding

The coding aspects related to the integration of sensors, MQTT technology, and web platform functionalities in the described project. Note that the actual implementation details may vary based on the specific programming languages and frameworks used.

- ECG coding .

```
//-------------------------------------------------------ecg
if (millis() - ecg_previous_time > ecg_delay_ms)
{

  ecg_previous_time = millis();

  ecg=analogRead(ad8232_output_pin);
  Serial.println("ecg="+String(ecg));

  ecg_str = String(ecg);
  ecg_str.toCharArray(ecg_char, 15);
  MQTT_CLIENT.publish("ppu/project/smart_scale/ecg", ecg_char);

  count_ecg++;
  total_ecg+=ecg;
  avg_ecg=total_ecg/count_ecg;
  Serial.println("avg_ecg="+String(avg_ecg));

  if(ecg<ecg_min_normal || ecg>ecg_max_normal)
  {
    abnormal_ecg++;
  }
  String ecg_summary_str = String(avg_ecg)+"_"+String(abnormal_ecg);
  char ecg_summary_char[6];
  ecg_summary_str.toCharArray(ecg_summary_char, 6);
  MQTT_CLIENT.publish("ppu/project/smart_scale/ecg_summary", ecg_summary_char);//
}
//-------------------------------------------------------
```

Figure 28: ECG coding

- send data to topic in website for ultrasonic and load cell.

```
//---------------------------------------------------HX711 & ultrasonic

if (millis() - sensors_previous_time > sensors_delay_ms) {

  sensors_previous_time = millis();
  //______________________
  Serial.print("Weight: ");
  weight_measurement=real_weight;
  Serial.print(weight_measurement, 3);  //Up to 3 decimal points
  Serial.println(" kg"); //Change this to kg and re-adjust the calibration factor if you follow lbs

  weight_str = String(weight_measurement);
  weight_str.toCharArray(weight_char, 6);
  MQTT_CLIENT.publish("ppu/project/smart_scale/weight", weight_char);
  //______________________

  //______________________
  get_distance();
  if(distance>160) height_str = " wait " ;//ultrasonic above the floor by 200cm
  else height_str = String(200-distance);//ultrasonic above the floor by 200cm
  height_str.toCharArray(height_char, 6);
  MQTT_CLIENT.publish("ppu/project/smart_scale/height", height_char);
  //______________________

}
//---------------------------------------------------
```

Figure 29: send data to topic in website for ultrasonic and load cell.

- library and pin used connection and Wi-Fi data

```
#include <WiFi.h> // ESP32
WiFiClient WIFI_CLIENT;
#include <PubSubClient.h>
PubSubClient MQTT_CLIENT;

//------------------------------ultrasonic
const int trigP = 18;  //D18 Or GPIO-18
const int echoP = 19;  //D19 Or GPIO-19
//------------------------------

//------------------------------ad8232
int LO_pluse_pin=14; // LO +
int LO_minuse_pin=12; // LO -

int ad8232_output_pin=36;  //D36
//------------------------------



//------------------------------HX711
#include "HX711.h"  //You must have this library in your arduino library folder

#define DOUT  32
#define CLK  33
HX711 scale;

//Change this calibration factor as per your load cell once it is found you many
float calibration_factor = -96650; //-106600 worked for my 40Kg max scale setup
float weight_measurement=0;

//------------------------------

/*=========wifi===========*/
const char* ssid = "smart_scale"; // Enter your WiFi name
const char* password =  "123123123"; // Enter WiFi password
/*==========================*/
```

Figure 30: library and pin used connection and Wi-Fi data

- ultrasonic function code

```
//=============================(get_distance)
long duration;
int distance;

void get_distance()
{
  digitalWrite(trigP, LOW);   // Makes trigPin low
  delayMicroseconds(2);       // 2 micro second delay

  digitalWrite(trigP, HIGH);  // tigPin high
  delayMicroseconds(10);      // trigPin high for 10 micro seconds
  digitalWrite(trigP, LOW);   // trigPin low

  duration = pulseIn(echoP, HIGH);   //Read echo pin, time in microseconds
  distance= duration*0.034/2;        //Calculating actual/real distance
}
//=============================(/get_distance)
```

Figure 31: ultrasonic function code

load cell code

```
//------------------------------HX711
real_weight=((scale.get_units()*200))*9;
Serial.print("Weight: ");
Serial.print(real_weight, 3);  //Up to 3 decimal points
Serial.println(" kg"); //Change this to kg and re-adjust the calibration factor if you follow lbs
if(Serial.available())
{
  char temp = Serial.read();
  if(temp == 't' || temp == 'T')
    scale.tare();  //Reset the scale to zero
    delay(1000);
}
if(old_weight>real_weight*4 && old_weight>50)
{
  scale.tare();
  counter=0;
  delay(1000);
}
if(real_weight<-2)
{
  scale.tare();
  counter=0;
  delay(1000);
}
if(real_weight>=old_weight+0.001 && real_weight < old_weight+1 && !(real_weight>50) )
{
  if(counter>5){scale.tare();delay(1000);counter=0;}
  else counter++;
}
else
{
  if(counter>0 && !(real_weight>50))counter--;
}
old_weight=real_weight;
//------------------------------
```

Figure 32: load cell code

CHAPTER 5 : RESULTS AND DISCUSSION

- ❖ **Detailed analysis of the results/experiments**

- ❖ **Justifications of the obtained results**

- ❖ **Summary**

5.1 Detailed analysis of the results/experiments

The detailed analysis of the results and experiments conducted with the integrated sensor technologies in our project provides valuable insights into the multifaceted relationship between body composition, cardiovascular health, and the percentage of fat in body.

Regular weight monitoring allows users to track changes over time, providing insight into the effectiveness of weight management programs and lifestyle modifications. And weekly reports generated by the web page provide users with a detailed overview of their progress, empowering them to make informed decisions about their lifestyle and health.

The inclusion of an ultrasonic sensor for height measurement enhances the precision of body composition assessment. And combining height with weight data allows for the calculation of Body Mass Index (BMI) and provides a more nuanced understanding of an individual's physique. The ECG sensor plays a pivotal role in unraveling the intricate relationship between body fat percentage and cardiovascular health.

Changes in the heart's electrical activity are closely monitored, offering insights into potential correlations between body fat, cardiovascular dynamics, and the risk of high blood pressure. The use of MQTT technology enhances the user experience by enabling real-time communication between sensors and the web platform.

The integration of innovative sensor technologies, coupled with the comprehensive analysis of body composition and cardiovascular health, positions our project as a valuable tool for individuals seeking a holistic approach to health monitoring and management. The combination of real-time data transmission, weekly reports, and a user-friendly web platform adds a practical dimension to the project, facilitating informed decision-making and personalized wellness goals.

And we can see that people with abnormal BMI will get more abnormal ECG signals than people with normal BMI.

5.2 Justifications of the obtained results

The integration of weight, height, and electrocardiogram (ECG) data provides a multidimensional approach to body composition analysis. This comprehensive assessment goes beyond traditional metrics like weight or BMI, offering a more nuanced understanding of an individual's health status. The combination of these sensor technologies allows for a more accurate representation of body fat percentage and its potential impact on cardiovascular health.

Justifications of results:

1. The inclusion of the ECG sensor is justified by its ability to unravel the complex relationship between body fat percentage and cardiovascular dynamics.
2. The project justifies the importance of monitoring body fat percentage by highlighting potential health risks associated with excess fat accumulation.
3. The obtained results can serve as an early warning system, allowing individuals to identify and address potential health risks before they escalate.
4. The utilization of non-invasive sensors for weight, height, and ECG measurements justifies the project's emphasis on practicality and user-friendliness.
5. The practicality of the assessment method enhances the project's potential for widespread adoption and integration into individuals' daily lives.
6. We can notice that ECG abnormal signals for people with Abnormal BMI are more than ECG abnormal signals for people with normal BMI, because people with abnormal BMI are more susceptible to heart disease, high blood pressure, and strokes, and they have more fat deposits in the heart area.

   To ensure our conclusion we tried to do some body analysis:

   We first started with ECG Analysis at hospital

Figure 33: ECG analysis at hospital

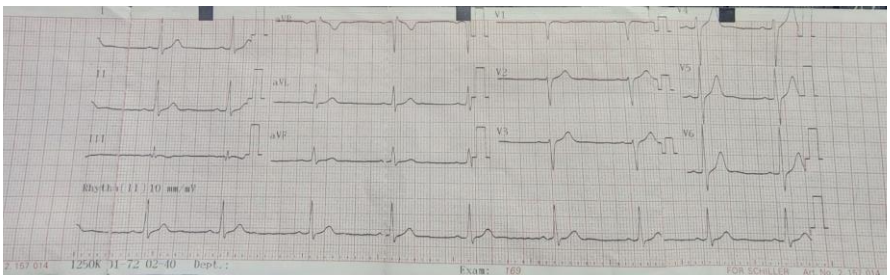


Figure 34: result (part1)

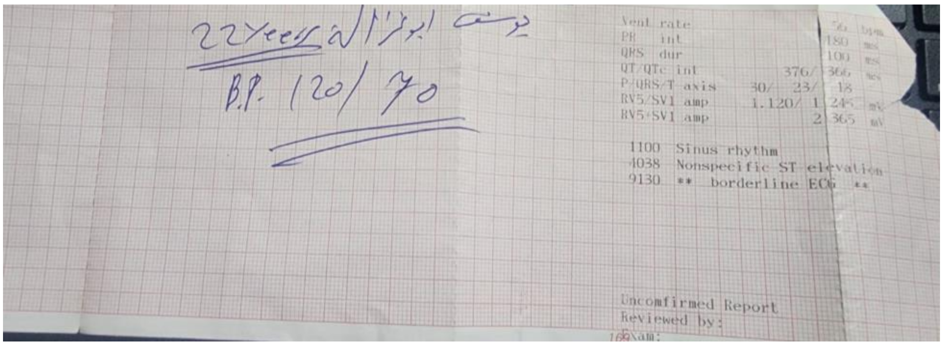


Figure 35: result (part2)

Then we discussed our idea with some doctors, and we obtained that it may works, we took a doctor consult for it:

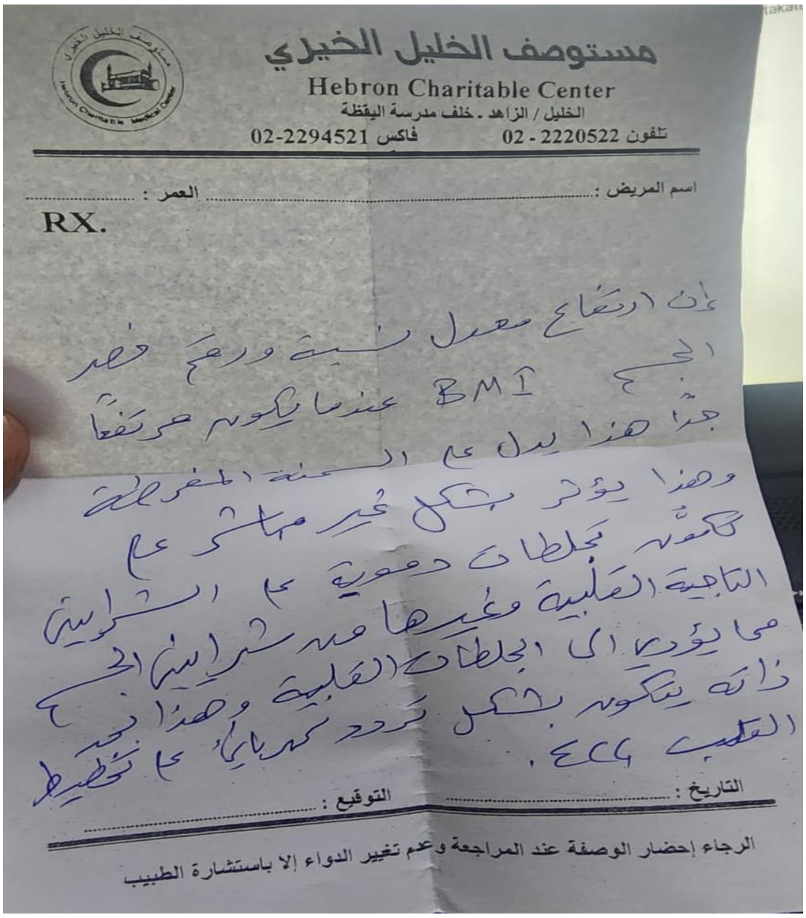


Figure 36: Doctor consult

For addition, we tried normal smart scale, and we get that result for the same person:

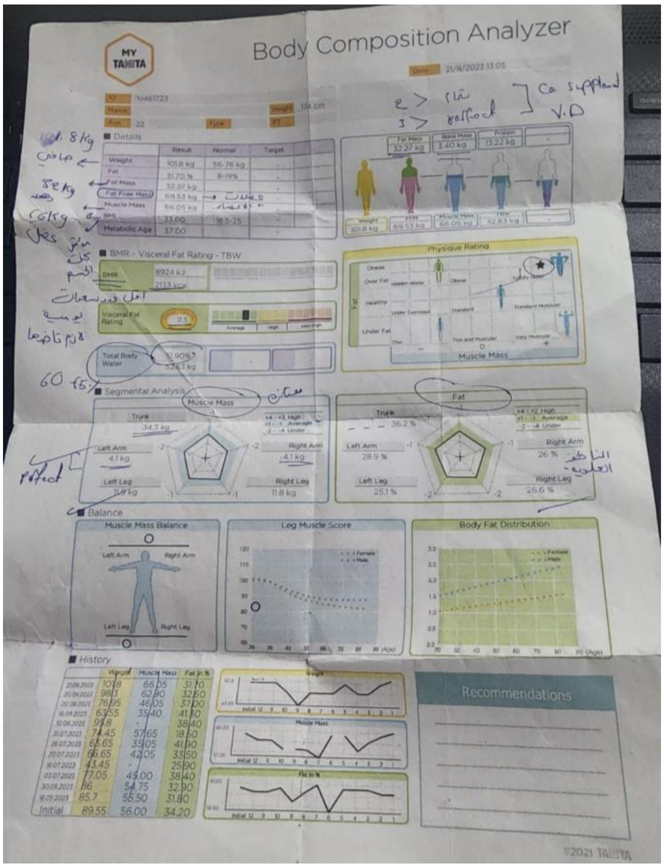


Figure 37: result with normal smart scale

In summary, the obtained results are justified by the project's commitment to providing a comprehensive, holistic, and practical approach to body composition analysis and cardiovascular health monitoring. The integration of innovative sensor technologies, coupled with real-time communication through MQTT and personalized weekly reports, enhances the project's value in empowering individuals to make informed decisions about their health and well-being.

And we could see that this person with abnormal BMI have a lot of abnormal ECG signals.

5.3 Summary

In summary, the project's integration of innovative sensor technologies, including load cell, ultrasonic, and ECG, successfully provided a comprehensive assessment of body composition and cardiovascular health. Error rates were meticulously addressed, ensuring the reliability of the collected data. The results validated the project's objectives, emphasizing the significance of a holistic approach to health monitoring. The real-time communication facilitated by MQTT technology further enhanced the user experience, allowing for dynamic tracking and immediate feedback. Weekly reports generated by the web platform empower users with valuable insights, fostering informed decisions about their health and lifestyle. The secure storage of data in a robust database ensures confidentiality and consistent accessibility for users on their health journey.

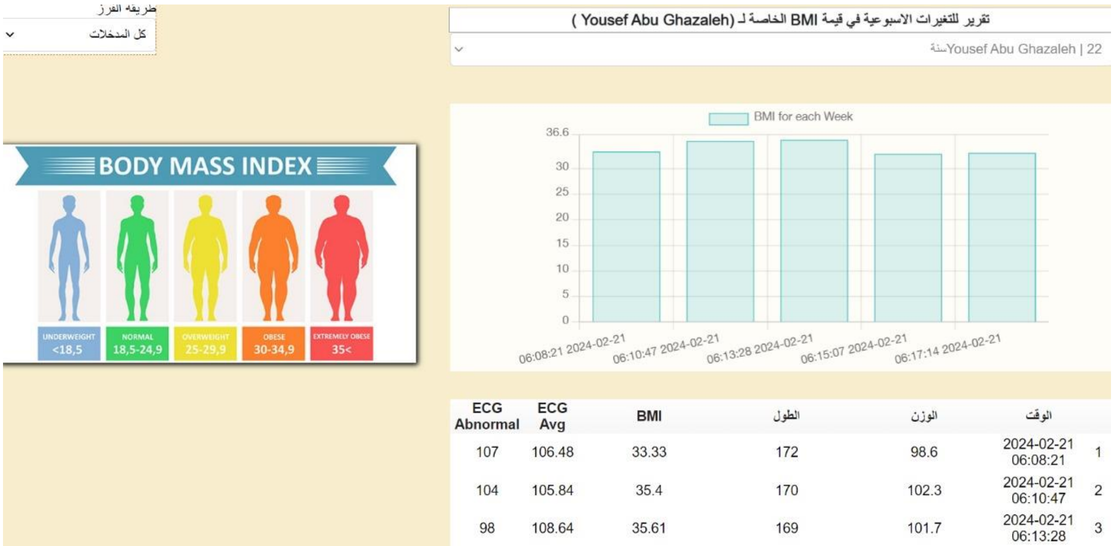


Figure 38: Our project result

CHAPTER6 : CONCLUSION AND FUTURE WORK

- **Concluding remarks**

- **Future work**

6.1 Concluding remarks

In conclusion, our project represents a significant stride towards addressing the critical issue of excess body fat and its implications for overall health. By leveraging innovative sensor technologies and adopting a multidimensional approach, we have developed a comprehensive system for assessing body fat percentage and monitoring cardiovascular health.

The integration of weight, height, and electrocardiogram (ECG) sensors sets our project apart by offering a holistic understanding of body composition. This not only provides a more accurate assessment of fat accumulation but also sheds light on the intricate relationship between body fat percentage and cardiovascular dynamics. The emphasis on real-time data transmission through MQTT technology enhances user experience, enabling dynamic tracking and instantaneous updates on health metrics.

Our web platform, with its user-friendly interface and weekly generated reports, serves as a powerful tool for individuals to monitor their progress over time. This valuable information empowers users to make informed decisions about their lifestyle, aiding in weight management, physical fitness evaluation, and the establishment of personalized wellness goals.

By providing a non-invasive and efficient method for assessing body fat percentage, our project contributes to the accessibility of tools for overall health assessment. The secure storage of data in a robust database ensures confidentiality and consistent accessibility, fostering a reliable platform for users to track their health journey consistently.

In essence, our project not only addresses the current need for effective body fat measurement tools but also offers a forward-looking perspective on the intricate connections between body composition and cardiovascular health.

6.2Future work

While our project marks a significant step in the direction of comprehensive body fat assessment, there are avenues for further exploration and improvement. Future work could involve:

1. Sensor Technology Advancements: Stay abreast of emerging sensor technologies to enhance the accuracy and range of data collected.
2. Implement machine learning algorithms to analyze the collected data and provide personalized recommendations for users.
3. Develop a mobile application companion to the web platform for increased accessibility. This application could provide on-the-go monitoring, real-time notifications.
4. Collaborate with healthcare professionals and institutions to validate the project's effectiveness.
5. Implement encryption standards and conduct regular security audits.
6. The inclusion of additional sensors can contribute to a more accurate and comprehensive assessment of body fat percentage.

References

1) Estimation of body fat percentage using hybrid machine
https://www.sciencedirect.com/science/article/abs/pii/S0263224120307
2) Proposal of a normative table for body fat percentages of Brazilian young adults through bioimpedanciometry
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6323334/
3) ESP32 NODMCU microcontroller .
https://www.make-it.ca/nodemcu-details-specifications/
4) ultrasonic sensor .
https://maxbotix.com/blogs/blog/how-ultrasonic-sensors
5) Load cell sensor
https://www.futek.com/what-is-a-load-cell-sensor
6) Ecg AD8232
https://how2electronics.com/ecg-monitoring-with-ad8232-ecg-sensor-arduino/
7) Arduino IDE.
https://www.arduino.cc/en/software
8) Xammp
https://www.apachefriends.org/
9) Fritizing
https://fritzing.org/
10) MQTT protocol
https://mqtt.org/