UNIVERSITY of RWANDA

COLLEGE OF SCIENCE AND TECHNOLOGY

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

# Design of a Smart Portable and Wearable Stress Level Detection and Monitoring System

By:

**KARANGUZA Francois**
**Reg. No.: 222001051**

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

Supervised by:

**Dr. Masabo Emmanuel**
**and**
**Dr. Moussa HAKIZIMANA**

## DECLARATION

I, KARANGUZA Francois, declare that this dissertation entitled "**Design of a Smart Portable and Wearable Stress Level Detection and Monitoring System**" is my original work based on research and prototype and has not been submitted for any other degree or professional qualification.

Student Name:

KARANGUZA Francois

Reg. No.: 222001051

Student Signature: ______________________________

Date: ________________________________

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## CERTIFICATE

This is to certify that the project entitled “Design of a Smart Portable and Wearable Stress Level Detection and Monitoring System” is a record of original work done by KARANGUZA Francois ,Reg. No.: 222001051, a MSc. Degree student in Biomedical Engineering.

This work has been submitted under the guidance of Dr. Masabo Emmanuel and Dr. Moussa HAKIZIMANA.

**Main Supervisor:**

Signature:

**Dr. Masabo Emmanuel**

**Co-Supervisor:**

Signature:

**Dr. Moussa HAKIZIMANA**

**Biomedical Engineering Master’s Program Coordinator**

**Dr. Gerard Rushingabigwi**

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## ABSTRACT

Stress is a common experience that can have a significant impact on our physical and mental health. Prolonged exposure to stress can lead to a variety of health problems, including heart disease, obesity, and depression. Stress is a serious issue in today's culture and can negatively affect both physical and mental health, especially for those who live in remote locations where access to mental health care may be limited. However, current stress monitoring technologies frequently lack mobility, real-time monitoring capabilities, and extensive physiological data gathering. In addition, many people, particularly those from rural regions, do not have knowledge and understanding of their own levels of stress. They also self-assess their stress inaccurately and have limited access to instruments for monitoring their stress levels. A system entitled ”A Smart portable and wearable stress level detection and monitoring system based on physiological responses in the body” is designed to overcome that issue and consists of sensors, microcontroller, GSM module, display, long-lasting power battery. Sensors are used to measure physiological signals such as heart rate, heart rate variability, and skin conductance. These signals would then be processed by a microcontroller used as a processor to identify patterns that are associated with stress. The data from the sensors would then be transmitted to a microcontroller for processing. Once the patterns have been identified, the system would provide feedback to the user about their stress levels using GSM. The system would be designed to be worn on the wrist or body. It would be small, lightweight, and comfortable to wear. The system would also be powered by a long-lasting battery. The feedback could be presented in a variety of ways, such as text, or graphs on the display of a system and on a user cellphone. A smart portable and wearable stress level detection and monitoring system could be a valuable tool for people who are looking to manage their stress levels.

**Keywords:** Portable, wearable, stress , sensor, Heart rate, Skin, GSM, Microcontroller, Display.

# LIST OF ACRONYMS

**ARM :** Advanced RISC Machine

**EEG :** Electroencephalogram

**FPGA :** Field Programmable Gate Array

**GPIO :** General Purpose Input / Output

**GPRS :** General Packet Radio Service

**GSM:** Global System for Mobile communication

**GSR:** Galvanic skin response

**HTTP:** Hypertext Transfer Protocol

**I2C :** Inter-Integrated Circuit

**IC:** Integrated Circuit

**IoT:** Internet of Things

**LED:** Light emitting diode

**MATLAB**: Matrix laboratory

**MQTT** : Message Queuing Telemetry Transport

**PCB:** Printed circuit board

**PIC:** Peripheral Interface Controller

**REST API:** Representational State Transfer Application Programming Interface

**RISC:** Reduced Instruction Set Computer

**RX:** Receiver

**SCL:** Serial clock line

**SDA:** Serial data line

**SIL :** Single inline

**SIM :** Subscriber Identity Module

**TCP/IP:** Transmission Control Protocol/Internet Protocol

**TX :** Transmitter

**UART:** Universal Asynchronous Receiver-Transmitter

**UMTS:** Universal Mobile Telecommunications System

**VSM :** Virtual System Modeling

**Wi-Fi :** Wireless Fidelity

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## DEFINITION OF KEY TERMS

**Display:** an electronic device for the visual presentation of data or images.

**GSM:** Global System for Mobile communication is a digital mobile network that is widely used by mobile phone users in Europe and other parts of the world.

**Heart rate:** the number of times the heart beats per minute.

**Microcontroller:** is a compact integrated circuit designed to govern a specific operation in an embedded system.

**Portable:** describes something you can carry around easily, capable of being transported or conveyed.

**Sensor:** a device that detects and responds to some type of input from the physical environment.

**Skin:** the thin layer of tissue forming the natural outer covering of the body of a person or animal.

**Stress:** a state of mental or emotional strain or tension resulting from adverse or demanding circumstances or a state of worry or mental tension caused by a difficult situation.

**Wearable:** a covering designed to be worn on a person's body.

# CHAPTER 1. GENERAL INTRODUCTION

## 1.1 Introduction

Stress is a natural response of the body and mind to demands or pressures placed upon them. It is a normal part of life and can be triggered by various factors, including work, relationships, financial difficulties, health problems, and major life changes. However, when stress becomes chronic, it can have negative effects on your physical and mental health. When a person experiences stress, their body releases hormones such as cortisol and adrenaline, which activate the "fight-or-flight" response [1].

This response prepares the body to face a perceived threat or challenge by increasing heart rate, blood pressure. Stress can lead to a variety of health problems, including heart disease, high blood pressure, anxiety, depression, and sleep problems. There are a number of different ways to manage stress. Some people find that exercise, relaxation techniques, or spending time with loved ones can help to reduce stress levels. Others may need to seek professional help from a therapist or counselor. There are also a number of technological solutions that can be used to manage stress. These solutions can help people to track their stress levels, identify stressors, and learn relaxation techniques. Based on the human's physical activity, the stress levels of the human being are detected and analyzed. A dataset of 2001 samples is provided for human body humidity, body temperature and the number of steps taken by the user. Three different classifications of stress are performed, low stress, normal stress, and high stress [2].

## 1.2 Problem statement

Stress is a major problem in today's society, and it can have a significant impact on both physical and mental health, especially for people from rural areas where access to mental health care can be limited. However, existing stress monitoring solutions often lack portability, real-time monitoring capabilities, and comprehensive physiological data collection. In addition, Lack of awareness and understanding of personal stress levels, Inaccurate self-assessment of stress and limited accessibility to stress monitoring tools , especially among people from rural areas.

The proposed project aims to address these limitations by designing and simulating a smart, portable, and wearable stress detection and monitoring system based on physiological responses in the body.

This system should be capable of capturing and analyzing multiple physiological parameters that are indicative of stress, such as heart rate variability, skin conductance, and body temperature.

By leveraging advanced sensor technologies, data analytics algorithms, and machine learning techniques, the system should be able to accurately detect and quantify stress levels in real-time.

### 1.3 Research Questions (Hypotheses)

The following research questions are the baselines which guided this study:

1. How can physiological responses such as heart rate variability, skin conductance, and temperature be effectively integrated into a portable wearable device for stress detection and monitoring?
2. What are the most accurate and reliable sensor technologies that can be employed in a portable wearable system to measure physiological responses related to stress levels?
3. How can machine learning and data analysis techniques be utilized to interpret physiological data collected from the wearable device and accurately classify different stress levels?
4. What are the design considerations and constraints in creating a user-friendly and unobtrusive smart wearable device for continuous stress monitoring in daily life scenarios?
5. How does the accuracy and reliability of stress detection from the wearable device compare to traditional methods (e.g., self-reporting, clinical measurements) under various environmental and physiological conditions?
6. What privacy and ethical implications should be considered in the development and deployment of a stress detection wearable device, especially concerning the collection and use of sensitive physiological data?

### 1.4 Objectives

#### 1.4.1 General Objective

The main objective is to design a smart portable and wearable stress levels detection and monitoring system based on physiological responses in the body that detects and provides in real time feedback to the user about their stress levels.

### 1.4.2 Specific Objectives

To achieve the general objective of this project, the following specific objectives are used as guiding points.

i. To design the architecture of the system with all requirements.

ii. To simulate the system by ensuring the functionality of the designed system.

iii. To analyze the results from provided data about the stress level.

## 1.5 Study Scope and Limitation

A smart portable and wearable stress levels detection and monitoring system project aims to develop a device that can detect and monitor stress levels in real-time. The scope of the project includes designing and simulating a device that can measure physiological responses such as heart rate variability, skin conductance, and temperature. The device should be portable and wearable, allowing for continuous monitoring of stress levels throughout the day. Additionally, it includes the simulation of the device's functionality in various real-life scenarios to ensure its reliability and effectiveness in diverse environments. However, limitations may arise concerning the device's accuracy in interpreting individual physiological variations, potential challenges in calibrating the device for different user demographics, and the need for continuous validation against established medical standards for stress assessment.

## 1.6 Significance of the Study

A smart wearable stress detection system based on physiological responses has the potential to significantly improve individual well-being by revolutionizing the way individuals manage stress, leading to improved mental health and contribute to broader public health initiatives. However, careful consideration of data privacy, accessibility, and accuracy is crucial to ensure its responsible and effective implementation.

The people who mostly benefits from this project are people from rural areas and patients who frequently visits the hospitals, doctors, nurses, authorities of the hospitals and authorities from the local government for the following reasons:

- Increased awareness of stress levels: The system would help users to become more aware of their stress levels, which would allow them to take steps to reduce stress before it becomes a problem.

- Improved stress management: The system would provide users with tools and resources to help them manage their stress levels, which could lead to improved physical and mental health.

- Reduced risk of chronic diseases: Chronic stress is a major risk factor for a number of chronic diseases, including heart disease, stroke, and diabetes. The system could help to reduce the risk of these diseases by helping users to manage their stress levels.

### 1.7 Organization

Chapter one gives the introduction about the project, problem statement, objectives, scope and limitation and significance of the study. Chapter two discusses the project related works and identifies gaps. The methodology employed in the study is described in Chapter 3, as is the research process, the research design method, the system design, flowchart and system requirements of both hardware and software used in the project. Chapter four discusses the results and findings of the study and finally chapter five discusses challenges, recommendations and conclusions from the research study.

# CHAPTER 2. LITERATURE REVIEW

In this section of a literature review presents a comprehensive investigation into existing studies, methodologies, and technologies related to stress measurement through physiological signals. This section aims to highlight the current state-of-the-art advancements, key findings, limitations, and gaps in the field.

**2.1 Project related Works**

TuerxunWaili et al in [3]suggested the solution of Stress recognition using Electroencephalogram (EEG) signal to detect stress. EEG (Electroencephalogram) signal is a neuro-signal that is produced due the diverse electrical exercises in the mind. Various sorts of electrical exercises relate to various conditions of the mind. These signs can be caught and handled to get the helpful data that can be utilized in the early location of some psychological state. EEG waves can be used to detect a variety of brain functions, including stress. This study uses EEG waves to detect stress. Stress causes a specific range of frequencies in the range to change their actions, which may then be evaluated. The test results were correctly filtered, and the frequency bands were measured. The statistics demonstrate a variation in the ratio of beta waves to alpha waves in the brain as a result of stress. The changes in the ratio is able to reveal the level of stress endured.

S. Vaikole et al., in [4] proposed a solution of Stress Detection through Speech Analysis using Machine Learning to analysis the stress level through the speech with Machine learning . Voice stress analysis is a pseudoscientific method that attempts to deduce deceit from voice stress. The technique seeks to distinguish between stressful and non-stressed responses to stimuli (e.g., questions given), with high stress indicating deceit. This can be done by extracting features from the speech signal, such as the pitch, loudness, and rhythm, and then using machine learning algorithms to classify the speech as stressed or not stressed. There are a number of different machine learning algorithms that can be used for stress detection, including support vector machines, decision trees, and neural networks. The choice of algorithm depends on the specific features that are extracted from the speech signal and the desired accuracy of the classification.

Josephin Arockia Dhivya et al., in [5] suggested a Stress Meter using Pulse and Sweat Sensor to detect the level of stress where they have been used different devices to access someone emotional suffering. If the stress level is extremely high, it alerts someone with a warning sound or buzzer.

It can anticipate stress based on changes in heart rate and electrical conductivity of the skin, as well as in temperature rate. These rates are provided using the Arduino atmega328 UNO microcontroller. A stress alarm (buzzer) is supplied to signal the stress, which can be adjusted using haptic feedback motors.

They divided people into three age groups: school and college students and workers, and they assigned tasks to school and college students such as mathematical computations and logical thinking. Workers' stress levels are calculated both before and after work.

J.Minguillon et al in [6]proposed an approach that detects stress at three levels (stress, relax, and neutral) with 86% accuracy and a resolution of a few seconds. The laboratory has installed the RABio w8 (real-time acquisition of biosignals, wireless, eight channels) system, which includes both hardware and software. RABio's electronics consist of three blocks (acquisition, control, and communication). They conducted a validation study on their technology with ten volunteers.

## 2.2 Identified gaps

Although attempts have been made to find solutions, the majority of them cannot be used in the special circumstances of Rwanda because of connectivity, financial, and power issues. In addition, none of the articles examined took into account all four metrics (blood pressure, heart rate, temperature, and GSR) at once to forecast user results, none of which are portable wherever the user travels, and none of which are inexpensive.

It might be possible to obtain more accurate findings by taking these four factors into account simultaneously when forecasting the user status. This is the rationale for my decision to carry out this study project, which combines all four of the aforementioned factors to offer an efficient method for user detection and monitoring.

# CHAPTER 3. RESEARCH METHODOLOGY

In this chapter the methods and approaches used to conduct the study are outlined. This includes the steps undertaken to complete the study, the system design methodology, the system requirements and tools used in data collection, flowchart and simulation of the proposed solution. During the design and simulation of this project, different hardware and software components have been used. Therefore, this chapter gives an overview on the architecture of the system throughout this study. It describes each component used and its function in the circuit. Furthermore, the mobile and web applications are presented.

## 3.1 Research Process

The research process for designing and simulating a smart portable and wearable stress level detection and monitoring system based on physiological responses involves several key steps: conducting a literature review to understand existing technologies and methodologies, defined objectives and formulating hypotheses, selecting appropriate sensors and data acquisition methods for stress response capture, designing and simulating the system and interdisciplinary collaboration among engineers, psychologists, and healthcare professionals to ensure the system's practical application.

## 3.2 Research Design Method

The research design method for the design and simulation of a smart portable and wearable stress level detection and monitoring system based on physiological responses involves several key steps: reviewing existing literature, user interviews, defined system requirements and objectives considering accuracy, portability, and user comfort, integrated physiological response measurement methods like body temperature, heart rate variability, and skin conductance, developed system architecture including hardware components, algorithms, flowchart, and data transmission protocols and employed simulation techniques to validate design and optimize performance under various conditions.

## 3.3. Data collection

In the process of data collection for the project, interviews were conducted with a diverse range of participants, including individuals experiencing stress or professionals in the field of stress management from mental health care service in hospitals, workers in different fields, students and individuals with expertise in wearable technology.

These interviews aimed to gather insights into users' preferences, needs, the types of physiological responses indicative of stress, preferred form factors for wearable devices, ease of use, privacy concerns, and potential integration with existing technologies or platforms and challenges related to stress monitoring and management, as well as to identify potential design features and functionalities of the proposed system. Questions focused on factors influencing stress levels, desired features in a stress monitoring device, preferred form factors for wearability and portability, and concerns regarding data privacy and security.

### 3.3.1 Sample size

Participants were selected based on different criteria where five individual experiencing stress or professionals in the field of stress management from mental health care service in hospital, twenty workers in different field, forty students and three individuals with expertise in wearable technology have been interviewed accordingly.

### 3.3.2 Research Instruments and Procedures

The research tool was a set of carefully thought-out questions for participants. An attachment to this thesis report contains a copy of the questionnaire. Because the questionnaires were anonymous, respondents were free to answer the questions as best they could base on their knowledge and experiences. This made it easier to gather further information, and it is safe to say that the data correctly represents the true state of stress in various individuals. Respondents received thorough instructions about the goal of the interview and how their information was used before they answered any questions.

### 3.3.3 Problems and Limitations

Participants don't have much time to respond to the interviewer's inquiries because of their hectic schedules. Due to the short data collection period and the absence of incentives for survey participation, sample size and generalization were both compromised.

### 3.3.4 Ethical Considerations

The approval of this research project by the UR/CMHS IRB Board guarantees that it conforms with ethical standards. The respondents were given a clear and concise explanation of the study's objectives as well as the methods utilized to collect the data. The data collection method was easy to understand and took minimal time from the participants. We only collected the data necessary to answer the research question. No private information was requested.

## 3.4. System Requirements

In order to meet the set objectives, this system needs hardware and software requirements.

### 3.4.1 Hardware requirements

Hardware requirements for this project typically encompass a range of components tailored to capture and analyze physiological signals indicative of stress levels in individuals.

#### 3.4.1.1 Microcontroller

A microcontroller is a small integrated circuit intended for controlling a particular function within an embedded system. A standard microcontroller consists of a chip that integrates a processor, memory, and input/output (I/O) peripherals. The elements of a microcontroller, the types of microcontroller are explained in detail [7].

#### 3.4.1.2 Arduino board

Based on Atmel microcontrollers, Arduino is an open-source hardware/software programming platform. Open source refers to the fact that enthusiasts can alter the source code of the software and circuit schematics utilized in designs, both of which are publicly accessible.

With their analog and digital inputs and outputs, Arduino development boards are perfect for designers, artists, and electronic hobbyists who want to assemble a system without needing to know a great deal about digital design.

The Arduino board has rows of female connectors into which single in line (SIL) connectors or individual leads can be plugged to provide input and output signals [8].

#### 3.4.1.3 ESP8266 NodeMCU

The ESP8266 Wi-Fi chip was developed by Espressif Systems at a low cost, using the TCP/IP protocol as its foundation.

Using a UART interface, the device has the capability to function independently or serve as a converter enabling other microcontrollers to establish a connection with a Wi-Fi network. To equip your Arduino board with Wi-Fi capability, you can establish a connection between an ESP8266 and your Arduino, as an illustration. An ESP8266 WiFi chip is part of the NodeMCU Development Kit/Board.

The serial communication protocol and GPIO pins of the ESP8266 chip are features of it. On the NodeMCU Development board, the features of the ESP8266 are extracted. NodeMCU Development board, which combines NodeMCU (LUA based firmware) with ESP8266 (Wifi enabled chip) chip, allows it to function as a stand-alone device in Internet of Things applications [9]. The  NodeMCU Dev Kit v1.0 PIN description shows all different pin numbers , corresponding names and roles of each pin [10].

### 3.4.1.4 Liquid Crystal Display (LCD)

Applications for liquid crystal displays (LCDs) are numerous in the electronics industry. It is frequently used to display different parameters and statuses in a variety of systems. LCD16x2 contains two lines, each containing sixteen characters. Every character consists of a 5 x 8 (row x column) pixel matrix. The  LCD 16x2 pin description shows all different pin numbers , corresponding names and role of each pin and some LCDs are interfaced with I2C Module, this makes using LCD16x2 simplified and also helps to avoid hardware connection complexity [11]-[12].

*Figure 3. 1:LCD16x2 _I2C Module*

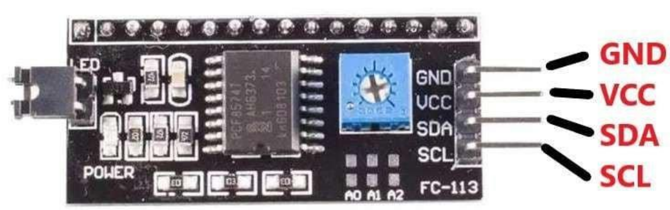



*Figure 3. 2:I2C Module PIN diagram*

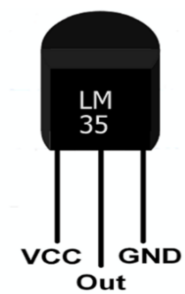
### 3.4.1.5 LM35 Temperature Sensor

- The LM35 is a temperature measurement device that outputs an analog voltage proportional to the temperature in Celsius. It doesn't need any external calibration circuitry [13].
- The sensitivity of the LM35 is 10 mV/°C. As the temperature rises, so does the output voltage; for example, 250 mV equals 25 degrees Celsius.

- It is a three-terminal sensor that measures the ambient temperature range from -55 °C to 150 °C.
- LM35 provides more exact temperature output than thermistors.


*Figure 3. 3: LM 35 Temperature Sensor*

**1. LM35 Temperature sensor pinout**




**3.4.1.6 GSM**

GSM  is a digital mobile network that is widely used by mobile phone users in Europe and other parts of the world. GSM uses a variation of time division multiple access (TDMA) and is the most widely used of the three digital wireless telephony technologies: TDMA, GSM and code-division multiple access (CDMA). GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its own time slot. It operates at either the 900 megahertz (MHz) or 1,800 MHz frequency band. GSM, along with other technologies, contributes to the advancement of wireless mobile telecommunications, which includes High-Speed Circuit-Switched Data (HSCSD), General Packet Radio Service (GPRS), Enhanced Data GSM Environment (EDGE), and Universal Mobile Telecommunications Service (UMTS) [14]. SIM cards with home network access settings can be swapped to those with metered local access, which dramatically reduces roaming fees while maintaining service levels [15].

#### 3.4.1.7 GSR Sensor

The galvanic skin response (GSR) reflects the activity of the sweat glands, which are located over all the body. Sweating is controlled by the sympathetic nervous system, and is an indication of psychological or physiological arousal while in a state of fear or stress. GSR electrodes should be located in an area of the skin that contains enough sweat glands to obtain a good GSR signal quality. Most commonly, GSR electrodes are placed on the palms, feet, fingers and shoulders [16].

The appropriate location of the electrodes  depend on the experiment setup, the type of electrodes available, and the level of intrusiveness that your participants allow. It is important to keep the same location and type of electrodes for all your participants to obtain comparable results.

| Body location | Sweat glands density | Type of electrode | Intrusiveness | Recommended for |
|---|---|---|---|---|
| Palm | High | Pre-gelled disposable and wet/dry reusable | Low | Stationary/mobile studies where the hand with electrodes will not be used. |
| Finger | Mid | wet/dry reusable | Low | Stationary/mobile studies where the hand with electrodes will not be used. |
| Foot | High | Pre-gelled disposable and wet/dry reusable | High | Stationary studies where both hands will be used. |
| Shoulder | Mid | Pre-gelled disposable and wet/dry reusable | Mid | Stationary/mobile studies where both hands will be used. |

**Palms & Fingers**

Palms have the highest density of sweat glands and are therefore the preferred place to attach the GSR electrodes. Fingers usually give a lower GSR signal than palms, but are most of the times a suitable place to attach the electrodes. It is common to attach the electrodes to the non-dominant hand, because the participant is less likely to move it during the recording, in particular when the participants needs to use their dominant hand to press keys on the keyboard or use a mouse. This avoids creating artifacts in the GSR signal [16].

Palm electrodes are usually attached to the skin using an adhesive collar around them. The electrodes should be placed on the lower part of the palm, with enough space between the electrodes to avoid contact.

#### 3.4.1.8 5V DC power supply

The 5V DC power supply is a popular power supply for communication electronic equipment. There are various varieties of DC power supply circuit architectures, which are typically split into two categories: single-ended converters (flyback, forward) and double-ended converters (push-pull, half bridge, and full-bridge). This study presents a design strategy for a 5V switching power supply based on a buck converter. The developed switching power supply system is highly efficient and may be utilized to charge mobile phones [17].

### 3.4.2 Software requirements

Software requirements for this project would include the ability to collect and analyze data from various sources such as wearable sensors, smartphones, and other health monitoring devices. The software should be able to process this data in real-time or near real-time, utilizing machine learning algorithms to detect patterns and indicators of stress. It should also have a user-friendly interface for both users and healthcare professionals to access and interpret the data, as well as features for personalized feedback and recommendations based on individual stress levels.

#### 3.4.2.1 Thingspeak Cloud Platform

Thingspeak is an IoT Cloud platform that allows you to transfer sensor data to the cloud. You can also use MATLAB or other software to analyze and visualize your data, as well as develop your own apps. MathWorks operates the Thingspeak service. To sign up for Thingspeak, you must first create a MathWorks Account or connect to an existing one. Thingspeak is free for modest, non-commercial enterprises.

Thingspeak offers a Web Service (REST API) that allows you to collect and store sensor data in the cloud while also developing Internet of Things applications. It works with Arduino, Raspberry Pi, and MATLAB (premade libraries and APIs are available), but it should work with any programming language that supports a REST API and HTTP [18].

### 3.4.2.2 Thingspeak for IoT

MathWorks®, the company behind MATLAB® and Simulink®, offers Thingspeak™, an IoT analytics platform service. Thingspeak allows you to aggregate, view, and analyze real-time data streams in the cloud. Thingspeak delivers real-time representations of data uploaded by your devices or equipment. Execute MATLAB code in Thingspeak and perform real-time data analysis and processing. Thingspeak speeds up the development of proof-of-concept IoT systems, particularly those requiring analytics. You can create IoT systems without having to install servers or develop web software.

Thingspeak offers a production-ready hosted solution for small to medium-sized IoT systems [19].

### 3.4.2.3 Arduino Integrated Development Environment

The Arduino Integrated Development Environment, or Arduino Software (IDE), includes a text editor for writing code, a message box, a text console, a toolbar with buttons for common functions, and a series of menus. It connects to the Arduino hardware to upload and communicate with it. Sketches are programs that are written using the Arduino Software (IDE). These sketches are created in a text editor and saved with the file extension.ino. The editor includes features for cutting/pasting and searching/replacing text.

The message area provides feedback during storing and exporting, as well as displaying errors. The console displays text output from the Arduino Software (IDE), which includes detailed error messages and other information.

The configured board and serial port are displayed in the bottom right corner of the window. The toolbar buttons let you validate and upload programs, create, open, and save sketches, and launch the serial monitor [20].

### 3.4.2.4 Proteus 8 Professional

Proteus 8 Professional is a software tool for designing, testing, and simulating electrical circuits and microcontrollers. It was created by Labcenter Electronics Ltd. and is commonly used by electronic engineers, amateurs, and students. In this article, we'll go over what Proteus 8 Professional is, its primary features and benefits, and how to utilize it for your projects [21].

Proteus VSM allows you to simulate and debug electronic circuits and microcontroller code. It enables mixed-mode SPICE simulation, which allows you to blend analog and digital components in a single circuit. It also supports over 750 microcontrollers from various vendors, including Arduino, PIC, AVR, and ARM. You can create and build your code in a variety of programming languages, including C, Assembly, and Basic, and then co-simulate it with your circuit in real time. You can also interact with your circuit with on-screen indicators and actuators like LEDs, LCDs, switches, and buttons. Proteus 8 Professional also provides other features and benefits [21].

### 3.5 System Components block diagram

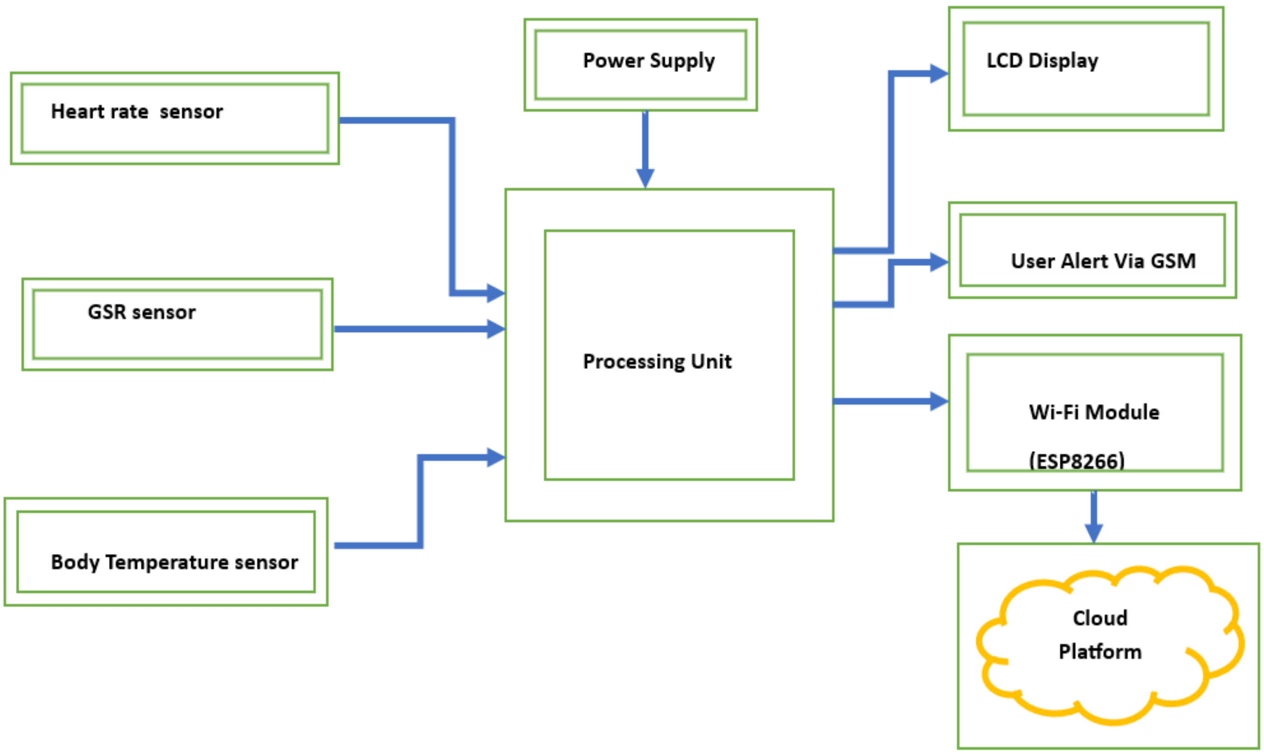



*Figure 3. 4:System block diagram*

### 3.6 Flowchart

The flowchart in fig. 3.18 is the representation of how the whole system works. This flowchart outlines the design and simulation process for a smart portable and wearable system that detects and monitors stress levels based on physiological responses in the body. It provides a visual representation of the key steps involved and the decision points encountered during development.

It begins with the collection of physiological data from the body, such as heart rate, skin conductance, and temperature.

This data is then processed and analyzed using algorithms designed to detect patterns indicative of stress levels. Next, the system determines the appropriate actions based on the analyzed data. This could involve providing real-time feedback to the user, alerting them to elevated stress levels.

The flowchart also includes provisions for data storage and management, ensuring that the collected physiological data is securely stored and can be accessed for further analysis or review.


*Figure 3. 5: System Flowchart*

### 3.7 System Circuit diagram

The circuit diagram of the project consists of different parts and each part plays its own role to provide the required information in order that the system properly operates. The parts are processing unit, sensors, user alert via GSM and display unit.

The following figure is the system Circuit  diagram that consists of all parts.

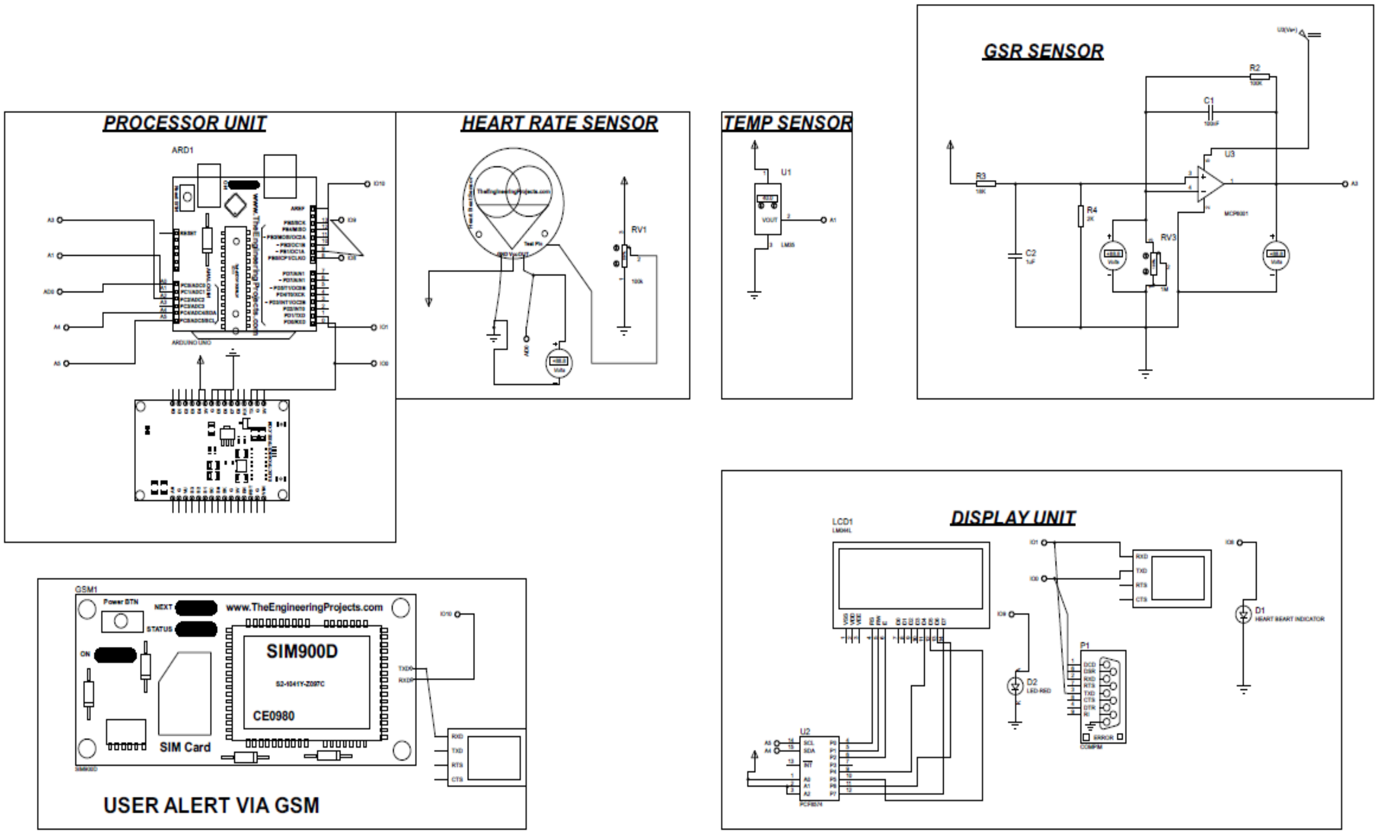



*Figure 3. 6:System circuit diagram*

### 3.7.1 Processing unit Part

This part is responsible  for  control sensing, data processing, and calculation. It consists of Arduino Uno which is a microcontroller board based on the Atmega328P and ESP8266 Wi-Fi module that enables a microcontroller to connect to Internet. The processing unit is the brain of the system, it takes the input data from sensors, processes them according to the program stored in it and produces the output to be transmitted to the cloud platform.

Processing unit Part is shown in the following figure 3.21.

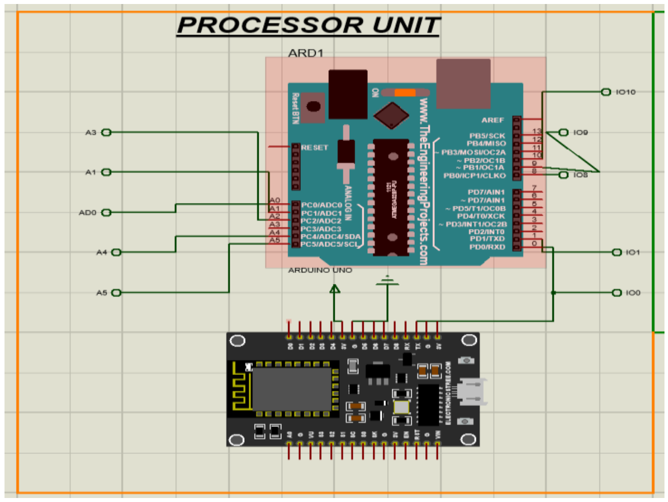



*Figure 3. 7:System processing unit connection*

### 3.7.2 Sensor part

This part is responsible for gathering and collecting the data from people who is using this system. The data is measured in different parameters like temperature,heart beat rate and skin conductance rate. It consists of a heart rate sensor, temperature sensor and GSR sensor.

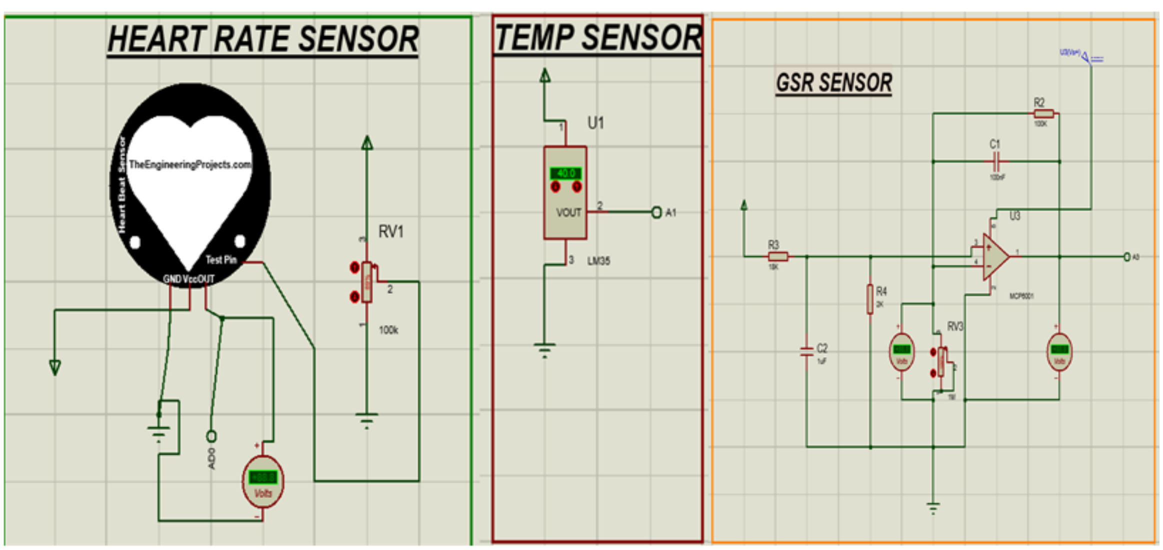



*Figure 3. 8:(a) Heartbeat sensor (b) Temperature sensor connections and Equivalent circuit of GSR sensor*

### 3.7.3 User alert via GSM

This is part consists of a user cellphone with SimCard where all information related to stress is displayed on the phone but only when all the sensors have shown the stress level. GSM, or Global System for Mobile Communications, is a type of cellular network technology that is primarily used for voice and data communication. GSM networks can be used to transmit data collected from stress detection devices to a central location for analysis. It is used for establishing the connection to a remote network using the GSM mobile communication technology. They are, in essence, equivalent to that of a typical mobile phone is in the eye of a cell phone, on the net, as long as the need to use a SIM card itself is determined by the network.

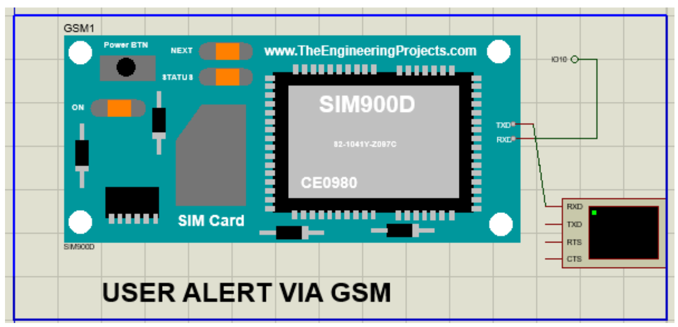



*Figure 3. 9:GSM connection*

### 3.7.4 Display unit

This part is responsible to display the information  where LCD display information about the data from sensors and show the stressed is either detected or not detected ,LED D1 to indicate the heart beat and LED D2 to indicate that the level of stress is detected, if condition of detecting high stress from all sensors  based on the parameter for each sensor about high stress level is met.

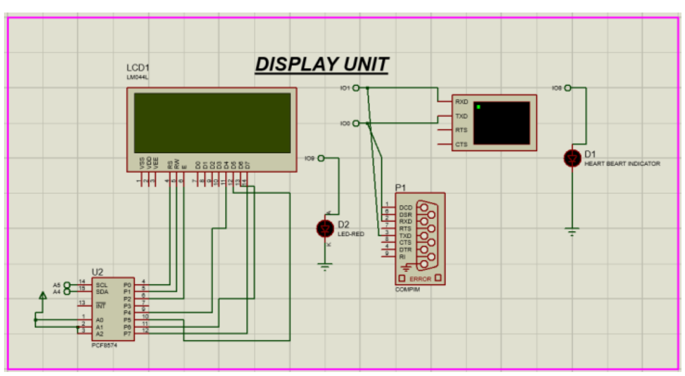



*Figure 3. 10:Display unit connection*

# CHAPTER 4. RESULTS AND DISCUSSIONS

This Chapter discusses the study's findings, detailing the data collection process and analytical methodology. The results are systematically presented, supported by empirical evidence from various sources such as experiments, surveys, and interviews. The discussion section evaluates the results in relation to existing literature, theories, and hypotheses, exploring implications and broader significance. Significant patterns, trends, and unexpected results are highlighted, with potential explanations or limitations discussed and finally it offers a detailed analysis and interpretation of the research outcomes, contributing to a comprehensive examination of the study findings.

## 4.1 System simulation results

Figure 4.1 shows the simulation of the system using Proteus software. The system utilized heartbeat, GSR, and LM35 temperature sensors as input sources. The microcontroller processes the data and sends it to a cloud platform for monitoring and management via an internet connection. The results are then displayed on the LCD. When the temperature increases above 38$^{o}$C, skin resistance decreases below 400 and heart rate increases above 100 bpm, the stress is detected and a message is sent to the cellphone. Figures 4.2, 4.3, and 4.4 show the simple outcomes from the simulation. The Arduino simulations in Proteus are widely regarded as being effective in accurately simulating the behavior and functionality of an arduino system. The Proteus simulation environment offers a useful tool for testing and confirming the functionality of an arduino circuit before constructing it in real life, as planned for future projects.

The figure shows different parts of a system done in computer and simulated to indicate different measurements form different sensors.

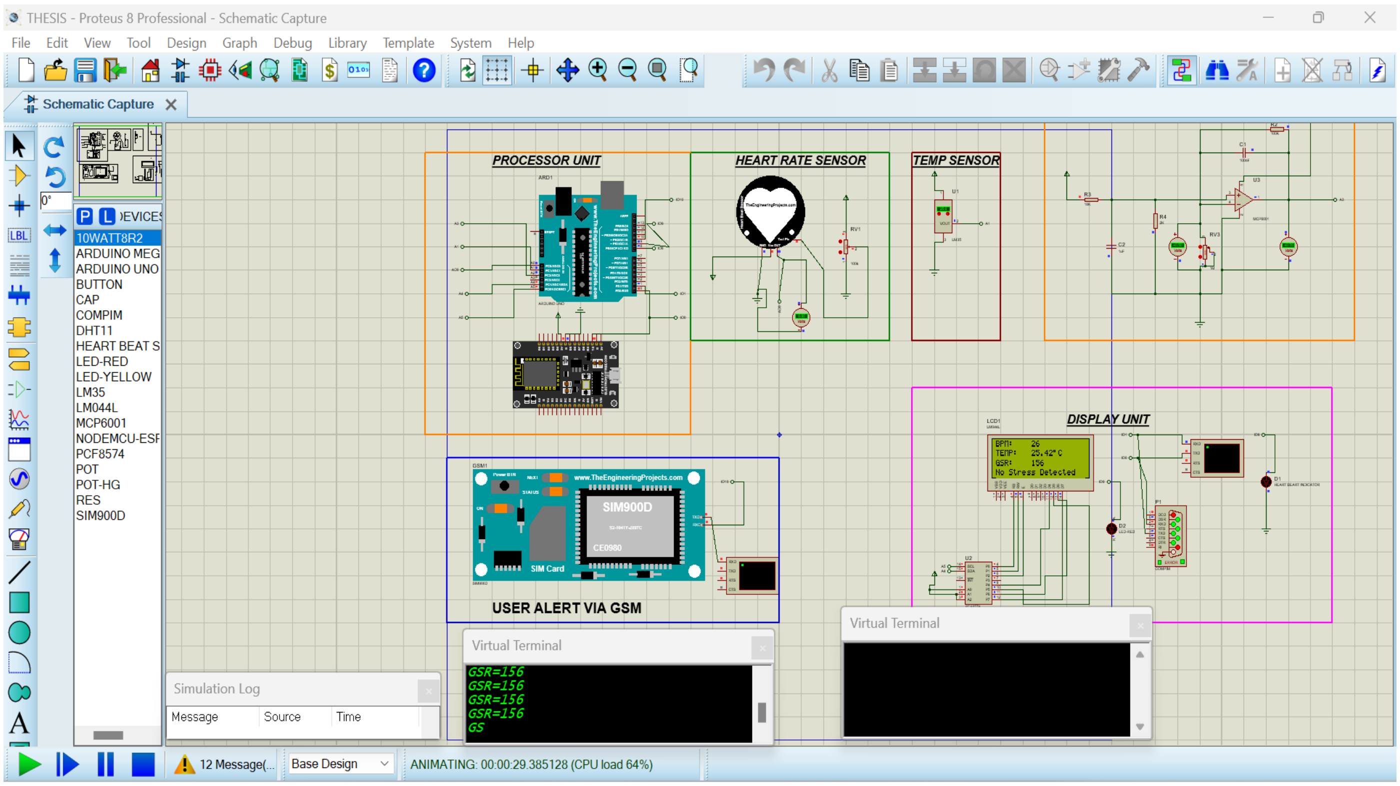


*Figure 4. 1:Simulation setup*

The figure below is a Liquid Crystal Display that shows different measurements form different sensors.

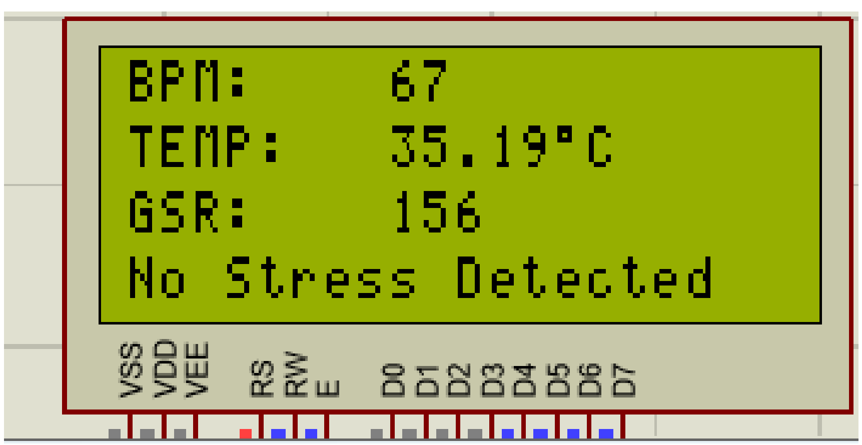


*Figure 4. 2:No  Stress status shown in LCD*

The figure below is a display that shows the message sent to the user when the stress is detected.

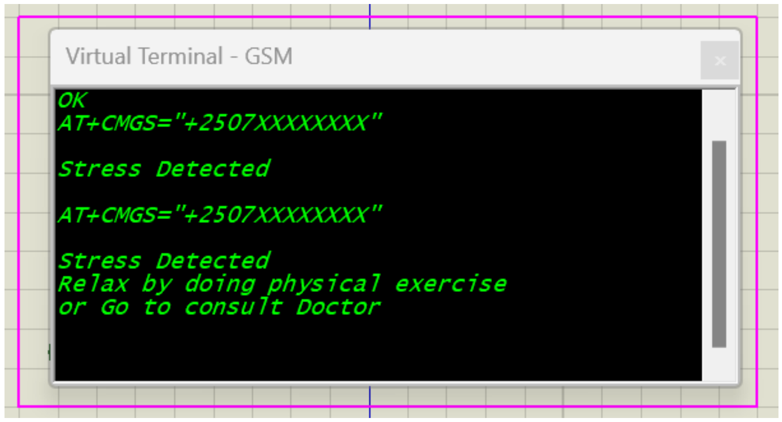



*Figure 4. 3:Message sent to the user cellphone*

The figure below is a Liquid Crystal Display that shows different measurements from stress persons.

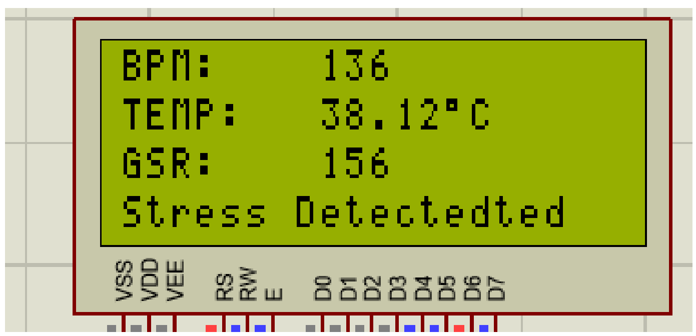



*Figure 4. 4:Stress detected status shown in LCD*

The responses showed that when people experience stress, their body may react by increasing its metabolic rate and releasing stress hormones like cortisol, which can lead to physiological changes. Their body's physiological responses can vary, including changes in body temperature. Stress can trigger the body's fight or flight response, which can lead to an increase in heart rate, blood pressure and changes in body skin resistance.

The result discussions are shown in the following Table 4.1 where the different data from each of the sensors show whether a person is stressed or not. Stress is detected if certain thresholds are surpassed if only if the temperature is above 38°C, heart rate is above 100 bpm and skin resistance is below 400 values. These specific criteria for stress detection must be met collectively by data from all sensors. The combination of elevated temperature, heart rate, and decreased skin resistance indicates stress. The analysis ensures accurate identification of stress in individuals based on sensor data.

*Table 4. 1:Measured Values of Sensors for Different Persons*

| User No | Temperature | GSR | BPM | Result |
|---|---|---|---|---|
| 1 | 35 $^{o}$C | 443 | 120 | No stress |
| 2 | 36 $^{o}$C | 156 | 80 | No stress |
| 3 | 37 $^{o}$C | 443 | 110 | No stress |
| 4 | 37 $^{o}$C | 139 | 62 | No stress |
| 5 | 39$^{o}$C | 205 | 132 | Stress |
| 6 | 40 $^{o}$C | 195 | 120 | Stress |

## 4.2 Discussions

### 4.2.1 Result Interpretation

#### 4.2.1.1 Fuzzy logic algorithm and simulation

Fuzzy logic approach is a machine learning technique for data analytics and intelligent decision making for uncertain problems based on the degree of truth. Fuzzy logic helps in right decision making as that can be made by human perception and reasoning based on the environment variation rather than convention true or false (1 or 0) logic.

#### 4.2.1.2 Fuzzy inference system for decision making

A Fuzzy logic algorithm consists of the pseudo-code for the working principle of the program controller from the beginning to the end. The system starts by defining the variable limits of experimental setup of the case. Next, the membership functions are determined according to the work controller in form of triangular or trapezoidal types for this study and this process is called Fuzzification. After, the Fuzzy rule based on IF-THEN sequence is set according to output command as per the needs. By applying the rules to the Fuzzy values, the results are obtained and sent to defuzzifier. Finally, the Defuzzifier converts the results from Fuzzy inference into crisp output.

#### 4.2.1.3 Construction of membership functions

In this study, there are three input membership functions for detecting stress in person such as temperature, beats per minute(BPM) and the galvanic skin response (GSR) and two output functions such as Stress and No stress as illustrated in the Table 4.2.

*Table 4. 2:Input and output membership functions with their linguistic variables and corresponding ranges*

| Input | | | | | | Output | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Temperature in ($^0$C)** | | **Beats per Minute in bpm** | | **GSR in Ohm** | | **Stress** | | **No stress** | |
| **Linguistic variable** | **Range** | **Linguistic variable** | **Range** | **Linguistic variable** | **Range** | **Linguistic variable** | **Range** | **Linguistic variable** | **Range** |
| Low(L) | 0-30 | Low(L) | 0-60 | Low(L) | 0-400 | YES | 0-1 | YES | 1-2 |
| Normal(N) | 30-37 | Normal(N) | 60-100 | | | | | | |
| High(H) | 37-40 | High(H) | 100-150 | High(H) | 0-1000 | NO | 1-2 | NO | 0-1 |

**4.2.1.4 Fuzzy inference system editor**

The Fuzzy logic tool box in MATLAB is used to demonstrate the Fuzzy inference system editor plots for input body temperature, BPM and GSR membership functions. It also indicates the outputs and functions of the system as illustrated in Figure 4.5.

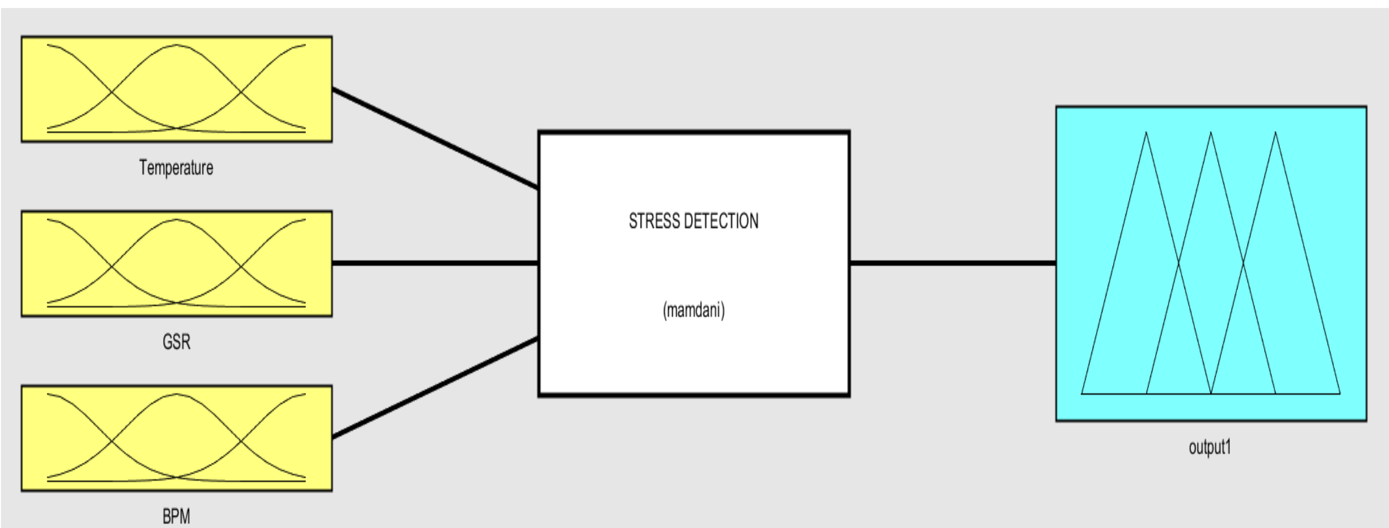



*Figure 4. 5:Fuzzy inference system editor*

**4.2.1.5 MATLAB Fuzzy logic toolbox results simulation**

The general interpretation of the entire Fuzzy inference process is viewed in the Rule viewer. By adjusting the input values of the temperature, heart rate and galvanic skin response, you can view the corresponding output of each Fuzzy rule, the aggregated output Fuzzy set and the defuzzified output values as illustrated in Figure 4.6.

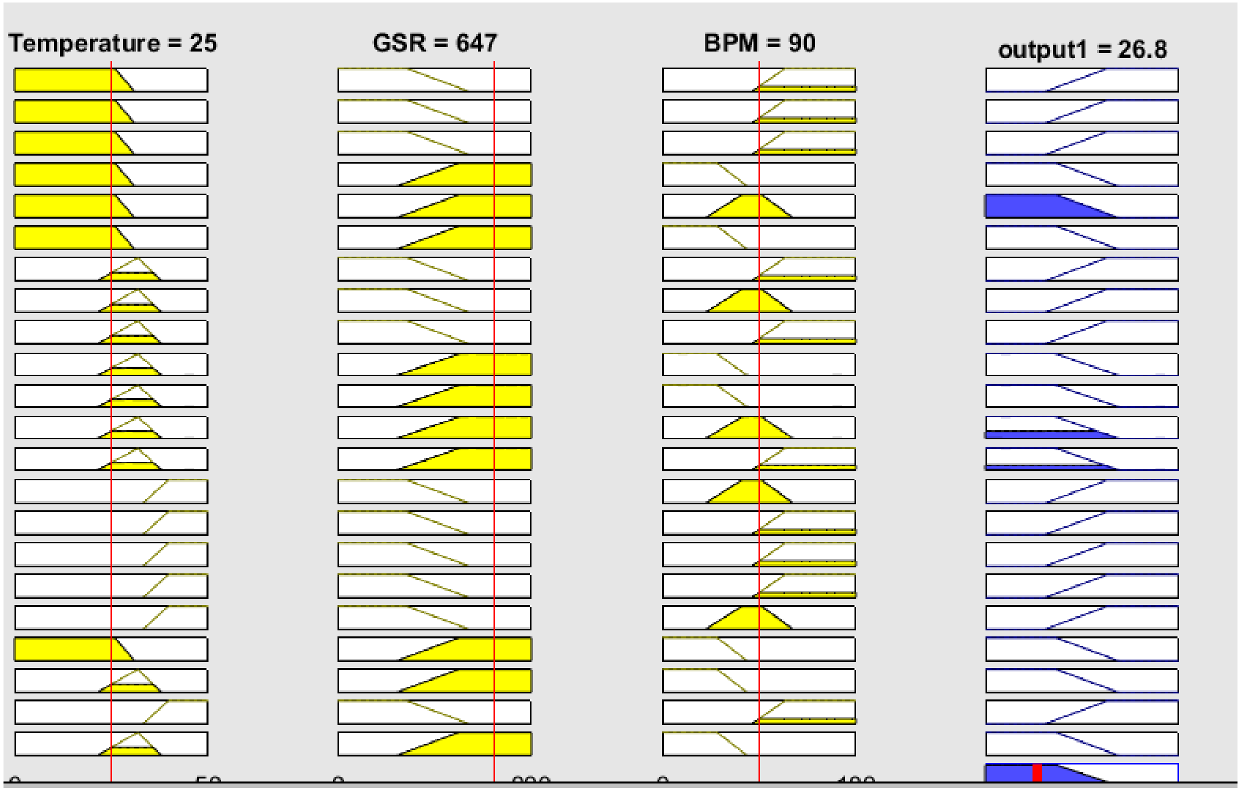



*Figure 4. 6:Fuzzy rule viewer*

The 3D Surface view of the proposed system allows viewing and interpreting the output surface of the Fuzzy system. In this project, figures 4.7a, 4.7b and 4.7c describe the outputs corresponding to the variation of temperature versus beats per minute(BPM) , the variation of temperature versus the galvanic skin response (GSR) and beats per minute(BPM) versus the galvanic skin response (GSR) fuzzy input variables.

Furthermore, in figure 4.8a, 4.8b and 4.8c the outputs corresponding to the variation of temperature, beats per minute(BPM) and the galvanic skin response (GSR) fuzzy input variables are illustrated.

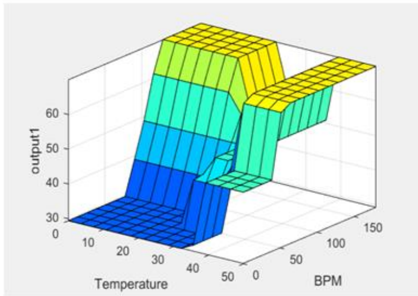



Figure 4.7a

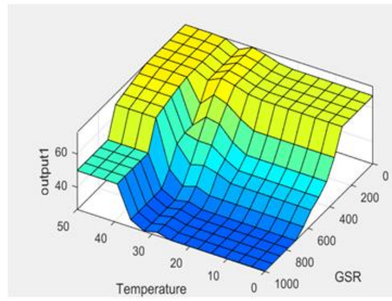



Figure 4.7b

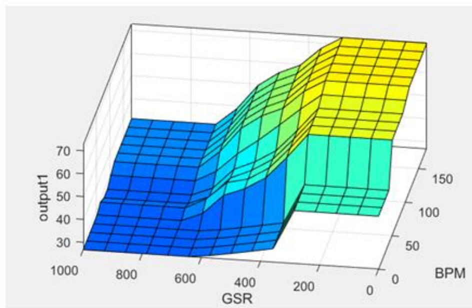



Figure 4.7c

*Figure 4. 7:Three-dimensional surface viewer for output versus two inputs*

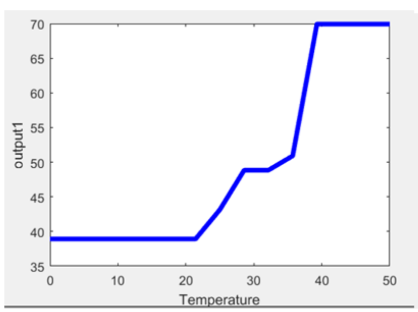



Figure 4.8a

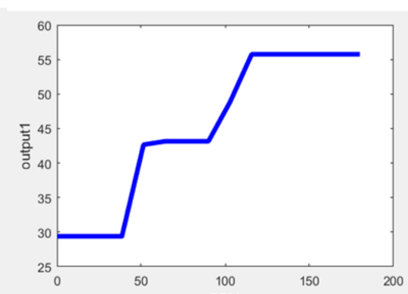



Figure 4.8b

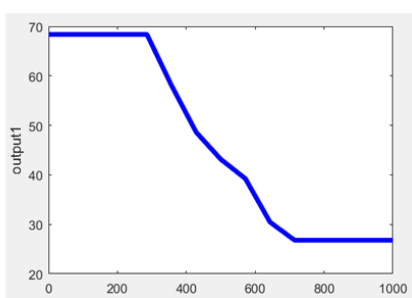



Figure 4.8c

*Figure 4. 8:Surface viewer for output versus single input*

The system has been designed and simulated in proteus as shown in Figure 4.1 to get data from different used sensors. The output results obtained from the simulation correspond to the input to the system as expected from the design objectives.

The system has been simulated in Fuzzy logic Toolbox in MATLAB software as shown in  Figure 4.5 and Figure 4.8 to interpret the data obtained for proteus simulation in order to help the implementers of this design in right decision making as that can be made by human perception and reasoning based on the situation a person is in, he or she may experience a stress.

# CHAPTER 5. CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

The design of a smart portable and wearable stress level detection and monitoring system represents a significant advancement in personalized healthcare technology. This project is designed and simulated using Arduino. The system successfully and accurately detects stress levels using various sensors such as heartbeat rate, body temperature and skin conductance. Based on the values of these sensors, the levels of stress is calculated and the information is transmitted to the concerned persons mobile for necessary action. The simulated model is more flexible and consuming less power.

By integrating sensors capable of measuring various physiological parameters such as heart rate variability, skin conductance, and body temperature, this system provides real-time insights into an individual's stress levels, empowering users to proactively manage their well-being. Through accurate data collection, analysis, and user-friendly interface, this innovative solution not only enhances personal health awareness but also opens avenues for preventive healthcare interventions and tailored stress management strategies, ultimately contributing to improved overall quality of life.

## 5.2 Recommendations

The main objective of this thesis was about to design a smart portable and wearable stress level detection and monitoring system. The proposed system was designed and simulated, and its accuracy and reliability were evaluated. Based on the findings of this study, the following recommendations are proposed to further improve this project. These recommendations aim to address the limitations of the current system and provide direction for future research in this field.

- Further research should be conducted to evaluate the long-term effectiveness and accuracy of the proposed system in various environments.
- Integration of additional vital signs and patient information, such as medical history and medication, could improve the predictive ability of the system.
- Incorporation of machine learning algorithms into the system's software to analyze the collected physiological data (heart rate, temperature, etc.) for improved stress detection accuracy.
- Integration of cutting-edge sensor technologies with advanced data processing algorithms to accurately capture and analyze various physiological parameters indicative of stress levels.

- Collaboration with healthcare professionals and medical institutions is recommended to ensure the safety and reliability of the system in real-world scenarios.
- Investment in hardware and software development to increase the scalability and compatibility of the system with different types of medical equipment.

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# APPENDICES

## Appendix 1: Questionnaire

**Q1:** Have you ever done a job that ended up feeling bad?

**Q2:** Have you been managing your workload lately ?and how?

**Q3:** Have you noticed any changes in your sleep patterns or energy levels recently?

**Q4:** Do you find it difficult to concentrate or focus on your tasks lately?

**Q5:** What are some common triggers or causes of stress that individuals may overlook, and how can they be effectively managed?

**Q6:** Have you ever received a patient with a stress disorder?

**Q7:** Have you ever received people from the rural areas who came for treatment with stress?

**Q8:** Is there any help that rural people receive in order to avoid stress?

**Q9:** Are there any physical symptoms like headaches ,changes in temperature ,blood pressure or muscle tension that they have been experiencing more frequently?

**Q10:** Can you provide examples of evidence-based techniques or therapies for stress reduction, and how can individuals integrate these into their daily routines?

**Q11:** Are there  the potential health risks associated with long-term use of wearable technology?

**Q12:** How do wearable technologies interact with the body's electromagnetic fields, and could this interaction pose any risks?

**Appendix 2: The Utilized Codes**

```
#include <ESP8266WiFi.h>
#include "ThingSpeak.h"
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <SoftwareSerial.h>
#define USE_ARDUINO_INTERRUPTS true
#include <PulseSensorPlayground.h>
String apiKey = "zzzzzzzzzzzz";
const char *ssid =  "xxxxxxxxx";
const char *pass =  "yyyyyyyy";
const char* server = "api.thingspeak.com";
WiFiClient client;
SoftwareSerial mySerial(9, 10);
LiquidCrystal_I2C lcd(0x27,16,2);  // set the LCD address to 0x27 for a 16 ch
const int PulseWire = A0;
const int LED = 8;
const int LED2 = 9;
int Threshold = 550;

PulseSensorPlayground pulseSensor;
float temp=A1;
float tempval;
float voltage;
float celcius;

const int GSR=A2;
int threshold=0;
int sensorValue;
 int tempe;
 int myBPM;
float temp_read,Temp_alert_val,Temp_shut_val;
int sms_count=0,TEMP_Set;

void setup() {
  mySerial.begin(115200);
  Serial.begin(115200);
    lcd.init();
     lcd.init();                    // initialize the lcd
  // Print a message to the LCD.
  lcd.backlight();
  lcd.clear();
pinMode(9,OUTPUT);
pinMode(A1,INPUT);
pinMode(A2,INPUT);
long sum=0;
```

```
for(int i=0;i<500;i++)
 {
 sensorValue=analogRead(GSR);
 sum += sensorValue;
 delay(5);
 }
 threshold = sum/500;
 Serial.print("threshold =");
 Serial.println(threshold);

  pulseSensor.analogInput(PulseWire);
  pulseSensor.blinkOnPulse(LED);
  pulseSensor.setThreshold(Threshold);
   if (pulseSensor.begin()) {
  lcd.begin(20,4);

  delay(10);
       dht.begin();

       Serial.println("Connecting to ");
       Serial.println(ssid);

       WiFi.begin(ssid, pass);

      while (WiFi.status() != WL_CONNECTED)
     {
            delay(500);
            Serial.print(".");
     }
      Serial.println("");
      Serial.println("WiFi connected");
    }
}
void loop(){
  loop1();
  loop2();
}

void loop1() {
if (pulseSensor.sawStartOfBeat()) {
int myBPM = pulseSensor.getBeatsPerMinute();
tempval=analogRead(A1);
voltage=(tempval*5000.0/1023);
celcius=voltage/10;
 Serial.print("TEMP:");
Serial.println(celcius);
```

```
 Serial.print("BPM: ");
 Serial.println(myBPM);
 lcd.setCursor(0,0);
 lcd.print("BPM:");
  lcd.setCursor(8,0);
  lcd.print(myBPM);
 Serial.print("TEMP: ");
 Serial.println(celcius);
 lcd.setCursor(0,1);
 lcd.print("TEMP:");
  lcd.setCursor(8,1);
  lcd.print(celcius);
  lcd.print(char(223));
  lcd.print("C");
 Serial.print("GSR: ");
 Serial.println(sensorValue);
 lcd.setCursor(0,2);
 lcd.print("GSR:");
  lcd.setCursor(8,2);
  lcd.print(sensorValue);

  if(myBPM > 108 and celcius > 38 and (abs(sensorValue)< 400)){
          lcd.setCursor(0,3);
       lcd.print("Stress Detected");
         digitalWrite(9,HIGH);
    }
    else{
      lcd.setCursor(0,3);
       digitalWrite(9,LOW);
       lcd.print("No Stress Detected ");
    }
  }

 sensorValue=analogRead(GSR);
 Serial.print("GSR=");
 Serial.println(sensorValue);
 }
void loop2()
{
CheckTEMP();
CheckShutDown();
}

void CheckTEMP()
{
Temp_alert_val=CheckTemp();
```

```
if(Temp_alert_val>39)
{
 SetAlert();
}
}
float CheckTemp()
{
temp_read=analogRead(A1);
temp_read=temp_read*5;
temp_read=temp_read/10;
return temp_read;
}
void SetAlert()
{
while(sms_count<1)
{
SendTextMessage();
}
TEMP_Set=1;
lcd.setCursor(0,3);
lcd.print("Stress Detected");
}

void CheckShutDown()
{
if(TEMP_Set==1)
{

Temp_shut_val=CheckTemp();
if(Temp_shut_val<39)
{
sms_count=0;
TEMP_Set=0;
}}}

void SendTextMessage()
{
  mySerial.println("AT+CMGF=1");
  delay(200);
  mySerial.println("AT+CMGS=\"+2507XXXXXXXX\"\r");          /*Add your Smart Phone
Number here*/
  delay(2000);
  mySerial.println("Stress Detected");
  delay(200);
  mySerial.println((char)26);
  delay(500);
```

```
   mySerial.println("AT+CMGS=\"+2507XXXXXXXX\"\r");  /*Add your Smart Phone Number
here*/
  delay(200);
  mySerial.println("Stress Detected");
    mySerial.println("Relax by doing physical exercise");
  mySerial.println("or Go to consult Doctor ");
  delay(200);
  mySerial.println((char)26);
  delay(500);
  sms_count++;

      if (client.connect(server,80))   //   "184.106.153.149" or api.thingspeak.com
      {

                          String postStr = apiKey;
                            postStr +="&field1=";
                            postStr += String(celsius);
                            postStr +="&field2=";
                            postStr += String(myBPM);
                            postStr +="&field3=";
                            postStr += String(sensorValue);
                            postStr += "\r\n\r\n";
                            client.print("POST /update HTTP/1.1\n");
                            client.print("Host: api.thingspeak.com\n");
                            client.print("Connection: close\n");
                            client.print("X-THINGSPEAKAPIKEY: "+apiKey+"\n");
                            client.print("Content-Type: application/x-www-form-urlencoded\n");
                            client.print("Content-Length: ");
                            client.print(postStr.length());
                            client.print("\n\n");
                            client.print(postStr);
                                                 }
          client.stop();
          Serial.println("Waiting...");
            delay(1000);
}
```