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Design And development of a Heartbeat and Temperature Monitoring System for Rural Health Centres Using Arduino

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Abstract
Cardiovascular disease is one of the main causes of death in many countries as it accounts for over 15 million deaths worldwide (WHO, 2019). In addition, several million people are disabled by cardiovascular disease. The delay between the first symptom of any cardiac ailment and the call for medical assistance has a large variation among different patients and can have fatal consequences. One critical inference drawn from epidemiological data is that deployment of resources for early detection and treatment of heart disease has a higher potential of reducing fatality associated with cardiac disease than improved care after hospitalization (Wald, and Law, 2018)[21].
This research endeavored to design and implement a model that would easily and quickly provide heartbeat and body temperature data on the go and in remote areas. Based on literature review, Current systems have proved to be very expensive, need electricity to function and not tailored for remote users. The model demonstrates how heartbeat and temperature vital readings are sent via GSM to the health providers who in turn can easily act on the data being received to better provide health care to the system users by responding on time. In addition, this method of sharing health data greatly reduces costs as there is no commuting to and from health facilities. Eventually health facilities are greatly decongested.
The paper describes the design and implementation of the heartbeat and temperature monitoring system based on a microcontroller Arduino ATmega, temperature sensor, heartbeat sensor, power supply, LCD and GSM module. A model was developed to demonstrate how heartbeat and temperature data would be captured remotely using sensors and sent to the analyst by means of a microcontroller using a GSM. On the receiving end, the data was displayed on an LCD monitor for further analysis. This research showed the importance of having automated health systems in the provision of quality health services. The heartbeat and temperature monitoring system showed the need for real-time and non-invasive monitoring systems that can accurately capture vital signs data and provide timely alerts for any anomalies or deviations from normal ranges.

I. INTRODUCTION

Both the world health organization and the ministry of health statistics indicate that the complications associated with cardiovascular have overtime been on upward trend. It also shows that rural communities are more vulnerable and harder hit compared urban communities. Rural communities lack basic access to health care infrastructure, connectivity to both power and internet. This makes it very difficult to implement or roll out technologically advanced equipment. Economic and cultural barriers do not make anything easier coupled to that are issues of affordability and availability of funding. Environmental factors such as weather conditions.
In view of the factor stated above this project was initiated as a solution The core of this project is to develop a low couple system that is cheaper, affordable, and easy to deploy and operate. A solution which does not require advanced IT knowledge to use and maintain while using green energy sources.

Background

In clinical settings, vitals refer to the fundamental physiological measurements that provide essential information about a patient's overall health and well-being. It is hypothesized that continuous vital signs monitoring may allow earlier detection of patient deterioration and thereby improve patient outcomes, but existing evidence is limited (Downey & et al., 2017)[5]. These vital signs are used to assess and monitor a patient's basic

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bodily functions and detect any abnormalities or changes that may require further evaluation or intervention. Heartbeat, pulse or heart rate and body temperature are among the vital signs commonly measured in clinical settings.

Heartbeat or heart rate refers to the rhythmic contraction and relaxation of the heart muscle, resulting in the pumping of blood throughout the body. It is a vital physiological process that ensures the circulation of oxygen, nutrients, and other essential substances to all organs and tissues.

Monitoring and assessing the heartbeat is essential in healthcare to evaluate cardiovascular health, detect irregularities or abnormalities, and diagnose various cardiac conditions. further emphasized that Heart Rate Variability (HRV), which refers to the variation in the time interval between consecutive heartbeats, is also analyzed to gain insights into autonomic nervous system activity and overall cardiovascular health.

Body temperature refers to the measure of the heat generated and maintained by the human body. It is a vital parameter used to assess the overall health and functioning of an individual. The average normal body temperature for adults is generally considered to be around 98.6°F (37°C), although slight variations can be considered normal depending on factors such as age, time of day, activity level, and individual variations.

Body temperature regulation is primarily controlled by the hypothalamus, a region in the brain that acts as the body's thermostat. The hypothalamus helps maintain a relatively constant internal body temperature through a process called thermoregulation. “When the body's temperature deviates from the set point, the hypothalamus triggers responses to either generate or dissipate heat, aiming to restore balance (Saper, and Lowell, 2014)” [20].

Monitoring body temperature is essential in healthcare settings for diagnosis, assessment, and monitoring of conditions such as infections, inflammatory diseases, heat stroke, hypothermia, and post-operative recovery. It helps healthcare professionals make informed decisions about the need for interventions, treatments, or further evaluations. “Heat exhaustion is characterized by cardiovascular hypoperfusion and a rectal core temperature up to 104°F without central nervous dysfunction or greater, multiorgan damage, and central nervous dysfunction (Gauer & Meyers, 2019)”[7] This research developed a model which was used to capture heartbeat and temperature readings remotely using sensors and the data was sent to the analysis center by means of a wireless system.

MOTIVATION OF THE STUDY

Cardiovascular disease is one of the main causes of death in many countries as it accounts for over 17.9 million deaths worldwide. World Health organization (WHO, 2019) added that several million people are disabled by cardiovascular disease. The time between the initial signs of a heart condition and seeking medical help varies greatly among patients and can lead to severe outcomes. An important conclusion from epidemiological data is that investing in resources for the early detection and treatment of heart disease could significantly lower the risk of fatalities linked to it. (Miguel Baigorri; Fermin Mallor,2022.) Designing a model for flu propagation in emergency department.

The heart is the powerhouse of the body. As it pumps blood throughout the veins, delivering the much-needed oxygen to one’s cells. However, the circulatory system becomes less efficient as one grows older. These changes make seniors more vulnerable to developing heart conditions. That's why it becomes increasingly important to monitor heart health at home as you age.

This research endeavored to design and implement a model that would easily and quickly provide heartbeat and body temperature data on the go and in remote areas. Based on literature review, Current systems have proved to be very expensive, need electricity to function and not tailored for remote users. The model demonstrates how heartbeat and temperature vital readings are sent via GSM to the health providers who in turn can easily act on the data being received to better provide health care to the system users by responding on time. In addition, this method of sharing health data greatly reduces costs as there is no commuting to and from health facilities. Eventually health facilities are greatly decongested.

SIGNIFICANCE OF THE STUDY

The main aim of this project is to design and implement a low-cost prototype for heartbeat and temperature monitoring which facilitates regular, remote, monitoring of vital signs of a patient by health providers and enhance pro-activeness in terms of response in an event that abnormalities are detected.

Heartbeat monitoring technologies have become increasingly significant due to their ability to provide real-time health insights, particularly for cardiovascular health. Their importance spans various fields, from healthcare and fitness to consumer electronics and emergency services.

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Here are key aspects which makes heartbeat monitoring very significant:

1. **Early Detection and Prevention**: Continuous heart monitoring can detect irregularities, like arrhythmias or early signs of heart disease, before they become life-threatening. Devices can alert individuals or healthcare providers to potential issues early, enabling timely intervention.
2. **Chronic Disease Management**: Heartbeat monitors play a crucial role for people with chronic conditions, such as hypertension or heart failure, allowing patients and doctors to keep track of heart activity remotely and adjust medications or lifestyle choices based on real-time data.
3. **Fitness and Performance Optimization**: Athletes and fitness enthusiasts use heart rate monitors to ensure they are training in their optimal heart rate zones, improving performance while minimizing the risk of overexertion.
4. **Emergency Response and Remote Care**: Wearable devices with heartbeat monitoring can trigger alerts in case of abnormal heart rate, potentially saving lives by enabling faster emergency response, especially for elderly users or those at high risk of cardiac events.
5. **Personal Health Insights**: By tracking heart rate variability (HRV) and trends over time, individuals can better understand their body's response to stress, sleep, and daily activities, promoting better mental and physical health.
6. **Advancement in Wearable and Mobile Health Technologies**: As wearable devices like smartwatches integrate more sophisticated heartbeat monitoring technology, they increase accessibility to health data, empowering users to take control of their health and encouraging proactive health management.

SCOPE OF THE STUDY

To develop a system capable of monitoring the heartbeat rate and body temperature of an individual in real-time and transmitting the data for remote monitoring and analysis. This system can be used for healthcare applications, fitness tracking, or early detection of health anomalies.

II. PROBLEM STATEMENT

It has been a huge challenge to constantly monitor the heartbeat and body temperature of patients, remotely, to enhance continuity of the Zambian healthcare system. Zambia being a developing country has most of its populace in the rural areas, most of whom cannot afford the expensive devices currently on the market for monitoring heartbeat and temperature. Electricity is also a major challenge in most rural parts of the country. Without proper, continuity clinical care, most people die or even develop more complications (over time) which become more expensive to treat or manage. Patients travel long distances to just have their heartbeat and body temperature checked at a health facility. In an emergency, a pulse rate can help find out if the heart is pumping enough blood. Help find the cause of symptoms, such as an irregular or rapid heartbeat (palpitations), dizziness, fainting, chest pain, or shortness of breath. Temperature measurement is significant in healthcare settings, as part of the regular routine checks of a patient's vital signs.

The objective of this research project was to design and develop an efficient, and low-cost heartbeat and body temperature monitoring model for remote patient care to address the identified gap. Based on the challenges indicated, a comprehensive monitoring system that can reliably track and transmit vital signs data was designed and implemented.

The purpose of this project is to provide a comprehensive analysis of cardiovascular related mortalities while working on an intervention meant to mitigate further loss of lives, while addressing key factors and potential outcomes associated with the cardiovascular diseases. The project seeks to integrate technology as key solution and an effective tool in reversing the current upward trends, enabling informed decision-making and strategic planning. By examining both qualitative and quantitative data, this project aims to present a clear understanding of how the heartbeat and temperature system can help save lives by timely feedback, notifications of the status of the patient thereby reducing costs, increasing efficiency in healthcare provision.

Ultimately, the intent is to offer actionable solutions based on the findings, sustainability and innovative technologies.

III. OBJECTIVES

GENERAL OBJECTIVE

The main aim of this project is to design and implement a low-cost prototype for heartbeat and temperature monitoring which facilitates regular, remote, monitoring of vital signs of a patient by health providers and enhance pro-activeness in terms of response in an event that abnormalities are detected.

SPECIFIC OBJECTIVES

The following are the objectives of this project:

1. To review literature on heartbeat and temperature monitoring system.

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2. To identify components required to setup a heartbeat and temperature monitoring system.
3. To design and implement a heartbeat and monitoring model for rural health centers using Arduino.

RESEARCH QUESTIONS

These where questions formulated for research.

1. What information does a heart rate monitor provide?
2. What are the objectives of heart rate monitoring?
3. Why is cardiac monitoring useful?

CONCEPTUAL MODEL

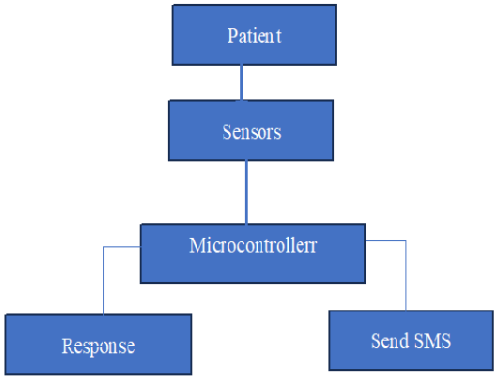

Figure 1
Conceptual structure of the design

DEFINITION AND TERMS

ADC Analogue Digital Converter
GSM Global System for Mobile communication
ISR Interrupt Service Routine
INTR Interrupt Routine.
LCD Liquid Crystal Display

IV. LITERATURE REVIEW

Overview

In recent years, there has been a growing interest in developing advanced monitoring systems to track vital signs such as heart rate and body temperature. These vital signs play a crucial role in assessing an individual's health status and can provide valuable insights into their overall well-being. Wearable sensors can gather the physiological parameters sch as body temperature, heart rate, ECG, Oxygen level, etc. and send the data to the medical cloud using a smartphone (Saif et al., 2022). Lately, the development of wearable health monitoring systems has garnered significant attention, driven by advancements in sensor technology and the demand for personalized healthcare solutions. Wearable health devices are increasingly helping people to better monitor their health both status at an activity/fitness for self-health tracking and medical level more data to clinicians with potential for earlier diagnostic and guidance treatment (Dias and Paulo Silva Cunha, 2018). Among the vital signs crucial for health assessment, heartbeat and body temperature monitoring play a pivotal role in diagnosing and managing various medical conditions (Sapra et al., 2020). This literature review focused on the application of Arduino-based systems integrated with GSM (Global System for Mobile Communications) technologies for heartbeat and temperature monitoring, thereby providing a comprehensive overview of the existing systems and their challenges.

Arduino, an open-source electronics platform, has gained popularity due to its versatility, ease of use, and affordability (Ismailov and Jo‘Rayev, 2022). It serves as a viable solution for prototyping and implementing wearable health monitoring systems, while GSM technology offers wireless communication capabilities, enabling real-time data transmission and remote monitoring,
(Zhang X (2022) Advanced Wireless Communication Technologies). The integration of Arduino and GSM technologies provides a promising platform for developing efficient and accessible heartbeat and temperature monitoring systems.

This literature review aims to explore and categorize the different types of heartbeat and temperature monitoring systems, providing a comprehensive overview of their characteristics, capabilities, and limitations.

Characteristics

1. **Non-invasive**: Most systems use sensors such as photoplethysmography (PPG), thermistors, or infrared technology, ensuring user comfort.
2. **Real-time Monitoring**: They provide continuous, real-time data, crucial for medical diagnostics or fitness tracking.
3. **Compact and Portable**: Devices are designed to be wearable (e.g., smartwatches, fitness bands) or handheld, offering convenience.
4. **Wireless Connectivity**: Many devices sync data with smartphones or cloud platforms using Bluetooth or Wi-Fi.
5. **User-friendly Interfaces**: Applications and devices often feature intuitive interfaces for easy use by non-specialists.

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Capabilities

Heartbeat Monitoring:
- Detect heart rate variability (HRV) to assess stress, fitness, or recovery levels.
- Identify irregularities like arrhythmias or tachycardia.
- Provide insights into cardiovascular health for long-term monitoring.
- Enable remote patient monitoring in telemedicine setups.

Temperature Monitoring:
- Measure core body temperature to detect fever or hypothermia.
- Aid in early diagnosis of infections or conditions with temperature abnormalities.
- Monitor temperature in controlled environments like ICUs or during exercise.
- Provide data for non-medical purposes (e.g., ovulation tracking).

Limitations

1. **Accuracy Concerns**:
   - Environmental factors (e.g., movement, ambient temperature, or sweat) can affect readings.
   - Devices may lack clinical-grade accuracy, making them unsuitable for critical medical decisions.
2. **Battery Life**:
   - Continuous monitoring drains battery quickly in portable devices.
3. **Sensor Limitations**:
   - Skin tone, tattoos, or body hair can impact the performance of optical sensors in heart rate monitoring.
   - Contact-based thermometers require proper placement for precise measurements.
4. **Data Interpretation**:
   - Requires expertise to interpret data correctly; users may misinterpret or ignore critical health signals.
   - Some devices may not detect complex medical conditions.
5. **Privacy and Security**:
   - Wireless connectivity increases risks of data breaches and misuse of sensitive health data.
6. **Cost**:
   - Advanced systems with high accuracy and features can be expensive, limiting accessibility.

Future Directions

To overcome these limitations, future systems aim to:
- Improve sensor accuracy through AI algorithms and better hardware.
- Enhance battery efficiency using energy-harvesting technologies.
- Provide seamless integration with health ecosystems for real-time diagnosis.
- Ensure compliance with privacy standards to safeguard user data.

Related works

HEARTBEAT AND TEMPERATURE

Heartbeat and temperature monitoring systems have become integral components of modern healthcare, providing valuable insights into an individual's physiological state (Parihar et al., 2017). These monitoring systems encompass various technologies and methodologies, each offering unique advantages and applications.

HEART

The heart is the main organ within the human body, which is responsible for pumping blood throughout the body. The heart is situated in the center of the chest, slightly to the left, and is encased by the lungs.

HEARTBEAT RATE

HR is the rate at which the heart beats and is affected by the expansion of the arterial wall with every beat. According to Saifa et al (2018) the most prominent areas for the pulses are wrist (Radial artery), neck (Carotid-artery), inside of the elbow (Brachial artery), behind the knee (Popliteal artery) and ankle joint (Posterior artery).

As earlier mentioned, the HR changes according to age and the physical and psychological impacts on the human body. An elevated pulse rate can signal an abnormal condition in the body, which may also result from factors like anxiety, anger, excitement, emotional states, and heart disorders. The pulse rate of an individual can help in determining various problems within the body, but it cannot be used alone to diagnose an abnormality (Haque et al., 2016).

Gaps in the literature

In rural Zambia, there are several gaps in heartbeat and temperature monitoring, which can significantly impact healthcare delivery and overall health outcomes. Here are some key gaps:

Limited Access to Health Facilities: Many rural areas lack accessible health clinics equipped with adequate monitoring devices. Patients often have to travel long distances to reach healthcare facilities, which can delay diagnosis and monitoring of vital signs.

Shortage of Medical Equipment: Even in health facilities, essential equipment like digital thermometers, heart rate monitors, and blood pressure cuffs may be limited or outdated. Rural

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clinics often operate with limited budgets, making it difficult to acquire or maintain advanced monitoring devices.

Lack of Trained Personnel: There is a shortage of trained healthcare workers in rural Zambia who can effectively use monitoring equipment and interpret data. This gap reduces the quality of care and the ability to address potential health risks early on.

Intermittent Electricity and Connectivity: Many rural clinics do not have reliable electricity, which is essential for operating medical equipment and charging digital devices. Additionally, weak internet connectivity hinders the use of digital health solutions, such as remote monitoring tools or mobile health applications.

Absence of Mobile Health (mHealth) Solutions: Although mobile technology has potential, there is limited implementation of mobile health solutions to facilitate remote monitoring and data collection. This technology could allow for temperature and heart rate data to be collected and analyzed without requiring frequent clinic visits.

Limited Data Collection and Tracking: Regular tracking of heartbeat and temperature is challenging without a robust data management system. Rural healthcare facilities often lack the infrastructure to store and analyze patient data, leading to missed trends that could indicate worsening health conditions.

Low Health Literacy and Community Awareness: Some rural populations have limited awareness of the importance of monitoring vital signs, making it harder to identify and manage conditions such as infections, hypertension, or cardiovascular issues. Health education campaigns could help bridge this gap.

Funding Constraints and Supply Chain Issues: There are funding limitations and inconsistent supply chains that affect the availability of essential medical supplies. This makes it difficult for clinics to consistently provide monitoring services.

Challenges with Follow-Up Care: Rural patients may face difficulties returning for follow-up appointments due to distance, transportation issues, or costs. This reduces continuity in monitoring vital signs and makes it harder to track changes over time.

Addressing these gaps will require coordinated efforts involving infrastructure improvements, training, investment in equipment, and health education programs tailored to rural needs.

TEMPERATURE

Monitoring body temperature is of utmost importance for several reasons, as it provides valuable information about an individual's health status. Here are some key reasons highlighting the importance of monitoring body temperature. (EV Ossila, 2023) Methods of testing and monitoring temperature

1. Firstly, monitoring body temperature helps detection fever. Body temperature monitoring allows the early detection of fever, which is a common symptom of various illnesses, including infections, inflammations, and certain medical conditions. Fever indicates that the body is fighting an infection or undergoing physiological changes Jevon P (**2020**). Monitoring body temperature helps in identifying fever promptly, enabling timely medical intervention and appropriate treatment.
2. Secondly, the importance of monitoring body temperature is that it helps indicate infection in the body. According to Jevon P (**2020**) "an abnormal increase or decrease in body temperature can indicate the presence of an underlying infection. An elevated body temperature is a common response to infections caused by bacteria, viruses, or other pathogens." Hence, monitoring temperature trends can aid in diagnosing infections and tracking their progression or response to treatment.
3. Assessment of health conditions can be aided by monitoring vital body signs. Body temperature monitoring is crucial for the assessment and management of specific health conditions. For example, in individuals with chronic diseases like diabetes, temperature monitoring can help identify complications such as diabetic neuropathy or foot ulcers (Jevon P (**2020**)). Additionally, temperature monitoring is essential in critical care settings, assisting healthcare professionals in evaluating the patient's condition and monitoring for signs of sepsis or other systemic infections.
4. Monitoring body temperature can be essential in tracking the effectiveness of medical treatments. For instance, in cases of bacterial infections, a decrease in body temperature may indicate a positive response to antibiotics (Jevon P (**2020**)). Conversely, persistent or increasing fever despite treatment may suggest a need for reassessment or alternative interventions.
5. Changes in body temperature can sometimes serve as an early warning sign of various medical emergencies (Jevon P (**2020**)). For instance, a sudden rise in body temperature accompanied by other symptoms like confusion or altered mental state may indicate heatstroke. Conversely, a significantly low body temperature (hypothermia) can indicate exposure to extreme cold or underlying health issues.
6. Lastly it helps monitor Vaccine Response after treatment. Body temperature monitoring is often recommended after vaccinations, especially in

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children, to observe for adverse reactions or fever as a response to immunization (Jevon P (**2020**)). It helps ensure timely medical attention if a fever or other concerning symptoms occur following vaccination.

Hence, the monitoring of body temperature is vital for early detection of fever, assessment of infections and health conditions, tracking therapeutic progress, serving as an early warning sign, and monitoring vaccine responses. It aids in promoting timely medical intervention, effective management of health conditions, and ensuring appropriate care for individuals of all age groups.

MICROCONTROLLER

According to Bolanakis (2019) microcontroller (MCU) is a small computer on a single IC. The program loaded in it specifies its functions. Like all computers microcontrollers are equipped with a Central Processing Unit or CPU, a memory system, an input/output system, a clock or timing system, and a bus system to interconnect constituent systems. The bus system includes an address bus, a data bus, and a control bus. The MCU consists of many systems that are usually integrated single integrated circuit package.

GSM

Wireless communication has experienced an explosive growth period and has become an integral part of modern society. The handiness and plasticity offered by mobile communications have made it one of the fastest growing areas of telecommunications.

According to Budd Margolis (2019) mobile communication systems have experienced rapid growth in the number of users as well as the range of services provided during the last two decades. The Global System for Mobile Communications (GSM) is a pan-European mobile communication system operating in the 900 MHz band, first introduced in the early 1990s. The growing need for data transmission services over GSM has been fueled by the widespread use of internet applications.

GSM for wireless communication, is one of the most widely deployed second generation wireless cellular systems in the world. Despite voice being the primary service provided in earlier times, current systems offer other transmission services. One of the most commonly used cellular systems is based on the Global System for Mobile communication, GSM, standard (Gu and Peng, 2010).

EXISTING SYSTEMS

The circuit design of Arduino based Heart rate monitor system using Heartbeat Sensor is very simple. First, to display the heartbeat readings in bpm, we must connect a 16×2 LCD Display to the Arduino UNO. The 4 data pins of the LCD Module (D4, D5, D6 and D7) are connected to Pins 1, 1, 1 and 1 of the Arduino UNO. Also, a 10KΩ Potentiometer is connected to Pin 3 of LCD (contrast adjust pin). The RS and E (Pins 3 and 5) of the LCD are connected to Pins 1 and 1 of the Arduino UNO.

Using an Arduino setup and sensors, an automated watering system where the humidity and temperature sensors were used to sense the soil conditions and based on that microcontroller was used to control the water flow. A Farmer was communicated to through GSM. The IoT sensors are placed in the soil and measure parameters such as soil moisture, temperature, and humidity. These data are then sent to the IoT controller, which analyzes the data and decides when and how much water should be applied. The controller then activates the irrigation system, which can be a drip, sprinkler, or other types of irrigation system (Kansara et al., 2015).

According to Anooz (2018), The tele-health monitoring system consists of three main modules, such as the data sensor unit, the data-processing unit, and the data-communication unit. The data sensor module includes both a temperature sensor and a heartbeat sensor to monitor changes in physiological parameters. This information is subsequently sent to the PIC controller within the data processing unit. The data processing unit analyzes input signals. The communication unit is used to transfer data between person and equipment. This contains basic components such as message, sender, receiver, mediator and protocol through which the message is sent to the doctor via mobile phones via the information gateway for treatment. The component used in the proposed system were: Arduino (UNO), Body Temperature Sensor (MLX90614), Heart Beat Sensor (KY039), nRF24L01 Module (x2), LCD (I2C), Voltage Step Down (X2) and Power Supply (batteries x2). Below are the block diagrams for the system.

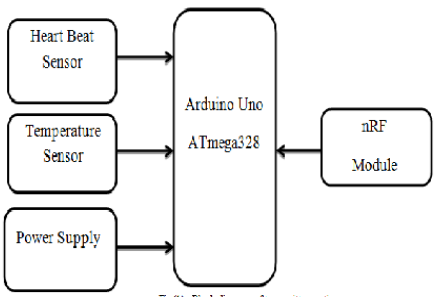

Figure 2: Block diagram for transmitter section

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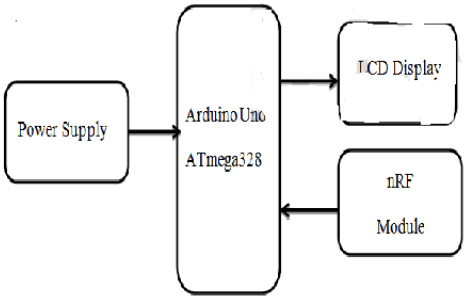

Figure 3: Block diagram for receiver section

According to Parihar et al (2017), they proposed the following architecture for a heartbeat and temperature monitoring system for remote patients using Arduino.

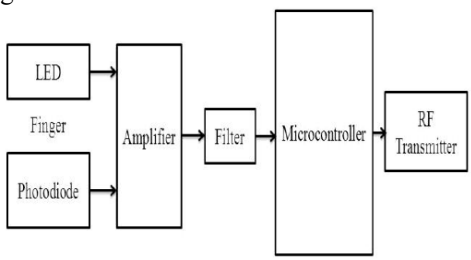

Figure 4: Block diagram showing heartbeat and temperature measuring and transmitting system.

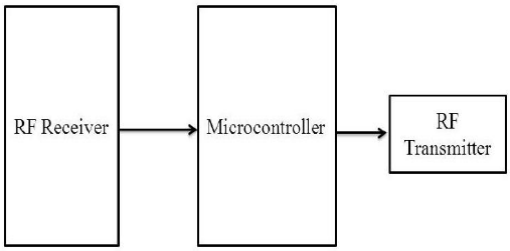

Figure 5: Block diagram of receiving end showing display

It is worth noting that most Arduino-based systems for monitoring heartbeat and body temperature use a pulse sensor to detect heartbeats and an LM-35 sensor to measure body temperature.
The sensor displays the readings in BPM (Beat Per Minute) on the LCD connected to it. The temperature is displayed on the serial monitor along with BPM readings. The technology employed is Arduino which senses the environment and accepts inputs from variety of sensors. Arduino sensors can affect the surroundings by controlling lights, motors and other actuators. This system's microcontroller is programmed using Arduino programming language. LM-35 sensor is used to sense body temperature. Body temperature is a fundamental parameter for monitoring and diagnosing human health. A heartbeat sensor is used to measure heart rate. This device enables the measurement of Mean Arterial Pressure (MAP) in approximately one minute, and it displays accurate body temperature on an Android device. This system can be used to measure the physiological parameters such as Heart Rate (Systolic and Diastolic), pulse rate. This system includes the following components: Pulse sensor, LM-35 sensor, Arduino Uno, 16 x 2 LCD, Bread board, 10k potentiometer and connecting wires.

Remote Heartbeat and Temperature Monitoring Systems in Zambia

It has been a huge challenge to constantly monitor the heartbeat and body temperature of patients, remotely, to enhance continuity of clinical care. Zambia being a developing country, most of its populace cannot afford the expensive devices currently on the market for monitoring heartbeat and temperature. Electricity is also a major challenge in most rural parts of the country. Without proper, continuity clinical care, most people die or even develop more complications which become more expensive to treat or manage; problems which would have been otherwise treated early. Patients travel long distances to just have their heartbeat and body temperature checked at a health facility. In an emergency, a pulse rate can help find out if the heart is pumping enough blood. Monitoring body temperature and heart rate helps identify symptoms like irregular or rapid heartbeat (palpitations), dizziness, fainting, chest pain, or shortness of breath. Temperature measurement is crucial in healthcare settings as part of routine vital signs checks, especially for patients who cannot communicate their discomfort. For instance, a young baby cannot express when they are unwell, making temperature measurement a vital indicator. Body temperature serves as an early warning sign of infection, with fever being one of the body's initial responses and a common symptom in many illnesses. Monitoring body temperature can help detect disease or infection early. (Zambia Country Report -PMC 2017)

Most models done in literature use radio frequency for data communication. Due to limited infrastructure in rural areas, the proposed system will use GSM technology for transmission of Short Messaging System (SMS) for communicating with the health experts. Since GSM technology is widely used in communication devices that are available in both urban and rural areas, this method of communicating health vitals will be both cheaper and reliable. (Developing Systems for Cardiac and Stroke care in Zambia – 2017)

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V. CONCLUSION

Heartbeat and temperature monitoring systems play a vital role in healthcare, fitness tracking, and remote patient monitoring. This chapter looked at similar heartbeat and temperature monitoring systems that were implemented using Arduino. The next Chapter to be covered is design methodology.

Overview

This chapter will look at the implementation details of the proposed system. It will outline the system block diagram, the circuit, and the components that will make-up the system.

Research Design

The proposed heartbeat and temperature monitoring system will be used, mainly, in rural or remote areas to detect heartbeats and body temperature and in turn transmit the readings via GSM module to health care providers.

Baseline Study

It shall consist of three main components such as data sensing module, data processing module and data communication module. The data sensing module consists of a temperature sensor and heartbeat sensor which sense the changes in the respective physiological parameters. The information is then conveyed to the microcontroller of data processing module. The data processing module, in turn, analyses the input signals.

This system will employ two main sensors namely pulse sensor, which sense the heartbeats, and the LM-35 sensor, which senses the body temperature. Arduino has been used, being an open source and a good start to building electronic projects. Arduino consists of both a physical programmable circuit board (MICROCONTROLLER) and a piece of software (Integrated Development Environment) that runs on our computer, used to upload computer code to the physical board.

Pulse Sensor

Figure 6

The Pulse sensor has three pins. Connect 5V and the ground pin of the pulse sensor to the 5V and the ground of the Arduino and the signal pin to the A0 of Arduino.

LM-35 temperature sensor

Figure 7; LM35 sensor

The LM35 is a popular and widely used analog temperature sensor. To use the LM35 sensor in this project, an analog-to-digital converter (ADC) will be used to facilitate interface with a digital microcontroller. The ADC will convert the analog voltage output from the LM35 into a digital value that can be processed and displayed or used for control purposes.

Liquid Crystal Display (LCD)

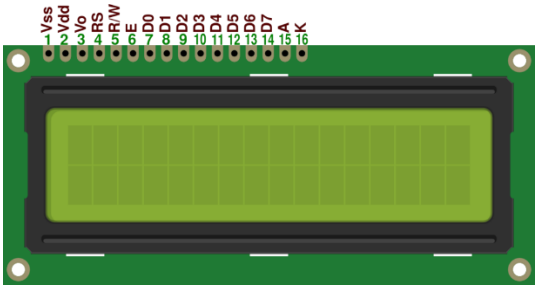

Figure: 8 Liquid Crystal Display (LCD)

Liquid Crystal Display (LCD) screens are currently the most popular choice for electronics.

When the circuit is powered by the battery, the Arduino begins reading the pulse rate from the pulse sensor and the ambient temperature from the LM-35 temperature sensor. The pulse sensor includes an infrared LED and a phototransistor that

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detect pulse at the fingertip or earlobe. The IR LED flashes whenever it detects a pulse, and this flash is detected by the phototransistor, causing its resistance to change with each pulse. A normal adult's heartbeat ranges from 60 to 100 beats per minute (BPM). To detect BPM, an interrupt is set to trigger every 2 milliseconds, giving the Arduino a sampling rate of 500 Hz, which is sufficient for pulse detection.

Every 2 milliseconds, the Arduino reads the analog voltage output from the pulse sensor. This analog output is converted to a digital value using the Arduino's built-in 10-bit ADC channel, resulting in values ranging from 0 to 1024. The middle value of this range is 512. Initially, the first beat is detected when the analog output exceeds 512, and subsequent beats are counted similarly, with the condition that 3/5 of the time between previously recorded beats has passed. Each time a beat is detected, a BPM variable is updated. This BPM value is stored in an array every minute to represent the actual heart rate. Additionally, the Arduino code includes a function that provides an LED fading effect with each beat.

The pulse sensor can also detect body temperature using the LM-35 sensor. The LM-35 operates within a temperature range of -55 °C to 150 °C, with an output voltage that changes by 10mV for each °C change in temperature, giving it a scale factor of 0.01 V/°C. The LM-35 does not require external calibration or trimming, providing typical accuracies of ±0.25 °C at room temperature and ±0.75 °C over its full range. Under normal conditions, the temperature measured by the sensor will stay within its operational range.

Development of the Application

The heartbeat and temperature monitoring system will be used to take heartbeat and body temperature readings and transmit the readings to the health provider via Global System for Mobile communication (GSM). This will be a low-powered device, allowing it to run on solar to enable usefulness in remote areas without electricity. The advantage of the GSM module is that it enables the health provider to monitor the vitals (heartbeat and body temperature) of the patients constantly and remotely.

System Design

Heartbeat and temperature monitoring system is done with modules of data sensing, data processing and data communication. Three sensors are contained in data sensing module such as temperature sensor, heart rate sensor. Temperature sensor is used to measure the body temperature. Heartbeat sensor is used to measure the function of heart by blood flow through the finger. The output from each sensor is connected to the Analog-to-Digital Converter (ADC) pins of the microcontroller. The data processing module features the ATmega328, a 28-pin, 8-bit microcontroller with Harvard architecture. This high-performance nRF circuit is used to convert RS232 signal voltages to TTL voltages and facilitates communication for sending SMS through an information gateway. An LCD is connected to the microcontroller to display the current physiological parameters. Patient monitoring is particularly relevant in situations where a patient is experiencing unstable physiological regulation, such as in cases of anesthesia overdose.

In unstable physiological regulatory systems – For instance, in the case of overdose of anesthesia.

- In a life-threatening condition – For instance, when there is an indication of heart attack in a patient.
- In a critical physiological state this system can assist in early detection.

Context Diagram

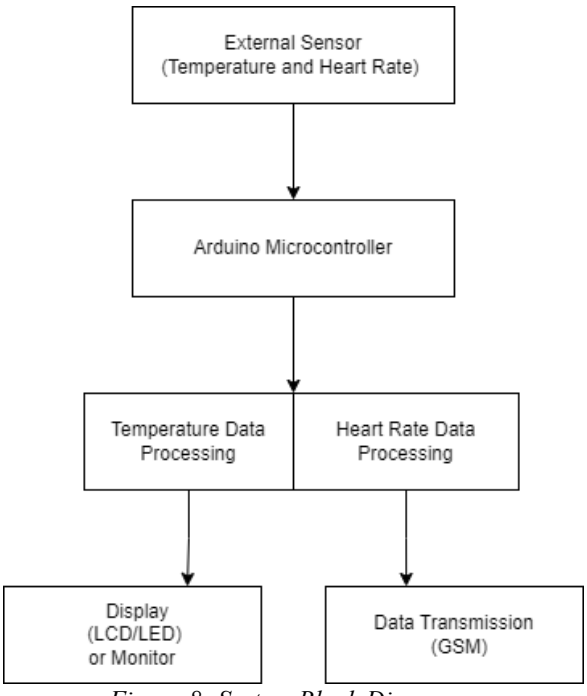

Figure 8: System Block Diagram

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System Software Level Architectural Design

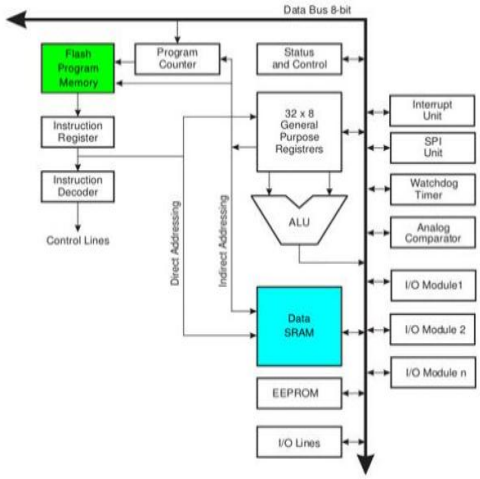

Figure 9:

2. Modular Design of the system functions

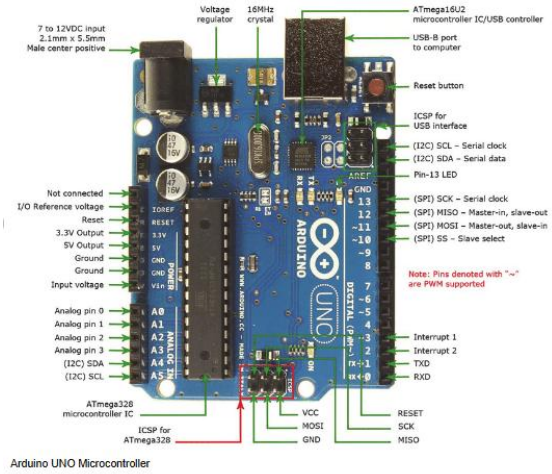

Figure:10

System Class Diagram

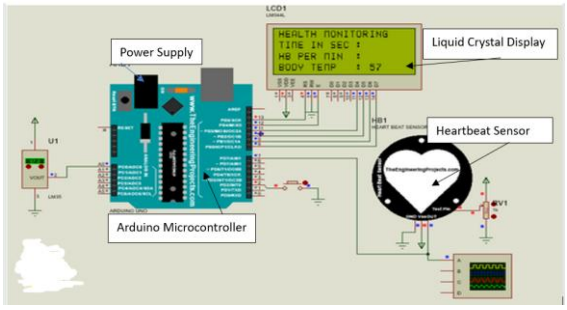

Figure:11 System Data Model Design

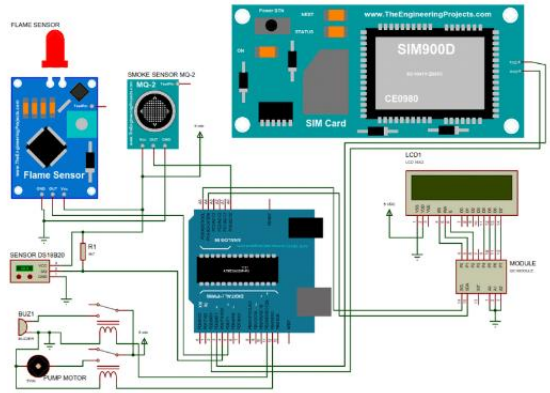

Figure: 12

User Interface Design

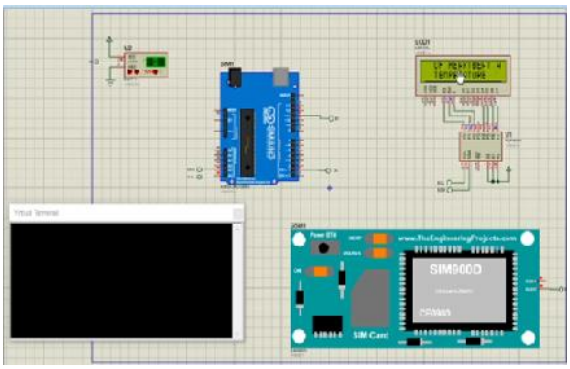

Figure 13

The Temperature

The temperature sensor is placed in contact with the body or at a suitable location for temperature measurement (e.g., under the armpit or on the forehead).

The sensor measures the temperature and sends the analog or digital temperature data to the Arduino.

3. Heart Rate Measurement:

The heart rate sensor is typically worn on a fingertip, earlobe, or another suitable location.

It emits infrared light into the body part and detects the changes in blood volume caused by the pulsing blood flow.

These changes are converted into electrical signals and sent to the Arduino.

4. Data Processing:

The Arduino receives the temperature and heart rate data.

It then performs any necessary data processing or filtering to ensure the accuracy and reliability of the measurements. For example, noise reduction or averaging.

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5. Display/Transmission:

The Arduino display the data on an LCD screen for real-time monitoring and transmit the data to a phone via GSM.

6. Power Supply:

Stable power is supplied to the Arduino and sensors from batteries, USB power, or an external power source or solar.

6. EXTERNAL SENSOR

This is the sensor used to measure body temperature and heart rate. They are a combination of sensors, one for temperature and one for heart rate. These sensors provide raw data to the Arduino.

Heartrate sensor

Temperature sensor

7. ARDUINO MICROCONTROLLER

The Arduino is the central processing unit of the system. It receives data from the sensors, processes the data, and manages the interactions with other components.

The Arduino processes temperature data, which may include calibration and conversion to human-readable units (e.g., Celsius or Fahrenheit).

The Arduino processes heart rate data, which may involve filtering and calculating beats per minute (BPM).

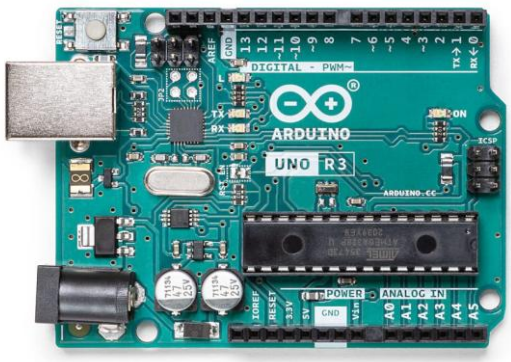

Figure 14 Arduino Microcontroller – (Mindkits)

8. DISPLAY (LCD/LED)

This component provides a real-time display of the temperature and heart rate data. It could be an LCD screen or LEDs for basic readouts. For more advanced applications, a monitor can display graphical data.

9. DATA TRANSMISSION (GSM)

GSM, which stands for Global System for Mobile Communications, is a widely used standard for digital cellular communication. It is the technology that underlies most of the world's mobile phone networks and is the basis for 2G (second-generation) mobile communication systems. GSM provides the framework for how cell phones and other mobile devices communicate with cell towers and with each other.

Figure 15 GSM Module SIM900A-(Instructables)

SIM900A features

The SIM900A is a GSM/GPRS module from SIMCOM, commonly used for adding wireless communication capabilities to embedded systems and IoT (Internet of Things) projects. This module operates on dual-band frequencies, specifically 900 MHz and 1800 MHz, making it suitable for use in regions where these bands are supported (mainly in Asia, the Middle East, and some parts of Africa).

GSM/GPRS Support: Offers GSM voice communication, SMS, and GPRS data capabilities.
Serial Communication: Typically communicates with microcontrollers through UART (Universal Asynchronous Receiver Transmitter), making it easy to interface with popular microcontrollers like Arduino, ESP32, and STM32.
Low Power Consumption: Operates on 3.2V to 4.8V, making it energy-efficient and suitable for battery-powered applications.
Quad-Band (with Firmware Modifications): The SIM900 (not 900A) is a quad-band module that operates on 850/900/1800/1900 MHz, making it suitable for global use. The 900A version is region-specific.
Embedded TCP/IP Stack: Has built-in support for TCP/UDP, HTTP, and FTP protocols, enabling internet-based applications.

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Applications
Remote Monitoring and Control: Used in systems that require remote control or monitoring, like security systems or industrial automation.
Vehicle Tracking: Integrated into GPS tracking systems to relay location data over the GSM network.
SMS-Based Alerts: Enables devices to send SMS alerts, useful in security, healthcare, or environmental monitoring.
Sample AT Commands
Make a Call: ATD<phone number>;
Send an SMS: AT+CMGF=1 (to set SMS mode) then AT+CMGS="<phone number>" followed by the message text.
GPRS Setup: Several AT commands are required to connect to a GPRS network, including AT+SAPBR (to set bearer settings) and AT+HTTP commands for HTTP sessions.

Advantages and Limitations
Advantages: Easy to use, low-cost, widely supported, has good community resources.
Limitations: Limited to certain GSM bands (region-specific), slower data rates compared to newer 4G/5G modules.

Feature	Implementation
Power supply	Single supply voltage 3.4V-4.5V
Power saving	Typical power consumption in SLEEP mode is 1.5mA (BS-PA-MFRMS=5)
Frequency Bands	• SIM900A Dual band: EGSM900, DCS1800.THE SIM900A can search the 2 frequency bands automatically. The frequency bands also can be set by AT command. • Complaint to GSM 2/2+
GSM class	• Small MS
Transmitting power	• Class 4 (2W) at EGSM 900 • Class 1 (1W) at DCS 1800
GPRS connectivity	• GPRS multi-slot class 10 (default) • GPRS multi-slot class 8 (option) • GPRS mobile station class B

Table 1: GSM Module Specifications

Overview
This chapter discusses the simulation process of the proposed Heartbeat and Temperature Monitoring system. The software which was selected for simulating the project is “Proteus Design Suite 8.6”. The simulation process was based on modeling a real phenomenon. It is essentially a program that enables users to observe an operation through simulation without actually performing it. Discussion of the heartbeat and temperature monitoring system was done using a microcontroller. In addition, discussion of the results of the simulation was based on the virtual circuit assembled with all the electrical components identified and the Arduino was used to write the program to perform the desired simulations.

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Baseline Study Results
PROTEUS VIRTUAL SYSTEM MODELING (VSM)
The system prototype was simulated in Proteus. Proteus Virtual System Modeling (VSM) combines mixed mode SPICE circuit simulation, animated components and microprocessor models to facilitate simulation of complete microcontroller-based designs. Proteus VSM uses my proven Schematic Capture software to provide the environment for design entry and development. Proteus capture is a long-established product and combines ease of use with powerful editing tools. It can support schematic capture for simulation (Bahir Dar Institute of Technology, 2015). The Proteus schematic capture module also provides a very high degree of control over the drawing appearance. These capabilities are used to the full potential in providing the graphics necessary for circuit animation. The project was built and tested in Proteus just by using the software prototype components without using the physical hardware prototype (Ibid, 2015). Therefore, using Proteus software, body temperature and heartbeat sensing circuits, and serial communication were all developed and tested.

SCHEMATIC DIAGRAM
This thesis deals with heartbeat and body temperature monitoring. In this system, a microcontroller is interfaced with a heartbeat and temperature sensors, and a GSM communication link. As designed in chapter 3, the circuit section consists of different components for different purposes. Arduino UNO microcontroller is used for programming and control. This system will be used to measure the heartbeat and body temperature of a patient. A dedicated GSM modem with a SIM card is required for the unit. The microcontroller sends the SMS to the caregiver’s phone when the patient’s

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temperature and or heartbeats are above the normal for quick response.
The given circuit diagram shows the heartbeat and temperature readings displayed on the LED for immediate response.

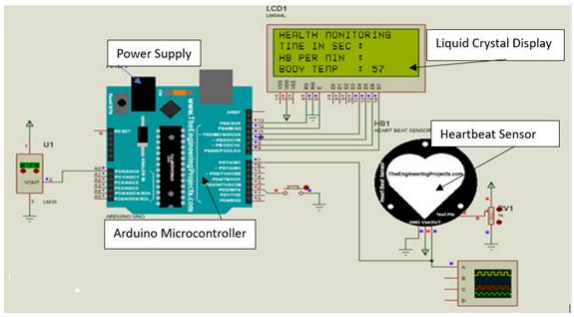

Figure 16 Simulation Circuit

Below shows the heartbeat readings displayed on the LED screen.

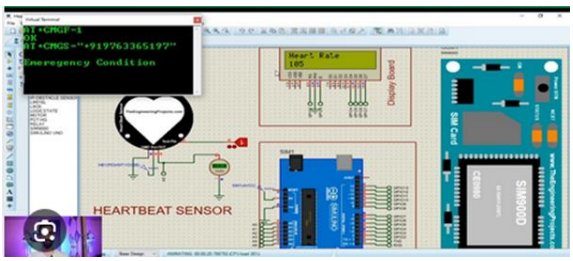

Figure 17 Heartbeat Reading Simulation – Proteus Virtual System

Below shows the body temperature readings displayed on the LED screen.

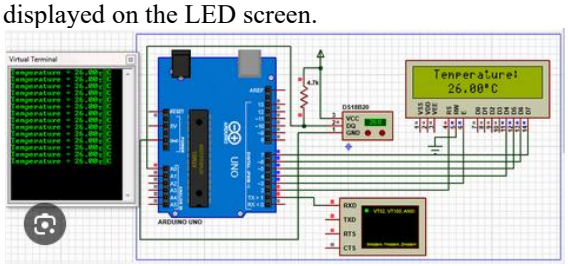

Figure 18 Temperature Reading Simulation

VI. RESULTS OF THE SIMULATIONS

Simulating a heartbeat and temperature monitoring system using Arduino involves creating a hardware setup, writing code, and collecting data from sensors. Below, I'll provide an overview of what was realized as results from such these simulations.

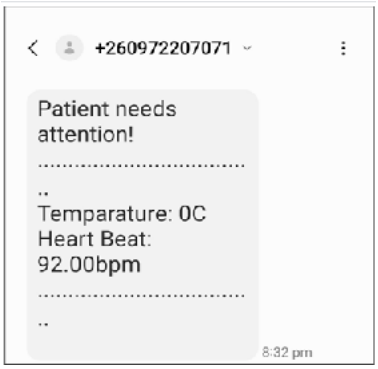

Figure 19

Message from the system alerting the health profession on the patient status

Figure 20

Heart Rate Data:
The system collected heart rate data from a heartrate sensor. The simulation provided a continuous stream of heart rate values in beats per minute (BPM).
Real-time Display: An LCD screen was used to display the real-time heart rate data, allowing me to observe fluctuations as they occur.
Alerts:
GSM module was configured to send alerts or alarms in the simulation to trigger when the heart rate exceeds or falls below certain thresholds, simulating conditions like tachycardia or bradycardia.

Temperature Monitoring Results:
Body Temperature Data:
Using a temperature sensor, the Arduino simulation generated continuous body temperature readings in degrees Celsius.

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Real-time Display:
Like heart rate monitoring, the real-time temperature data was captured on the LCD screen.

Fever Detection:
Alerts were programmed to trigger an SMS alert when the simulated body temperature exceeds a predefined fever threshold of 36 degrees Celsius.

The primary purpose of these simulations was to test and demonstrate the functionality of a heartbeat and temperature monitoring system and, in some cases, to create a proof-of-concept for a real-world application in healthcare or fitness tracking.

System Implementation Results (Testing Results)

Testing of components is a very important step in the formation of any working prototype to ensure every part of the prototype is safe and working. If components are not tested it may lead to eminent prototype failure.

System testing is an essential phase in the software development lifecycle, where the entire software system is evaluated to ensure that it meets its specified requirements and functions correctly as a whole. There are several types of system testing, each with its specific focus and objectives.

ARDUINO TESTING

The reason why testing of components is done before assembly is to find out if the Arduino Board on the receiving end would interpret the interpret readings from the two sensors, send alert via GSM module and display results on the LED. In this case Arduino UNO was powered by the computer. After this code was uploaded to the Arduino UNO Board. The initial stage of uploading the code to the Arduino UNO Board and the connection of the GSM Module to the Arduino UNO Board was also done. The Arduino powered the GSM Module via 5V pin, with the Arduino Rx and Tx pins connected to the GSM Tx and Rx pins respectively to ensure serial communication. The message or alert generating code was uploaded to the Arduino UNO Board as well.

GSM TESTING

After connecting the GSM Module to the Arduino Board, temperature and heartbeat sensor of the Arduino were tested by changing their states: HIGH and LOW for temperature and heart rate.

The receiving end was taken to be a mobile phone for alerts; to check if the GSM Module was able to send text messages or alerts. When the temperature sensor received a high temperature, the receiver received the "HIGH BODY TEMPERATURE DETECTED" text message, and when the temperature sensor received a low temperature, below 36 Degrees Celsius, the receiver received the "LOW BODY TEMPERATURE DETECTED" text message.

Similar results were observed on the heartbeats where a "HIGH BPM DETECTED" and "LOW BPM DETECTED" messages were received upon getting the readings of the heartbeats in different scenarios.

These processes were done repeatedly, and the receiver kept on receiving text messages based on the state of the heartbeat and temperature sensors, an indication that the GSM was working.

CIRCUIT CONTINUITY TESTING

The aim of this test was to check if the wired circuit will not have any open circuits. This was conducted by setting the buzzer (Sound indicating continuity) on the ohm meter and testing circuit board for continuity. Individual components were also subjected to continuity tests before being soldered on the board. After the completion of setting up and wiring the circuit, the completed circuit was also tested for continuity. The test was aimed at finding any electrical open paths in the circuit.

The process of soldering and circuit alignment is shown in the figure below. This included the construction of the circuit by soldering circuit components to the board.

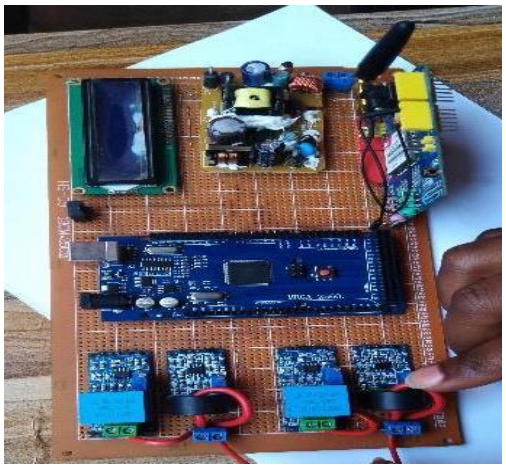

Figure 21 Prototype Testing

FUNCTIONAL TESTING

Functional testing is a type of testing that ensures each function of the software application operates according to the requirements and specifications. This testing focuses on the application's behavior rather than its source code.

This testing was conducted to ensure conformity to the specification requirements ascribed from inception. Concentration was on what the system was intended to achieve and that to be able to measure body temperature and heartbeats of a

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patient and later transmit the results to the health provider via GSM module.
After assembly, the system's functionalities were tested separately, and outcomes recorded.

Data Analysis
Simulation Analysis
The simulation design and connection of all the components to the Arduino. An Arduino UNO board was used while simulating in the Proteus software. The temperature sensor output as well as the heart beat sensor output will be in analog form which needs to be converted into digital output. There are 6 analog to digital conversion pins present on the Arduino board (A0 – A5) which takes in analog signals as input and converts it into digital output. Hence, the heartbeat sensor is connected to pin A0 while the temperature sensor is connected to the A1 pin of the Arduino board [21].
The result of this simulation is shown in table2The obtained results are:
Heartbeat: 90 BPM & Temperature: 32oC
Measured Response/Experimental Results
Three health parameters of three different individuals were measured using our health monitoring system. The health parameters were Body Temperature (F), Heart Beats Per Minute (BPM) & Oxygen Saturation Percentage/SpO2 Level (%).
The table below shows the measured response after user 1 pressed on the LM-35 sensor. The LCD screen displayed the readings as follows:

Sample Patients	Temperature (Deg Celsius)	BPM	O2 (%)
Patient 1	38.20	60.31	
Patient 2	37.13	93.21	91
Patient 3	37.34	109.46	95
Patient 4	36.67	70.26	96

Table 2 Experimental Results

Overview
In conclusion, the objective of this thesis was to design, implement, and evaluate a body temperature and heartbeat monitoring system using Arduino technology. The importance of the system was emphasized in the introductory part and the research objectives were met as follows.

VII. DISCUSSION

The Baseline Study
Literature review was done to understand the heartbeat and body temperature systems done using Arduino. Various components that need to be part of the proposed system were identified.

Use of Technology
The prototype was successfully developed demonstrating the feasibility of creating an accessible and cost-effective monitoring system. The integration of sensors with Arduino allowed for real-time acquisition and processing of vital health parameters, enabling continuous monitoring without imposing discomfort on the user. Secondly, the system exhibited commendable accuracy and reliability in capturing body temperature and heartbeat data. Comparative analysis with established medical devices showcased promising levels of precision, highlighting the potential for this system to serve as a valuable tool in healthcare settings, especially in resource-constrained environments.
Moreover, user feedback and testing revealed the user-friendliness and simplicity of the interface, suggesting its potential for widespread adoption among diverse user groups.
The implications of this research extend beyond the academic sphere. The developed system holds promise for various applications in remote patient monitoring, home healthcare, and telemedicine, offering a convenient and affordable solution for continuous health monitoring.

Development of the System as a Solution
Accurate and continuous monitoring of vital signs like heartbeat and body temperature is crucial in medical diagnosis, early detection of health issues, and patient care. However, traditional systems are often expensive, cumbersome, or inaccessible, particularly in remote areas or for low-resource settings. This calls for an affordable, portable, and efficient solution.
Real-Time Monitoring: Design a system to measure and display real-time heartbeat and body temperature.
Affordability: Ensure cost-effectiveness for widespread accessibility.
Portability: Develop a compact and user-friendly device.
Reliability: Provide consistent and accurate readings.

Proposed System (Components)
Measures the pulse rate using photoplethysmography (PPG) technology by detecting blood volume changes. Typically consists of a light source and a photodetector. Temperature Sensor (e.g., LM35 or DS18B20): Monitors body temperature with high precision. Converts temperature data into a readable format for microcontrollers. Microcontroller acts as the central unit, processing data from sensors. Interfaces with

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output devices (e.g., display, GSM Module, or mobile phones).
LCD or OLED screen to show heartbeat and temperature readings.
Alternatively, data can be transmitted to a mobile app or cloud.
Power Supply:
A battery or USB-powered system ensures portability.
Communication Module (Optional):
Bluetooth/Wi-Fi module for remote monitoring via mobile applications or cloud services.
Identify suitable sensors and components based on cost, accuracy, and availability.
Design a schematic diagram for hardware integration.
Assemble components on a breadboard for testing.
Write microcontroller code to read sensor data and process it.
Test functionality and calibration of heartbeat and temperature sensors.
Testing and Calibration:
Validate the system with controlled experiments.
Compare readings with standard medical devices for accuracy.
System Optimization:
Refine code and hardware for energy efficiency and faster response.
Minimize noise and errors in sensor readings.
Deployment:
Package components into a compact, durable casing.
Provide user instructions and an intuitive interface.
Applications
Healthcare Monitoring:
For hospitals, clinics, and home-based care.
Beneficial for elderly patients, chronic disease management, and post-operative monitoring.
Remote Health Services:
Useful in telemedicine to monitor patients in rural or remote areas.
Fitness and Wellness:
Integrated into wearable devices like fitness bands and smartwatches.
Advantages
Cost-Effective: Affordable alternative to hospital-grade equipment.
Portable: Lightweight and easy to carry for continuous monitoring.
Real-Time Data: Immediate access to vital parameters.
Scalability: Can be scaled with additional features like SpO2 monitoring.

Future Scope
Integration with AI for predictive health analytics.
Cloud-based storage for long-term data tracking.
Development of a mobile app for remote monitoring and emergency alerts.
This system provides an efficient, affordable, and scalable solution to improve healthcare monitoring, especially in underserved regions

Possible Application
The application of a heartbeat and temperature monitoring system can be highly beneficial across various fields, particularly in healthcare, fitness, and safety. Here are some notable applications:
Healthcare and Patient Monitoring
Remote Patient Monitoring:
Continuous monitoring of patients' heart rate and body temperature is valuable for people with chronic conditions like cardiovascular diseases or respiratory problems. Real-time data can be sent to healthcare providers for analysis, enabling quick responses in case of abnormal readings.
ICU and Emergency Care:
In intensive care units, monitoring vital signs like heart rate and temperature helps medical staff provide timely interventions. Any sudden change can trigger alerts for immediate medical action.
Wearable Health Devices:
Devices like smartwatches equipped with heart rate and temperature sensors allow users to keep track of their health metrics. They can detect anomalies and even prompt the user to seek medical help if necessary.
Fever Detection and Illness Prediction:
Elevated body temperature often signals infection. Systems can be used to detect fever early on, especially in pandemics or flu seasons, to help contain the spread of contagious diseases.
Fitness and Wellness
Heart rate monitoring during exercise helps individuals understand their workout intensity. For example, monitoring the heart rate can ensure they are exercising within their target zone for maximum efficiency, be it for fat-burning, endurance, or performance.
Body Temperature Regulation: Overheating during exercise can lead to exhaustion or even heatstroke. Monitoring body temperature allows athletes and individuals to take preventive measures if their temperature rises too high, such as taking breaks or hydrating.
Safety and Workplace Monitoring
Occupational Health and Safety: In environments like factories, mines, or construction sites, workers can be exposed to extreme temperatures or physical strain. Real-time monitoring systems can alert supervisors if an employee's heart rate or body temperature exceeds safe limits, reducing the risk of accidents and health issues.

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Firefighting and Military:
These professions often involve extreme physical stress and high-risk environments. Wearable monitoring devices ensure that firefighters, soldiers, or emergency responders are safe and can receive support if their health metrics indicate distress.

Smart Home and Elderly Care
Home Monitoring for Elderly Individuals: Heartbeat and temperature monitoring systems can allow family members or caregivers to remotely monitor elderly individuals living alone. If an abnormal reading is detected, alerts can be sent for immediate assistance.
Sleep Monitoring: Monitoring heart rate and body temperature during sleep can provide insights into sleep quality, helping in the diagnosis of sleep disorders or providing data to improve sleep health.

Animal Health Monitoring
Veterinary Applications: These systems can also be used in veterinary practices or animal husbandry to monitor the health of pets, livestock, or wildlife, helping detect diseases or stress early on. Technology and Components in Such Systems. A heartbeat and temperature monitoring system typically includes:
Sensors: Photoplethysmography (PPG) for heart rate, infrared thermometers for temperature, and other specialized sensors. Microcontrollers: To process the data from sensors.
Wireless Communication Modules: To transmit data to connected devices like smartphones or hospital servers. Power Management: Efficient batteries and power-saving technologies, especially for wearables.

Future Directions
With advances in AI and machine learning, these systems may soon be able to predict health issues by analyzing trends over time. Integrating this technology into telemedicine and electronic health records could significantly enhance personalized healthcare.

VIII. SUMMARY

This project involves monitoring heart rate and body temperature using an Arduino microcontroller. The pulse sensor detects heartbeats, and the LM-35 sensor measures temperature. The Arduino processes these signals and displays the heart rate in beats per minute (BPM) and the temperature in degrees Celsius on an LCD screen. The system can also transmit the data based on the set parameters, if the parameters are outside the normal range the SMS is sending alerting the healthcare provider of the detected abnormality.
Heartbeat and Temperature Monitoring Systems in Rural Zambia: A Summary
The Challenge:
Rural Zambia faces significant healthcare challenges, including:

- Limited Access to Healthcare: Many rural communities are geographically isolated, making it difficult to access healthcare facilities.
- Shortage of Healthcare Professionals: There is a critical shortage of healthcare workers, especially in rural areas.
- Delayed Diagnosis and Treatment: Delayed diagnosis and treatment of critical health conditions can lead to severe consequences.
- The Solution: Remote Health Monitoring Systems
- To address these challenges, remote health monitoring systems, including heartbeat and temperature monitoring devices, have emerged as a promising solution. These systems can:
- Enable Remote Patient Monitoring: Healthcare providers can monitor patients' vital signs remotely, even in remote areas.
- Early Detection of Health Issues: Early detection of critical conditions like heart problems and fevers can lead to timely interventions.
- Reduce the Burden on Healthcare Workers: By automating certain tasks, these systems can help healthcare workers focus on more complex cases.
- Improve Patient Outcomes: Early detection and intervention can significantly improve patient outcomes.
- How it Works:
- Patient Monitoring: Patients wear wearable devices that continuously monitor their heart rate and temperature.
- Data Transmission: The collected data is transmitted wirelessly to a central server or a healthcare provider's smartphone.
- Data Analysis: Healthcare providers analyze the data to identify potential health issues.
- Alert System: If abnormal readings are detected, the system can trigger alerts to notify healthcare providers.
- Remote Consultations: Healthcare providers can conduct remote consultations with patients to provide advice and treatment.
- Potential Impact:
- Improved Access to Healthcare: Remote monitoring systems can extend healthcare services to remote areas.
- Enhanced Patient Care: Early detection and timely intervention can lead to better patient outcomes.
- Reduced Healthcare Costs: By reducing the need for frequent hospital visits, these systems can help lower healthcare costs.

- Empowered Patients: Patients can take a more active role in managing their health.
- While remote health monitoring systems hold great potential for improving healthcare in rural Zambia, challenges such as reliable power supply, internet connectivity, and data security need to be addressed to ensure their effective implementation.

IX. Conclusion

Sensor Accuracy and Calibration

Sensors used provided inconsistent or inaccurate readings due to environmental factors or sensor drift. This was mitigated by calibration routines developed to adjust sensor readings periodically or compensate for environmental variations. Use of high-quality sensors and conducting regular calibration checks to enhance accuracy was also employed.

Power Consumption

The system, coupled with sensors and displays, proved to consume a lot of power, thereby, affecting battery life in portable.

This was mitigated by employing power-efficient coding practice which forced the device to enter sleep mode.

Availability of Components

Some of the components to be used were not available on the local market and though available on the international market, it was difficult to get them on time.

Future works

While this study marks a significant step towards a portable and accessible health monitoring system, further research and development are necessary to address the identified limitations and fully harness the potential of this technology for practical healthcare implementations.

Future research in heartbeat and temperature monitoring using AI and Arduino holds significant potential to enhance healthcare, sports, and wellness monitoring. Below are key areas and directions for exploration:

1. Advanced Sensor Integration
- Multi-Modal Sensors: Combine ECG, PPG (Photoplethysmography), and temperature sensors for comprehensive vital sign monitoring.
- Wearable Devices: Develop compact, wearable systems for continuous monitoring, like smartwatches or fitness bands.
- Enhanced Accuracy: Use AI to compensate for noise and artifacts in sensor data caused by movement or external factors.

2. Real-Time Data Processing
- Edge Computing: Implement AI models directly on Arduino or other microcontrollers for real-time processing without relying on cloud services.
- Low-Power AI Models: Develop lightweight AI algorithms optimized for microcontroller platforms.

3. Predictive Health Analytics
- Anomaly Detection: Use machine learning to identify irregular heartbeats, fevers, or early signs of conditions like arrhythmias or infections.
- Trend Analysis: Monitor long-term patterns in heart rate and body temperature to predict chronic health issues.

4. AI-Powered Diagnostics
- Disease Detection: Train AI models to detect conditions like cardiac arrest or hypothermia based on sensor data.
- Personalized Alerts: Develop systems that learn individual baselines and issue warnings when deviations occur.

5. Integration with IoT
- Remote Monitoring: Connect Arduino-based devices to IoT networks for remote patient monitoring.
- Smart Environments: Integrate with smart homes or hospitals to provide context-aware health monitoring.

6. Energy Efficiency
- Power Optimization: Research ways to optimize the power consumption of Arduino-based systems for prolonged use.
- Battery-Free Solutions: Investigate energy harvesting methods, like using body heat or movement to power devices.

7. Data Privacy and Security
- Secure Transmission: Use encryption and secure protocols for transmitting health data.
- On-Device Processing: Minimize data transmission by processing sensitive information locally.

8. Improved Machine Learning Models
- Transfer Learning: Use pre-trained models to enhance AI accuracy on small datasets collected via Arduino.
- Federated Learning: Collaborate across devices to improve AI models without compromising privacy.

9. Customization for Specific Applications
- Athlete Monitoring: Optimize for real-time feedback during intense physical activities.
- Elderly Care: Focus on fall detection and irregular heartbeat monitoring for senior citizens.
- Pandemic Applications: Use temperature monitoring to screen for fever as a symptom of infectious diseases.

10. Open-Source Development

- Encourage open-source projects combining Arduino and AI to democratize access to advanced monitoring technologies.
- Create modular libraries for easy integration of AI models with Arduino.

By focusing on these areas, researchers can create innovative solutions that are affordable, efficient, and capable of transforming personal and clinical health monitoring.

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