A Smart Bed Approach for Personalized Health Management

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***Abstract*—This paper presents a comprehensive study on the design, implementation, and evaluation of a smart bed system aimed at revolutionizing sleep monitoring and optimization for enhanced health outcomes. The proposed system integrates advanced sensors, data analytics, and machine learning algorithms to capture and analyze various physiological and environmental parameters during sleep. The intelligent system employs real-time data processing to provide personalized insights into sleep patterns, identify potential health issues, and optimize sleep conditions for individuals. The research encompasses the development of a robust framework for data collection, secure storage, and efficient analysis, ensuring the privacy and confidentiality of user information. Experimental results demonstrate the effectiveness of the smart bed system in improving sleep quality and contributing to overall health and well-being. The integration of emerging technologies in healthcare and the Internet of Things (IoT) highlights the potential of the proposed solution to address contemporary challenges in sleep monitoring and health management.**

***Index Terms*—Smart Bed,Sleep Monitoring,Health Optimization,Biomedical Signal Processing,IoT Integration,Sensor Fusion,Data Privacy,Real-time Data Processing,MATLAB Simulation,Sleep Quality,Health Management,Digital Health**

I. INTRODUCTION

In recent years, the intersection of healthcare and technology has witnessed transformative advancements, offering innovative solutions to address contemporary health challenges. One such area of exploration is the integration of smart technologies into everyday objects, such as beds, to revolutionize sleep monitoring and health optimization. This paper introduces a groundbreaking research endeavor focused on the development and implementation of an Intelligent Sleep Monitoring and Optimization System, employing a novel smart bed approach for personalized health management.

Sleep, an essential component of overall well-being, plays a pivotal role in maintaining physical and mental health. The conventional understanding of sleep has been significantly enhanced by the advent of advanced sensor technologies, the Internet of Things (IoT), and sophisticated data analytics. Our research responds to the growing need for personalized health solutions by proposing a comprehensive smart bed system capable of monitoring various physiological parameters during sleep. By integrating biomedical signal processing, sensor fusion, and machine learning algorithms, the proposed system aims to provide real-time insights into sleep patterns, identify potential health issues, and optimize sleep conditions tailored to individual needs.

The paper unfolds with an exploration of the key components of the smart bed system, elucidating the intricacies of sensor integration, data privacy considerations, and the utilization of **MATLAB** for simulation purposes. Emphasis is placed on the innovative aspects of the research, including the seamless integration of wearable sensors, intelligent sleep analysis algorithms, and a user-friendly human-computer interface for effective interaction. The convergence of these technologies promises not only to enhance the understanding of sleep dynamics but also to pave the way for a new era of personalized health recommendations.

As we delve into the details of this research, it is evident that the proposed Intelligent Sleep Monitoring and Optimization System has far-reaching implications for healthcare. The integration of emerging technologies in a smart bed system offers a holistic approach to health management, aligning with the principles of precision medicine. This paper serves as a contribution to the broader discourse on the amalgamation of technology and healthcare, showcasing the potential of a smart bed to redefine how we monitor, understand, and optimize sleep for improved health outcomes.

II. LITERATURE REVIEW

A. Smart Bed Innovation

The term ”relax” can be defined as inducing a state of reduced activity, increased calmness, and heightened happiness, resulting in the alleviation of stiffness in certain parts of the body. A pivotal means to achieve heightened relaxation is through sleep or rest on a bed. Notably, Brand et al. [2] underscored that varying levels of sleep depth are recognized individually, influenced by factors such as sleep position and the type of relaxation apparatus employed, be it a chair or a bed.

In recent years, literature has put forth numerous propositions advocating the utilization of smart beds for diverse purposes, introducing a spectrum of sensors and related information. Hart et al. [3] proposed a smart bed employing a contact-free method to monitor respiration by capturing movement patterns. Furthermore, Park et al. [4] recommended the use of smart beds to mitigate stress in healthy individuals by capturing preferred sound, temperature, and light settings, particularly during the waking period.

*1) **Smart Bed for Heartbeat and Movement Detection**:* Sivanantham [6] asserts that a system employing contactless measurement stands out as the most suitable approach for analyzing sleep stage patterns and measuring key body parameters, including heart rate, breathing pattern, and body movement. This method leverages Ballistocardiography (BCG), where the cardio ballistic force applied near the thorax region during the ejection of blood from the left ventricle serves to measure heartbeat. Additionally, the system captures the breathing effect caused by a slightly slower frequency variation in the same thorax region to obtain the respiration signal.

To measure the respiration signal, alternative methods proposed by previous researchers have been integrated. Azimi et al. [7] suggested the application of non-invasive methods, specifically in-bed pressure sensor arrays, for calculating respiratory effort. Furthermore, these in-bed pressure sensor arrays can be effectively employed to interpret crucial signals, such as the respiratory effort of users, in smart home and hospital environments [8].

*2) **Smart Bed for Pressure Ulcer Prevention**:* Pressure ulcers, commonly known as bedsores or pressure sores, are localized injuries that affect the skin and underlying tissue. These wounds typically develop in areas of the body subjected to prolonged pressure, often in individuals who are immobile or have difficulty changing positions. Pressure ulcers can range from mild skin reddening to severe, deep tissue damage, and they pose significant challenges in healthcare settings.

A notable advancement in healthcare technology addresses the prevention of pressure ulcers through the development of a smart bed. Specifically designed to mitigate the risk of pressure ulcers among patients, this innovative solution underwent experimental testing across multiple hospitals. The smart hospital bed aimed to optimize the conventional practice of patient repositioning, a task traditionally carried out by healthcare workers. By automating and enhancing the ”turning” process, the smart bed ensured consistent patient repositioning, simultaneously alleviating the workload for caregivers.

In a related study, Yousefi et al. [5] emphasized the substantial economic and labor-related burdens associated with pressure ulcers. Individuals experiencing pressure ulcers not only endure prolonged hospital stays but also contribute significantly to the labor-intensive nature of healthcare. Recognizing this, the study advocated for the development and implementation of smart beds, particularly for critical pressure ulcers. The rationale behind this technological intervention lies in its potential to reduce both the financial and time costs incurred by patients undergoing medical treatment. In essence, the integration of smart beds emerges as a promising solution to address the multifaceted challenges posed by pressure ulcers, promising improved patient outcomes and more efficient healthcare practices.

Fig. 1. Revolution of Health Monitoring

B. *Health Monitoring*

In the contemporary landscape of healthcare, the integration of advanced technology has given rise to sophisticated health monitoring systems that offer comprehensive insights into an individual’s well-being. Today, health monitoring extends far beyond sporadic check-ups at medical facilities, with the advent of wearable devices, smart sensors, and interconnected platforms revolutionizing the way we track and manage our health(See Fig 1).

Modern health monitoring systems leverage a diverse range of technologies, including wearable fitness trackers, smartwatches, and mobile applications, creating a seamless and continuous flow of health-related data. These systems are designed to monitor various physiological parameters, such as heart rate, physical activity, sleep patterns, and even more specialized metrics like blood glucose levels and oxygen saturation. The real-time nature of these systems provides individuals with immediate feedback on their health status, empowering them to make informed decisions about their lifestyle, fitness routines, and overall wellness.

According to Deen [9], the incorporation of health monitoring systems provides individuals with the option to remain in their homes, avoiding the need to invest significant time and financial resources in frequent visits to healthcare facilities. This innovative approach enables healthcare professionals to remotely supervise patients’ well-being through online systems, offering a cost-effective and streamlined method for onsite clinical monitoring. Central to the effectiveness of these systems are inconspicuous and non-intrusive wearable sensors, functioning as diagnostic tools within healthcare monitoring structures. In practical terms, healthcare practitioners frequently employ these sensors to observe essential physiological indicators in real-time from a distant facility, contributing to the integration of technology into individualized healthcare solutions.

C. *Sensor Development*

The development of sensors for health monitoring has witnessed remarkable advancements in recent years, playing a pivotal role in transforming the landscape of healthcare. From traditional medical devices to modern wearable technologies, sensors have become integral components in capturing and interpreting vital physiological data. This evolution has not only enhanced the accuracy and efficiency of health monitoring but has also facilitated the transition towards personalized and real-time healthcare solutions. The continuous innovation and miniaturization of sensors have led to their integration into various devices, contributing to the seamless monitoring of diverse health parameters. This introduction explores the trajectory of sensor development in health monitoring, highlighting its impact on ushering in a new era of data-driven and patient-centric healthcare practices.

As per Ring and Jones [10], the normal body temperature is dynamic, ranging from 36.2 ℃ to 37.5 ℃, exhibiting variability in both healthy and unhealthy individuals. Temperature extremes are often observed in peripheral tissues such as the skin, influenced by environmental factors and the absence of protective connective tissue. In a study by Kim [11], it was noted that an elevated magnetic field strength and a decrease in heart rate correlate with an increase in body temperature.

Mohrman and Heller [12] elaborate on the heart's fundamental role in propelling blood throughout the body through rhythmic contractions. Additionally, the cardiovascular system (CVS), comprising the heart, arteries, and veins, is crucial for supplying blood to human organs. Al Ghatrif [13] underscores the significance of the electrocardiogram in providing objective insights into the structure and function of the heart. This technological introduction has significantly contributed to a more comprehensive understanding of cardiac dynamics, offering valuable information for both diagnosis and monitoring of cardiovascular health.

III. Methodology

A. *Research Methodology Structure*

In this project, an in-depth examination of the system's functionality and project design was undertaken to achieve the defined objectives. The initiative commenced with the creation of an electrocardiogram (ECG) sensor and a temperature sensor, designed to efficiently capture signals emanating from the human body. Once the signals were successfully detected, the acquired data were transmitted to a micro controller for further processing. The culmination of this data processing was a real-time display facilitated by the **MATLAB** environment, providing a comprehensive and user-friendly visualization of the monitored parameters.

There were some elements used as an important role to ensure the system will operate well as planned. The elements use in the study include Heart Rate Monitor sensor, Body Temperature sensor, structure of the bed, micro controllers, Biomedical Sensor Pad and Electrode Pads. The interconnection between these elements were presented in term of block diagram as shown in Fig 2. In this project, the bed structure played as the foundation to place all the other elements.

For oxygen level monitoring, the **MAX30100 Pulse Oximeter** and **Heart Rate Sensor Module** are recommended due to their integrated pulse oximetry and heart rate monitor capabilities. This sensor, featuring an I2C interface, is compact

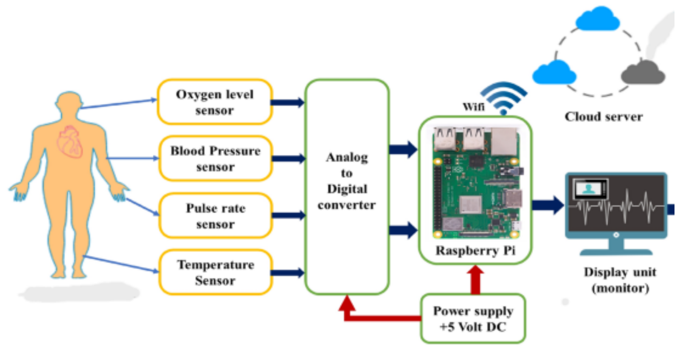

Fig. 2. Block Diagram of the System

and well-suited for wearable applications. To measure blood pressure, the **Freescale Semiconductor MPX5050DP Blood Pressure Sensor** is suggested, offering a differential pressure sensor design with analog output for accurate pressure readings. For heartbeat monitoring, the **AD8232 ECG Measurement Module** is a suitable choice, functioning as a single-lead ECG sensor with adjustable gain for signal amplification. Since pulse rate measurement is the focus, the **Pulse Sensor Amped** is a reliable option, utilizing a **Photoplethysmogram (PPG)** sensor and offering compatibility with microcontrollers like Arduino. Lastly, for temperature monitoring, the **DS18B20 Digital Temperature Sensor** stands out with its digital interface, high accuracy, and a wide temperature range, making it suitable for ambient and body temperature measurements. When selecting these sensors, it's important to consider factors such as accuracy, power consumption, communication interfaces, and compatibility with chosen microcontrollers for seamless integration into the overall smart bed system.We can use **Arduino Mega** and **Uno** as the micro controllers. The heart rate sensor was affixed to the human body through the application of biomedical sensor pads and electrode pads, while the temperature sensor found placement beneath the armpit. The monitoring of the acquired data took place within the **MATLAB** environment.

B. *Project Flow*

Figure 3 illustrates the procedural flow within the project system. The sequence initiates as the user attaches the temperature and heart rate sensors, both connected to electrode pads, onto the body. These sensors capture vital parameters from the human body and transmit the data to microcontrollers for signal processing. Placed proximate to the heart, the electrode pads capture electrical impulses, while the temperature sensor, positioned under the armpit, records body temperature. Subsequently, the Arduino Mega and Uno receive and process signals from the respective sensors. The **MATLAB** software facilitates real-time monitoring by presenting these signals graphically, incorporating coded algorithms to calculate factors aligned with the project objectives, such as heart rate.

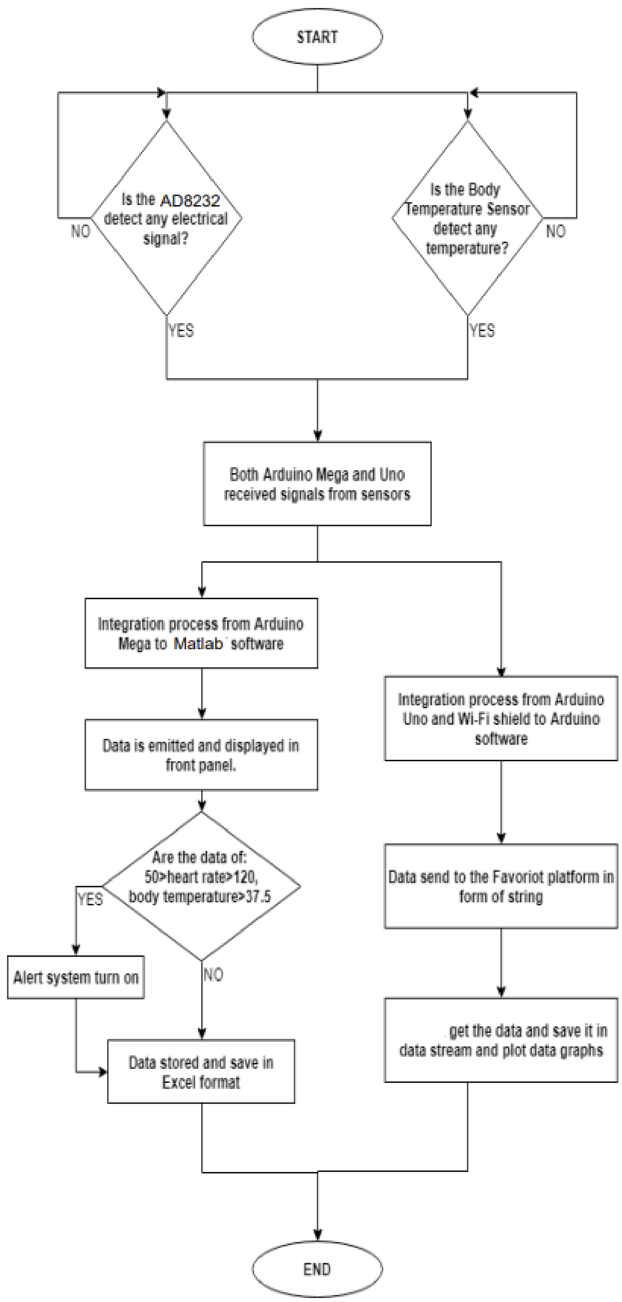

Fig. 3. System Flow Chart

C. System Design

The system design integrates multiple sensors strategically placed on the user's body to capture vital health data. The heart rate sensor, connected with electrode pads, is affixed near the heart to accurately detect electrical impulses, providing real-time insights into the user's cardiac activity. Simultaneously, a temperature sensor is positioned under the armpit to consistently monitor body temperature. These sensors serve as the primary data sources for the health monitoring system.

MATLAB plays a pivotal role in the system design by facilitating seamless data processing and analysis. The signals acquired from the heart rate and temperature sensors are first digitized and preprocessed using **MATLAB** algorithms. For the heart rate sensor, **MATLAB** employs signal processing techniques to filter noise and extract the essential cardiac signal. In order to filter noise, we have designed a filter using **MATLAB** software. Additionally, temperature data undergoes calibration and normalization to ensure accurate readings.

The processed data is then used to derive essential health parameters, such as heart rate and body temperature. **MATLAB's** extensive toolbox for signal processing and data analysis enables the development of algorithms that can identify patterns and anomalies in the acquired data. This capability ensures a robust and accurate interpretation of the user's physiological state. Furthermore, MATLAB enables the creation of a user-friendly graphical interface for real-time monitoring. The processed health parameters are visually presented through plots, charts, and graphs, providing a clear and intuitive representation. **MATLAB's** capabilities in GUI development enhance the user experience, allowing for easy interpretation of health metrics.

In the event of critical health conditions, MATLAB can be programmed to trigger alerts or notifications. For instance, if the heart rate exceeds a predefined threshold, MATLAB can activate a notification system, alerting the user or healthcare professionals. This proactive approach enhances the system's responsiveness to emergency situations.

*1) **Designing a Filter to remove noise in Heart Beat** Signal:* **(This part was done by Kaushalya K.T.S.-210280T)**
The electrocardiogram (ECG) serves as a critical biomedical signal, offering insights into the heart's electrical activity. Traditionally featuring six discernible peaks and valleys denoted as P, Q, R, S, T, and U (illustrated in Figure 4), an ECG captures the electrical impulses originating from the myocardium, providing a comprehensive depiction of the heart's condition. The acquisition of a high-quality ECG signal is imperative for accurate health diagnoses, especially in life-threatening situations. However, real-world scenarios often introduce challenges in the form of prevalent noises, artifacts, and interference, including power line interference (PLI), electrode movement noise, white noise, and muscle artifacts. These unwanted elements necessitate meticulous removal to ensure precise diagnostic outcomes. Among these artifacts, PLI stands out prominently, originating primarily from electromagnetic interference by the power line. In Order to get rid of those unwanted noise we came up with a **Low Pass Filter** design as a solution.The filter was totally designed using **MATLAB** software. The consecutive application of this filter serves to significantly purify the ECG signal, rendering it devoid of artifacts for more accurate diagnostic evaluations.

In this case our team decided to use **Butterworth Approximation** instead of **Chebyshev Type 1 Approximation** in filter design. The main reason for that is it has flat pass band. Since PLI originates from electromagnetic interference generated by the power lines, typically operating at **50 Hz** in Sri Lanka, we have chosen the cutoff frequency of the Low Pass Filter

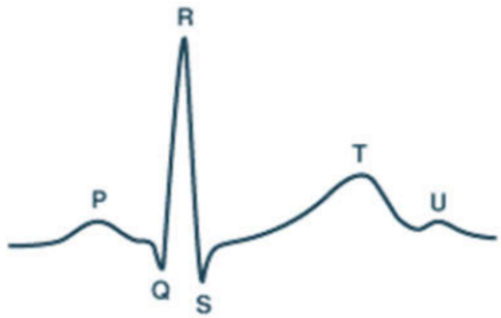

Fig. 4. ECG Signal

as 45 Hz. The frequencies of the heartbeat lie around 0-10 Hz. It is possible to pass the frequencies in the above range and remove unwanted frequencies from PLI by using a Low Pass Filter. Here, we have used a second order Low Pass Filter in our design. In some cases, increasing the filter order beyond a certain point may result in overfitting, where the filter becomes too tailored to the specific characteristics of the noise in the training data. This may compromise the filter's generalization to unseen data. Removing noise in the signal is essential in analysing, synthesizing and making decisions. Figure 5 illustrates the specifications of the designed filter in MATLAB environment. The raw ECG signal is first directed to the filter and the output signal of the filter is then analysed. The designed MATLAB model is shown in figure 6 including the filter.

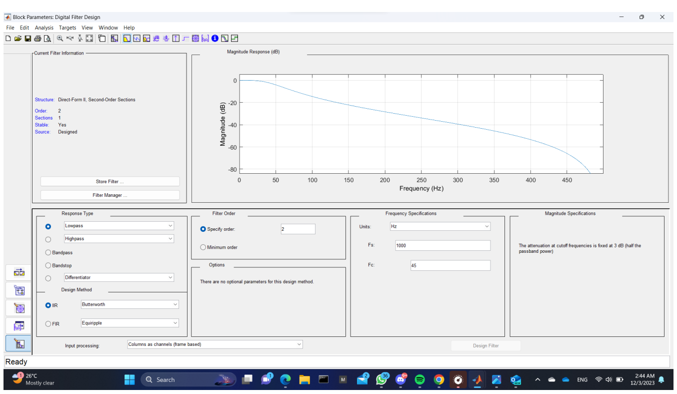

Fig. 5. Specifications of the Filter Design in MATLAB

2) Plotting Live Data of the Temperature Sensor using MATLAB: **(This part was done by Kapiladewa M.N.G.-210271R)**

In the realm of health monitoring, the placement of temperature sensors plays a pivotal role in ensuring accurate and meaningful data collection. Selecting appropriate anatomical locations for these sensors is essential to capture temperature readings that reflect the individual's overall body temperature dynamics. Common locations include the oral cavity, where placing a sensor under the tongue offers a non-invasive method for measuring core body temperature. But in this case we can

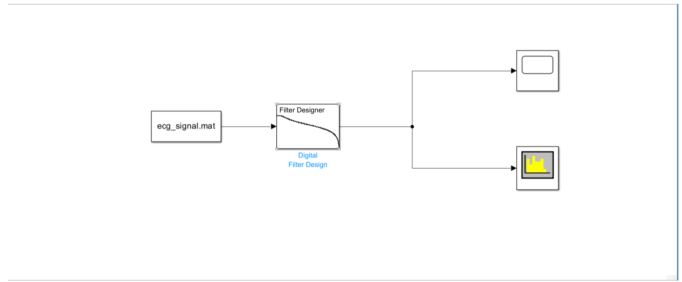

Fig. 6. MATLAB Model

not do that. The axillary region (under the armpit) provides a practical and non-intrusive alternative with slightly longer response times. For scenarios where contactless measurements are preferred, infrared temperature sensors positioned on the forehead or over the temporal artery offer convenient options.

Once the temperature sensors are strategically placed, the acquired data becomes the foundation for insightful analysis. The process involves meticulous calibration of the sensors to ensure precision in temperature readings, accounting for environmental factors and sensor-specific characteristics. Continuous monitoring is then established, capturing temperature readings at regular intervals through either dedicated data acquisition hardware or interfacing with sensors providing analog or digital outputs. Data logging mechanisms are implemented to record temperature data over time, creating a comprehensive dataset for subsequent analysis.

In the analysis phase, **MATLAB** serves as a powerful tool for processing and deriving meaningful insights from the temperature data. Time-series analysis tools enable the examination of temperature trends over specific intervals, facilitating the identification of patterns or fluctuations. Statistical metrics, including mean, standard deviation, and variability, are calculated to quantify the characteristics of the temperature data. These metrics provide a quantitative understanding of the overall temperature dynamics.

Considering all the above scenarios, we have created a script called Temperature Logging and separated it down into sections. To run a section of code and advance to the next one, you can use the run and advance button inside MATLAB Editor. First, we calculated the frequency at which MATLAB can collect the data and then come to see why the data is choppy. So the frequency is about 72 hertz. The data is choppy because the Arduino we are using is an 8-bit device and it only reads values between 0 and 1023 on its analog pins. So when we use these values, we can see that it corresponds to a reading of about 0.5 degrees centigrade and 1 Fahrenheit. That explains a little bit on why the data is so choppy, because even a small change in the voltage value means that there is a significant change in temperature. Figure 7 represents the view of the designed interface in MATLAB. (All the MATLAB functions are attached as a separate zip file.)

Moreover, the analysis can extend to the establishment of threshold values for abnormal temperature ranges. By setting

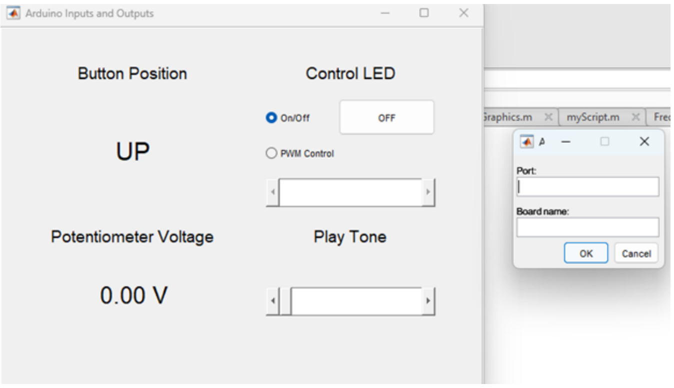

Fig. 7. MATLAB View

thresholds indicative of potential health concerns, alerts or notifications can be implemented in MATLAB to prompt timely interventions. For instance, an elevated temperature above a predefined threshold may trigger an alert advising further medical attention. Integrating these functionalities enhances the capability of health monitoring systems to proactively respond to changes in an individual's temperature, potentially indicating health-related anomalies.

3) SIMULINK and ARDUINO based real time blood Pressure monitoring system: **(This part was done by Kahandawa Arachchi K.A.M.N.-210265D)**

When measuring blood pressure, the smart bed system combines a digital blood pressure sensor, an Arduino microcontroller, and MATLAB Simulink. Together, they work in real-time, bringing a fresh perspective to how we understand and manage blood pressure. This article gives a quick overview of how these components team up, paving the way for more proactive and personalized healthcare. Following are the main components of the designed system.

Digital Blood Pressure Sensor:

The digital blood pressure sensor serves as a crucial component for accurate and continuous monitoring. It detects blood pressure levels and converts them into digital signals. This sensor is instrumental in providing essential data for further analysis.

Arduino Board:

The Arduino board acts as the interface between the digital blood pressure sensor and MATLAB Simulink. Through serial communication, the Arduino board transmits the digital input from the sensor to the MATLAB Simulink environment for real-time processing.

MATLAB Simulink:

MATLAB Simulink serves as the central processing unit, analyzing the incoming data from the digital blood pressure sensor. It employs sophisticated algorithms to detect blood pressure levels and generates real-time graphical representations. Additionally, Simulink controls external devices, such as a buzzer and LED bulb, based on the analysis results.

Following will be the tasks of each components.

Digital Blood Pressure Sensor:

- Detect and measure blood pressure levels.
- Convert analog readings into digital signals for further processing.

Arduino Board:

- Facilitate communication between the sensor and MATLAB Simulink.
- Transmit digital data to MATLAB for analysis.

MATLAB Simulink

- Receive and process digital blood pressure data in real-time.
- Implement algorithms to determine blood pressure levels.
- Generate real-time graphical representations of blood pressure.
- Control external devices (buzzer, LED bulb) based on analysis results.

Fig. 8. Pressure Sensor

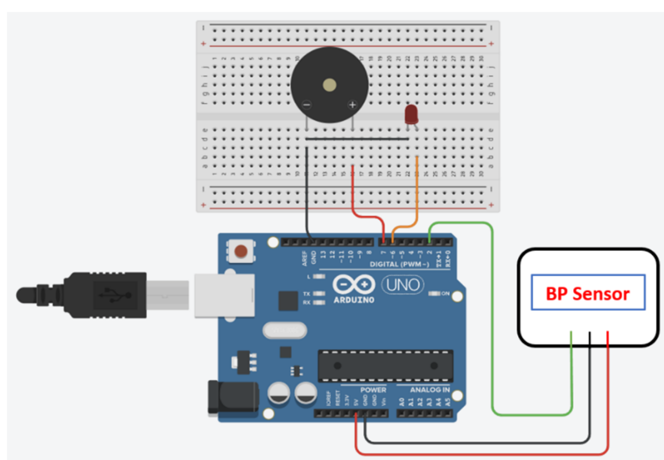

Fig. 9. Arduino Board Setup

MATLAB Simulink receives input data from the Arduino through digital pin 2. This input likely contains the blood pressure data transmitted from the digital blood pressure sensor connected to the Arduino.

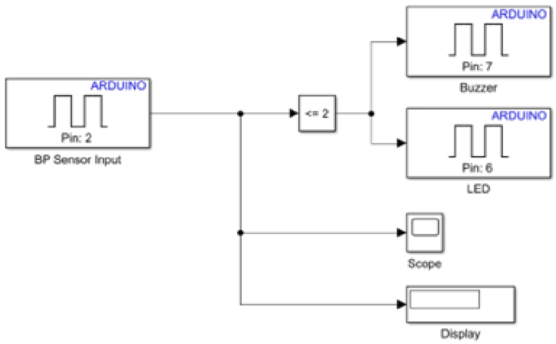

Fig. 10. MATLAB SIMULINK Model

MATLAB Simulink provides output signals to the Arduino, which are then directed to external devices. Specifically, the output for the buzzer is connected to digital pin 7, and the output for the LED bulb is connected to digital pin 6.

The Simulink Scope block graphically displays real-time blood pressure variations, offering crucial insights through a dynamic chart for comprehensive health monitoring.

In the Simulink Display block offers an instant snapshot of the current blood pressure level, simplifying quick assessments without continuous reference to the real-time chart.

The integration of a digital blood pressure sensor, Arduino board, and MATLAB Simulink in a smart bed system demonstrates the feasibility of real-time blood pressure monitoring. The system's ability to detect abnormalities and provide instant alerts enhances its potential for proactive healthcare management.

IV. RESULT AND DISCUSSION

A. *Analyzing Heart Beat Signal*

(This part was done by Kaushalya K.T.S.-210280T)

For analyzing purposes we have used a sample ECG signal. First of all we need to ensure that the ECG signal data is available in a format that MATLAB can read. Common file formats for ECG data include .txt, .csv, or standard biomedical formats like .edf or .mat. Here the data was converted to .txt format in Excel file. Figure 11 illustrates the plot of the data in the noisy signal and the figure 12 shows the frequency spectrum of the noisy signal. Frequency spectrum can be generated using **Spectrum Analyser** in MATLAB software.Frequency component that is responsible for the noise can be clearly seen as a spike in Spectrum as shown in figure 12.

Then we sent the signal through the designed Digital Low Pass Filter. The plot and the frequency spectrum of the filtered signal are shown in Figure 13 and Figure 14 respectively. By comparing the plots of the original noisy signal and the filtered signal it can be clearly seen that the noise is totally removed. The spike of the PLI component was totally removed as shown in Figure 14 in the frequency

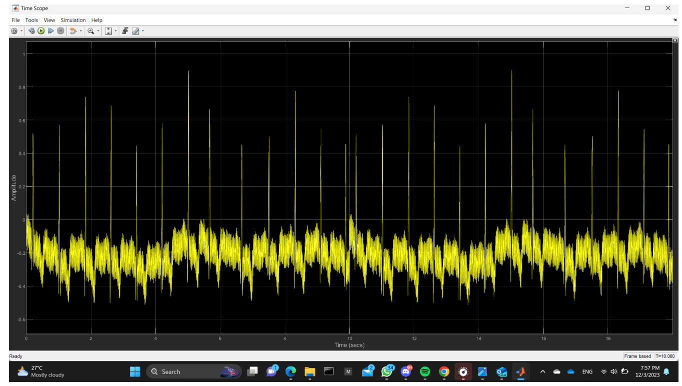

Fig. 11. Noisy ECG Signal with PLI component

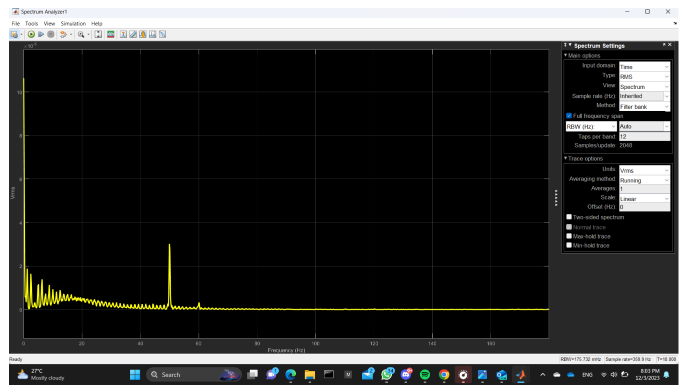

Fig. 12. Frequency Spectrum of the noisy Signal

spectrum. After that the signal can be analyzed properly to make decisions.If the heart rate is significantly above or below the normal range, we set an alert for medical evaluation.It can be done using a simple MATLAB code.

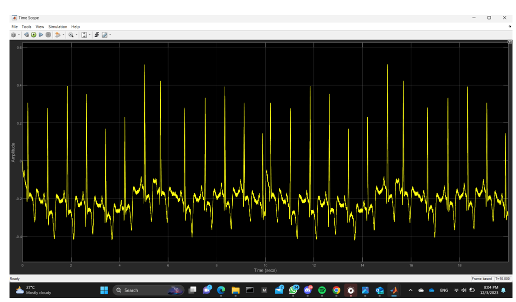

Fig. 13. Filtered Heart Beat Signal

Alerts and notifications in the context of analyzing heart rate in a smart bed play a crucial role in keeping users informed about their health status and potential issues during sleep. We can define specific heart rate thresholds that, when exceeded, trigger an alert. These thresholds can be personalized based on the individual's age, fitness level, and health conditions. For example, a sudden increase or decrease in

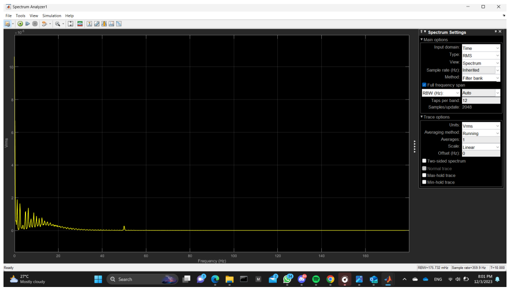

Fig. 14. Frequency Spectrum of the Filtered Signal

heart rate beyond a certain limit could indicate a potential health concern. Furthermore we can implement algorithms to detect irregular heart rate patterns, such as arrhythmias or other anomalies. If the smart bed identifies unusual heart rate variations, it can generate an alert to notify the user or their designated contacts.It is possible to allow users to customize alert preferences based on their comfort level and the severity of the situation. Some users may prefer to receive notifications only for significant deviations from the norm, while others may want alerts for any noticeable change in heart rate.If the user wears a smartwatch or fitness tracker, consider integrating the smart bed's heart rate data with these devices. This can enhance the overall monitoring experience and ensure that users receive alerts on devices they regularly check.

B. Analyzing Body Temperature

(This part was done by Kapiladewa M.N.G.-210271R)

For testing purposes we have analyzed the temperature in a room besides analyzing body temperature.we saw that the temperature is directly proportional to the voltage output that it gives. This is the equation. When we executed the section, we could see what the temperature reading was in the room, both in Celsius and Fahrenheit. We created a script called Temperature Logging and broken it down into sections. To run a section of code and advance to the next one, you can use the run and advance button inside MATLAB Editor. we have a snapshot from the data sheet of the sensor. we could see that the temperature is directly proportional to the voltage output that it gives. When we executed the section, we could see what the temperature reading is in this room, both in Celsius and Fahrenheit. See Figure 15.

We used the same equation to collect data for a specified period of time using tic and toc. We can see that it takes a long time to collect this data. This is because MATLAB sends a serial command to the device and receives a response every time to acquire a new data point. This is causing a bottleneck, which determines the fastest speed at which we can acquire data. We could also see that the data is pretty choppy. First, we calculated the frequency at which MATLAB can collect the data and then came to see why the data is choppy. So the frequency was about 72 hertz. See Figure 16.

- The data is choppy because the Arduino we are using is an 8-bit device and it only reads values between 0 and 1023 on its analog pins. And remember, the voltage range was 0 to 5. So when we use these values, we can see that it corresponds to a reading of about 0.5 degrees centigrade and 1 Fahrenheit.
- That explains a little bit on why the data is so choppy, because even a small change in the voltage value means that there is a significant change in temperature.
- Oftentimes, it is helpful to observe the data values as they are being collected. And during this, touching the temperature sensor with finger to see how the measured value changes and if we can influence the temperature.
- So the function being used is animated line, which makes it easy to stream new data to a plot. The other useful feature of this function is that the data is automatically stored in the plot and we don't have to log it. We have set up the script so when we push the button, it stops collecting data.
- Let us take a look at the data that we collected. This data definitely needs some post-processing. The high-frequency noise in the temperature signal can be removed by applying a moving average filter. we know that the temperature sensor has a tolerance of about 2 degrees

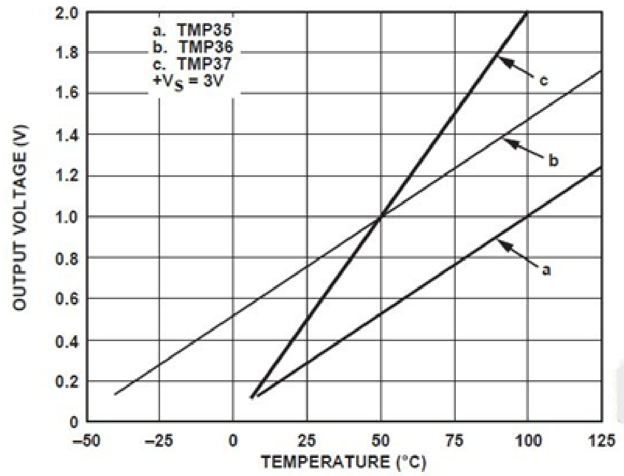

Fig. 15. Output Voltage vs Temperature

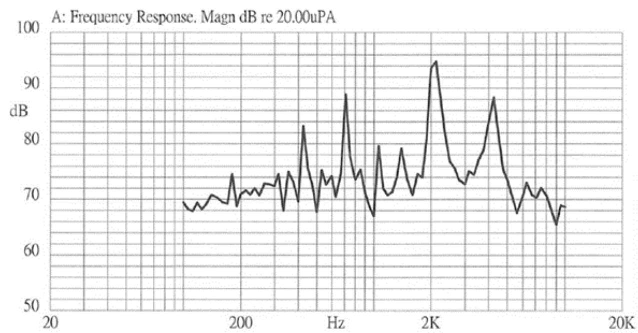

Fig. 16. Frequency Response

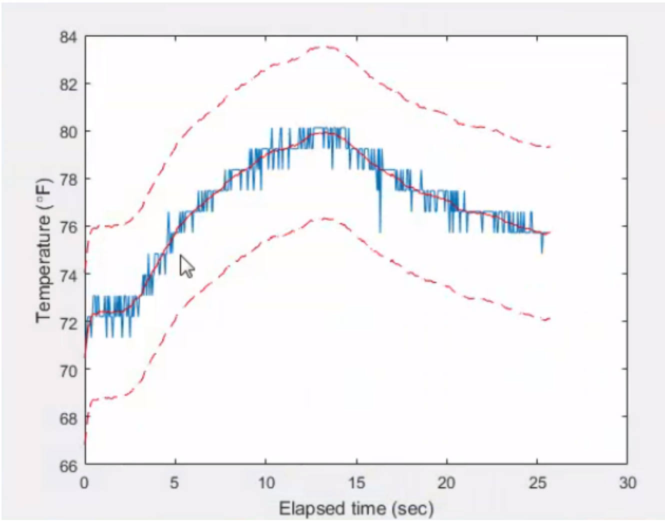

Fig. 17. Collected Data

centigrade at room temperature.

So using this information, we have calculated the largest and smallest possible value and plotted both the collected and the process data.

The continuous line shown in Figure 17 is the filtered data. And the temperature sensor tolerance is represented using the dotted lines in this figure. Now that we have done all the analysis and can see the data, we might want to save the data that we collected to a file. One way to do this is to store the data in a table and then write the table itself to a file. You can see that the file has all the necessary information and the collected data itself.

C. *Analyzing Blood Pressure*

(This part was done by Kahandawa Arachchi K.A.M.N.-210265D)

In this section, we examine the harmonious integration of a blood pressure sensor, Arduino, and MATLAB for precise measurement. From data acquisition to real-time analysis, we offer a brief overview of results and simulations in contemporary healthcare applications.Figure 18 shows an illustrative example of potential output data for the blood pressure measurement system discussed in the above section.

Systolic Blood Pressure (SBP):

- SBP is the higher of the two numbers in a blood pressure reading and represents the pressure in the arteries when the heart beats or contracts.It is measured in millimeters of mercury (mmHg).

Diastolic Blood Pressure (DBP):

- DBP is the lower of the two numbers in a blood pressure reading and signifies the pressure in the arteries when the heart is at rest between beats. It is also measured in millimeters of mercury (mmHg).

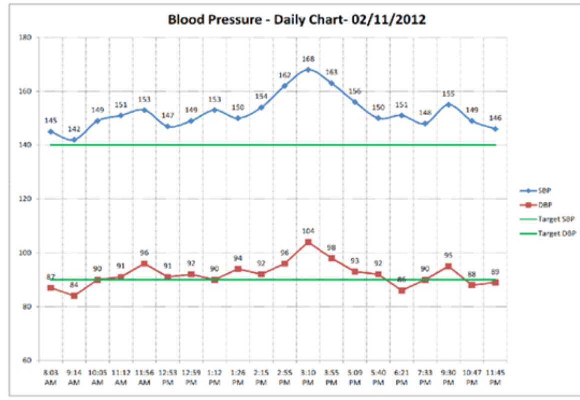

Fig. 18. Collected Data

Blood Pressure Ranges:

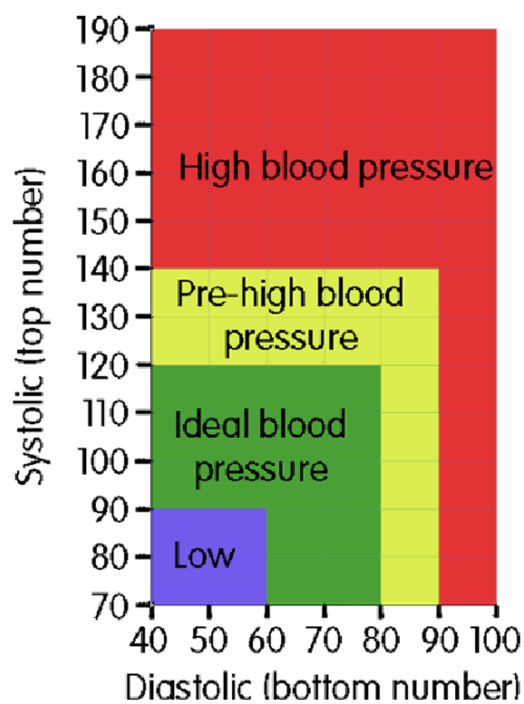

Fig. 19. Blood Pressure Ranges

1.High Blood Pressure (Hypertension):

- Reading: 140/90 mmHg or over
- High pressure in the arteries, a risk factor for heart disease and stroke. Lifestyle changes and medications may be recommended.

2.Pre-High Blood Pressure:

- Reading: 120/80 mmHg up to 140/90 mmHg

- Warning stage before hypertension. Encourages lifestyle changes to prevent progression.

3.Ideal Blood Pressure:

- Reading: 90/60 mmHg up to 120/80 mmHg
- Healthy blood pressure range associated with lower cardiovascular risk.

4.Low Blood Pressure (Hypotension):

- Reading: 90/60 mmHg or lower
- Lower than normal pressure; may cause dizziness or fainting. Treatment depends on underlying causes.

V. Conclusion

In conclusion, the integration of temperature sensors in health monitoring systems is a crucial component for obtaining valuable insights into an individual's well-being. By strategically placing sensors in anatomically significant locations, such as the oral cavity, axillary region, forehead, or ear canal, we can capture accurate and representative temperature readings. The chosen locations offer diverse options based on considerations of invasiveness, response time, and contact preferences.The process of data acquisition involves meticulous sensor calibration and continuous monitoring, with data logging mechanisms ensuring the creation of comprehensive datasets. MATLAB proves to be an indispensable tool for the subsequent analysis of temperature data. Through time-series analysis and statistical metrics calculation, we can discern temperature trends and quantify the characteristics of the data, providing a nuanced understanding of an individual's temperature dynamics. Furthermore, the implementation of threshold values and alerts within MATLAB enhances the health monitoring system's proactive capabilities. By setting thresholds indicative of abnormal temperature ranges, the system can prompt timely interventions when deviations from the norm are detected. This functionality adds a layer of responsiveness, aiding in the early detection of potential health concerns and facilitating prompt medical attention. As we navigate the evolving landscape of health monitoring technologies, the thoughtful placement of temperature sensors and the sophisticated analysis facilitated by MATLAB contribute significantly to the development of systems capable of providing real-time, actionable insights into an individual's health. The continuous refinement of these technologies holds great promise for improving healthcare outcomes, fostering preventive measures, and ultimately enhancing the overall well-being of individuals under monitoring.

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