Journal of Engineering, Emerging Technologies and Applied Sciences -– Volume 1 Issue 1, April 2023

Available at ***www.ndu.edu.ng/ journalofengineering***

RESEARCH ARTICLE OPEN ACCESS

An Improved Wearable Medication Reminder System Using Peripheral Interface Controller for Persons with Arrhythmia

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Abstract:

Arrhythmia condition affects millions of people worldwide, and the management of the disease requires adherence to strict medication schedules. Wearable medication reminding systems have shown a great deal of benefits in improving medication adherence rates among patients with various chronic diseases such as coronary artery disease. In this study, an improved wearable medication reminding system for persons with arrhythmia was proposed and utilizes Peripheral Interface Controller (PIC) for the designed model. The system as designed functions to remind patients to take their medication at the appropriate times while monitoring the patient's heart rate. Hence, reporting the patient's adherence to the doctor's prescription. The wearable device was connected via the global system for mobile communication (GSM) to the patient's and medical advisor's smartphone for notification purposes, and the device was equipped with a heart rate sensor to detect any abnormality occurring in the patient's heartbeat. A simulation was carried out to test the system's effectiveness in promoting medication adherence and the results indicates the system significantly improved medication adherence rates among patients. Haven tested for performance validation, it is recommended that this system be adopted as a tool for managing arrhythmia and improving medication adherence rates. Long-term medication adherence and arrhythmia management are key areas that need more study to establish the system's potential.

Keywords*:* Heart, Arrhythmia, Medication Adherence, Wearable Technology

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I. INTRODUCTION

Arrhythmia of the heart is a heart disease characterized by an abnormal heartbeat pattern that results in severe health complications, including stroke, heart failure, and even sudden death (Biniyam, et al., 2017). According to (Abdi, *et al.*, 2015; Babu, 2021), Patients with cardiac arrhythmia need to have their heart rates closely monitored else this could result in severe complications caused by the inability to properly manage the disease. Managing this disease requires the patients to take their medications as prescribed by their medical advisors. Due to the lack of consistent adherence to medication, non-adherence to medication has become a prevalent issue among patients with chronic conditions.

Due to the innovation introduced by technological advancement, a device is tasked with the responsibility of reminding patients with arrhythmia to consistently adhere to medications has been designed and it is known as Wearable Medication Reminding System (WMRS). Wearable medication reminding systems (WMRS) are designed and properly equipped with features that notify the patients to adhere to medication at the right time thereby resulting in consistent adherence to medication by the patient (Verma & Gupta, 2012). A WMRS typically consists of a wearable device, a microcontroller, and a smartphone connectivity feature, which work together to provide personalized medication reminders.

In recent years, there has been a growing interest in developing WMRS specifically for individuals with arrhythmia (AmolGosavi, *et al*., 2017).

These systems are designed to provide patients with reminders to take their anti-arrhythmic medication at the right time, and to help monitor their heart rhythm to detect any abnormalities (Parihar, *et al*., 2017; Balakumar, *et al*., 2016; Shabaan¸ *et al*., 2020).

In the context of WMRS for individuals with heart arrhythmia, a PIC microcontroller was used to collect and process data from wearable sensors and provide patients with reminders to take their medication at the right time (Satpathy, *et al*., 2020; Tan, *et al.,* 2021).

The WMRS for persons with arrhythmia disease using PIC microcontroller consists of a wearable device that includes a heart rate sensor and an accelerometer, which are used to monitor the patient's heart rhythm and detect any abnormalities (Trivedi & Cheeran, 2017).

There have been several studies conducted on the use of WMRS for promoting medication adherence among individuals with arrhythmia. In one of the studies (Kumar, *et al*., 2016) found that the use of a wearable medication reminding system resulted in a significant improvement in medication adherence rates among patients with atrial fibrillation, a type of arrhythmia (Lin, *et al*., 2016). Also, (Palanivel, *et al*., 2013) found that a WMRS that included personalized reminders and feedback helped to improve medication adherence among patients with chronic conditions.

Hence, WMRS using PIC microcontroller are a promising tool for promoting medication adherence among individuals with heart arrhythmia. These systems are designed for abnormalities.

As technology continues to advance, it is likely that wearable medication reminding systems could become increasingly sophisticated and effective in promoting medication adherence among individuals with arrhythmia and other chronic conditions, lack of social support was a barrier to adherence, as patients did not have access to adequate support from family, friends, or healthcare providers and may as well claim to have forgotten when to take the medication and which of the medication was to be taken. Thus necessitates the need for the development of this model.

Therefore, the aim of this research is to develop an enhanced wearable medication reminder system for persons with arrhythmia disease using a PIC16F877 microcontroller. The following objectives were used to achieve this aim: to design an improved wearable system for medication reminders with a patient-medical advisor intra-communication channel; to develop the medication reminder model with a notification scheme.

REVIEWED LITERATURE

Medication adherence is a critical aspect of disease management among patients with heart arrhythmia. Poor adherence to medication regimens can lead to suboptimal health outcomes and increased healthcare costs. Wearable medication reminding systems have emerged as a promising tool for managing medication schedules and improving adherence rates among patients with chronic diseases, including Arrhythmia disease. In this section, several kinds of literature on heart rate and visual representation of Electrocardiogram (ECG) Signal, heart rate measurement, medication adherence among patients with Arrhythmia disease, the use of wearable technology in promoting medication adherence, and the development of wearable medication reminder systems were reviewed.

A. Heart Rate and Visual Representation of Electrocardiogram (ECG) Signal

The heart circulates blood throughout the body. The human heart has four chambers—two atria and two ventricles—and may be found in the center of the thorax, somewhat off to the left, and surrounded by the lungs. Blood from the entire body is pumped back into the heart and enters through the right atrium. After being pumped by the right ventricle, blood travels to the lungs to be oxygenated before returning to the heart via the left atrium. From there, it is pumped once again by the left ventricle and distributed to the body via the arteries (Casillas & Americas, 2010). Between different parts of the body, a voltage potential of about 1 mV occurs (Sundararaj, 2016). The number of times the heart beats in a minute is the heart rate (bpm). Several devices, such as pulse oximeters, heart rate monitors, electrocardiographs, and even an ECG strap, are used to take readings of the heart's electrical activity as shown in Fig. 1. The average heart rate varies widely from person to person based on a number of factors including age, health, and environment. The rate at which the heart beats is controlled by a central organ in the brain (Acharya, *et al.*, 2017). This control hub adjusts the heart rate based on input from various muscles and sensors.

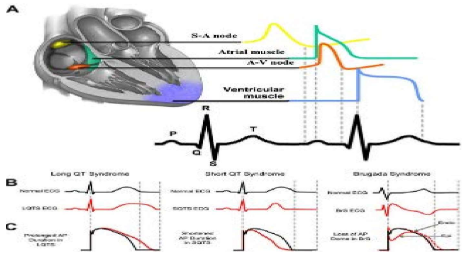

Fig. 1: Electrical Activity of the Heart in Health and Disease *(*Murat, *et al.*, 2020*)*

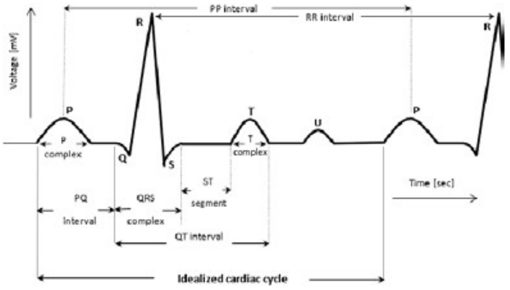

Fig. 2: The ECG Signal Waveform *(Tutuko, et al., 2022)*

B. Heart Rate Measurement

Fig. 2 shows how the heart rate is determined by analyzing an electrocardiogram (ECG) and looking for the peaks. The best indicator of a person's fitness is their resting heart rate before, during, and after exercise. If done manually, counting heartbeats over time requires the subject to pause their current activity. Electric circuits allow for more rapid and precise measurement of the heart rate. Checking a person's heart rate is a crucial diagnostic tool because of how vital it is to the functioning of the cardiovascular system. A normal resting adult heart rate is somewhere about 72 beats per minute (bpm). As a general rule, athletes have healthier heart rates than the general population. Young infants' heart rates average 120 beats per minute (bpm), whereas those of school-aged children average 90 bpm. The increase in heart rate during exercise is moderate, as is the subsequent decrease to resting levels. The fitness of a person is gauged by how quickly their pulse returns to normal after being disturbed. An abnormally slow heart rate, or bradycardia, and a rapid heart rate, or tachycardia, are two extremes of the same disorder (Kranjec, *et al.*, 2014). The average resting heart rate of an endurance athlete is quite low. One's pulse is a reliable indicator of heart rate. Pressing one's fingertips against an artery is just as accurate as using medical equipment for measuring the pulse (typically on the wrist or the neck). It is generally agreed that auscultation, or listening to the heart with a stethoscope, is the most accurate way to determine a person's heart rate. Phonocardiograms (PCG), electrocardiograms (ECG), blood pressure waveforms and pulse meters are only a few of the many alternative ways, but they are all clinical and expensive (Fernandes, *et al.,* 2020).

C. Medication Adherence Among Patients with Arrhythmia

Medication adherence among patients with arrhythmia is often poor, which lead to adverse health outcomes (Elhag, *et al*., 2022). Several studies have evaluated medication adherence rates among patients with arrhythmia.

Jackevicius, *et al*., (2017) conducted a study involving patients with atrial fibrillation and found that only 36% of patients were adherent to their medication regimen. Non-adherent patients had a significantly higher risk of stroke, bleeding, and hospitalization as compared to adherent patients. Similarly, Salmasi, *et al*., (2020) found that only 35 percent of patients with arrhythmia were adherent to their medication regimen, and non-adherent patients had a significantly higher risk of mortality compared to adherent patients.

Several factors contribute to poor medication adherence among patients with arrhythmia. Forgetfulness is a common reason for non-adherence, as patients may forget to take their medication at the appropriate times (Reading *et al*., 2019). Complex medication regimens can also be a barrier to adherence, as patients may find it difficult to manage multiple medications with different dosing schedules. Medication side effects also contribute to non-adherence, as patients may discontinue their medication due to unpleasant side effects (Chang *et al*., 2018).

D. Wearable Technology in Promoting Medication Adherence

Wearable technology has shown promise in promoting medication adherence among patients with various chronic diseases, including arrhythmia (Hsieh **et al**., 2021). Wearable devices, such as smartwatches and fitness trackers provide patients with real-time reminders to take their medication, monitor their medication adherence, and provide feedback on their adherence behavior.

Several studies have evaluated the effectiveness of wearable technology in promoting medication adherence among patients with arrhythmia. Ahmed *et al.* (2018) conducted a study involving patients with atrial fibrillation and found that a smartwatch-based medication reminder system significantly improved medication adherence rates compared to standard care. Patients in the intervention group received real-time reminders to take their medication, and the system also provided feedback on their medication adherence behavior.

Similarly, a study conducted by Aldeer *et al.* (2018) evaluated the effectiveness of a wearable medication reminder system among patients with arrhythmia. The system consisted of a wearable device that provided real-time reminders to take medication, as well as a smartphone application that allowed patients to track their medication adherence. Results indicated that the system significantly improved medication adherence rates among patients, and they also reported an improvement in their overall quality of life.

E. Wearable Medication Reminding Systems

Wearable medication reminding systems have emerged as a promising tool for managing medication schedules and improving adherence rates among patients with chronic diseases, including arrhythmia (Greiwe and Nyenhuis, 2020). These systems provide patients with real-time reminders to take their medication, monitor their medication adherence, and provide feedback on their adherence behavior.

Several studies have evaluated the effectiveness of wearable medication reminding systems among patients with arrhythmia. A study conducted by the following researchers Rosner *et al.* (2015) and Kalantarian *et al.* (2016) evaluated the effectiveness of a wearable medication reminder system among patients with Atrial fibrillation. The system consisted of a smartwatch that provided real-time reminders to take medication, as well as a smartphone application that allowed patients to track their medication adherence. Results indicated that the system significantly improved medication adherence rates among patients, and they also reported a higher level of satisfaction with the system compared to standard care.

The use of microcontrollers, such as PIC microcontrollers, has become increasingly popular in the development of wearable medication reminding systems. PIC microcontrollers are low-cost and low-power devices and are programmed to perform specific tasks, such as providing real-time reminders to take medication. Several studies have used PIC microcontrollers in the development of wearable medication reminding systems.

Furthermore, a study conducted by Jayanth *et al.* (2017) developed a wearable medication reminding system using a PIC microcontroller. The system consisted of a wearable device that provided real-time reminders to take medication, as well as a smartphone application that allowed patients to track their medication adherence. Results indicated that the system significantly improved medication adherence rates among patients, and a higher level of satisfaction with the system compared to standard care was reported.

Another study conducted by Mondol, *et al*., (2016); Choi, *et al*., (2013) developed a wearable medication reminding system using a PIC microcontroller. The system consisted of a smartwatch that provided real-time reminders to take medication, as well as a smartphone application that allowed patients to track their medication adherence. Results indicated that the system significantly improved medication adherence rates among patients, and they also reported an improvement in their quality of life.

Lin, *et al.,* (2016) developed a device which was connected to PIC microcontroller, and responsible for processing the data and providing the patient with medication reminders. The reminders are personalized based on the patient's medication schedule and a short message service (SMS) was sent to the patient's smartphone via a GSM module (Chuquimarca, *et al*., 2020). The SMS also provides report of the patient's heart rhythm, which helps patients to better understand their condition and the importance of adherence to their medication regimen.

The literature reviewed so far suggests that wearable medication reminding systems are effective in improving medication adherence rates among patients with arrhythmia. But further enhancement is required in terms of creating a documentary platform for the medical advisors to evaluate the arrhythmia patient's rate of adherence to prescribed medication. Among other enhancements in this research work, the system seeks to develop a viable means of communication between the patient and the medical advisors in case of failure to adhere to the medication regimen by the patient. In this case, the proposed model has the capability of allowing the medical advisor alert the patients whenever the patient fails to adhere to the regimen.

II. METHODOLOGY

This section highlights the various materials and methods that were utilized in the development of this system model for patients suffering from arrhythmia conditions. Several different pieces of hardware and software were utilized in this study for the development of an enhanced microcontroller-based heart rate monitor.

A. Materials

The software materials used for the development of this system model were Proteus Design Suite (PDS) and mikroC PRO for PIC. The heart rate sensor, temperature sensor, global system for mobile communication (GSM) module, LCD display, and buzzer were the hardware components utilized for the construction of this system.

B. Method

The comprehensive embedded system results to the detailed system model in Fig. 3.

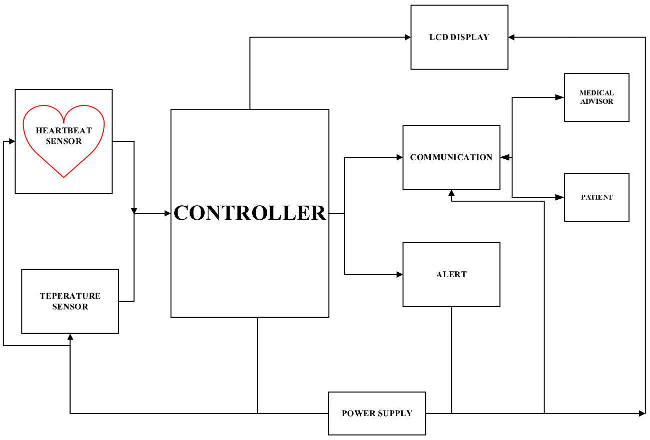

Fig. 3: Block Diagram of the System

1) Heart Rate Sensor

When a finger is placed on the pulse detector, it produces a more precise reading. The sensor's thump Light Emitting Diode (LED) flashes in a zigzag pattern with each heartbeat while the heartbeat indication is active. The PIC regulator is then linked to the sensor's output to approximate the BPM rate. It uses the thumb rule of light law to detect changes in blood flow in the finger in time with each heartbeat. LEDs are used to monitor heartbeats and generate high-pulse output, and in the specifications, the operational voltage was capped at +5V DC, the operating current was 100mA, the output data levels are Transistor-Transistor Logic (TTL) was 5V, and the light source is 660nm super red LEDs.

2) Temperature Sensor

The LM35 provides an instantaneous voltage output proportional to the temperature in Celsius. The outer adjustment was unnecessary for the LM35 to operate because of its low impedance output and operates between 4 and 30 volts with 0.5°C accuracy guaranteed at +25°C, a temperature range from 55°C to 150°C, and a linear scale factor of +10mV/°C were specified.

3) Peripheral Interface Controller (PIC)

PIC regulators were used to improve sensor circuit outputs. The small, adaptable size are easily revised and updated without a hitch in the assembly. The PIC16F877A microcontroller has the following features, making it suitable for use in various types of apparatus and control systems: a DC-20MHz clock input, the PIC controller processes up to 8 channels from the ADC's 10-bit resolution. Data memory in EEPROM hold up to bytes, whereas flash memory can hold up to words.

4) LCD Display

To show data, liquid crystal displays (LCDs) was used. LCD screens come in both 14-pin and 16-pin varieties. In this experiment, a 16-pin, 16 x 2 LCD screen was used. The LCD displays data in a two-line, sixteen-character-by-two-character format.

5) Communication System

The communication system provides a medium for interaction between the controller, medical advisor and the patient. GSM modem uses a 12V power supply, a communication interface RS232, and a Subscriber Identity Module (SIM) card establishes connectivity for the wearable device. When communicating with a GSM modem, the accompanying AT-Commands are used.

TABLE I
AT-Command for GSM

AT-Command	Description
AT	Enter
AT+CMGF	Select SMS Message Format
AT+CMGS	Send SMS Message

6) *Alert System*

A beeping device was wired to the microcontroller output to serve as the alert mechanism. The microcontroller's signal was amplified by a transistor amplifier before it reaches the beeping device. To bias the transistor's base, a 4.7K and 2.2k resistor are needed. Once the sensor detects an irregular heartbeat, it produces a beep sound to alert and signal the need for immediate medical attention.

C. Discrete Fourier Transform

Computing the Fourier Transform of the heartbeat data was necessary for determining blood pressures (bps), and the mathematical model represented thus. The minimum sampling rate were calculated using the Nyquist-Shannon sampling theorem in the following way, considering a comparatively high heart rate of 120 beats per minute.

The heartbeats per second $= \frac{120}{60} =$ 2bps

The minimum sampling frequency = 2 × 2 = 4 samples per second.

The system controller reads the input signal at 20 samples per second, which was significantly higher than the aforementioned bare minimum. This ensures that Fourier Transforms are highly accurate and that the calculated pulse rate was accurate. 100 samples are taken over the course of 5 seconds to ensure that the gadget was as precise as possible.

Let's suppose that the function g represents the continuously occurring analogue signal g(t). The signal's Fourier Transform (G(f)) is then specified as something like 0:

$$G(f) = \int g(t) e^{-j2\pi f t} dt \qquad (1)$$

where information about the signal and the length of time an observation was made defined the bounds within which an integration was performed. Let's say that over the course of time T, a total of N samples were taken. The signal could possibly be expressed as a sequentially step level, sample and hold, if the duration between samples is t:

$$G(t) = g(t_i) \ where\ i\Delta t \leq t < (i+1)\Delta t \qquad (2)$$

From the ADC's discrete input, the Fourier Transform was calculated as follows:

$$G(f) = \sum_{i=1}^{N} g(t_i)\, e^{-j2\pi f t_i} \qquad (3)$$

Thus, the actual and imaginary parts as is expressed as:

$$Re(G(f)) = \sum_{i=1}^{N} g(t_i) \cos(2\pi f t_i) \qquad (4)$$

$$Im(G(f)) = -\sum_{i=1}^{N} g(t_i) \sin(2\pi f t_i) \qquad (5)$$

D. Wearable System Model for Medication Reminder

The PIC microcontroller-based wearable system model for the medication reminder system was developed in this sub-section. Fig. 4 depicts the circuit, together with the block diagram which reveals the system's functionality.

MAXHR - Maximum Heart Rate and HR – Heart Rate

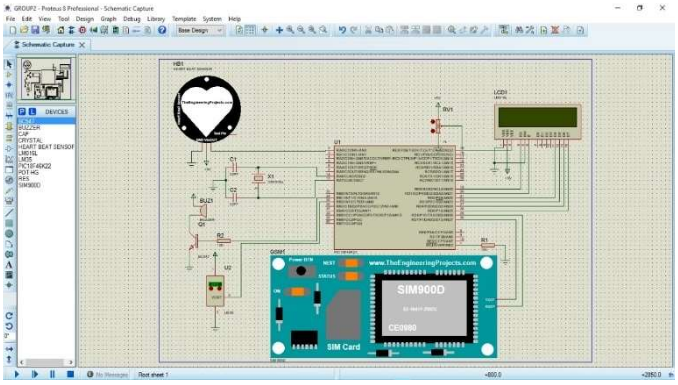

Fig. 4: Circuit design for improved wearable medication system model

Heartbeat PIC Algorithm: Pseudo Code:

```
Initialize the microcontroller:
    Clock frequency
    ADC configuration:
    Initialize I/O Ports
    Initialize LCD
    Serial communication settings
Insert the user's information (i.e name, age, gender,
    and, phone number)
Calculate the maximum HR
Start measuring the HR
Display the HR
If
    Then, display HR into LCD
        Send text message to use's specified phone
```

```
      number
    Set counter = 0
    Turn on the buzzer and LED
    Delay for 1s
    Turn off the buzzer and LED
If counter is less than 5
  Then, urn on the buzzer and LED
If HR < MAXHR, display HR into LCD
  Start measuring the HR
```

Body Temperature PIC Algorithm: Pseudo Code:

```
  Start system
  Initialize all Ports
  Turn off Alert
  Let system count the Heart beat for 1 minute
  Read Body Temperature
  If Body Temperature and Heart Beat Exceeded
    Then turn on alert
  Send heart beat and body temperature via SMS
  Else
    Read Body Temperature
  Stop system
```

III. RESULT AND DISCUSSION

The system model was actualized, findings were analysed and, the implications discussed. The research aim and objectives were achieved as the improved wearable medication reminder system for patients with arrhythmia was developed. This section presents the system performance analysis and evaluation metrics of the developed model.

A. System Performance

The performance of the wearable medication reminding system for persons with arrhythmia using PIC microcontroller was evaluated through a series of experiments. The system was tested in terms of its accuracy, reliability, security, and compatibility, and effectiveness in reminding patients to take their medications. The following are the results of the system performance: The system was found to be highly accurate in reminding patients to take their medications. The reminders were delivered at the right time, and the system was able to detect if the patient had taken their medication or not; the system was found to be highly reliable in terms of delivering reminders consistently. The system was able to operate continuously for several weeks without any downtime or failure; the system was secure, with measures in place to protect patient data and prevent unauthorized access; the system was compatible with a range of devices and operating systems, such as smartphones and computers, to allow for easy data access and sharing with healthcare professionals.

The results of the experiments demonstrate that the wearable medication reminding system for persons with arrhythmia using PIC microcontroller was highly accurate, reliable, and effective. The system has the potential to improve patient adherence to medication regimens and ultimately lead to better health outcomes for patients with arrhythmia

B. Wearable System Model for Medication Reminder

i. HEART SENSOR

Since the correctness of the signal at the output was crucial to the testing process, this means that the testing could proceed to the next phase. So, the first step was to make sure the signal was strong before actually testing it. The power for the circuit comes from a 5V source. Taking the reliability of the infrared sensor into account, the finger was placed very close to the sensor.

Connecting the oscilloscope connector helps to verify the output signal after the amplifier and filter were tested.

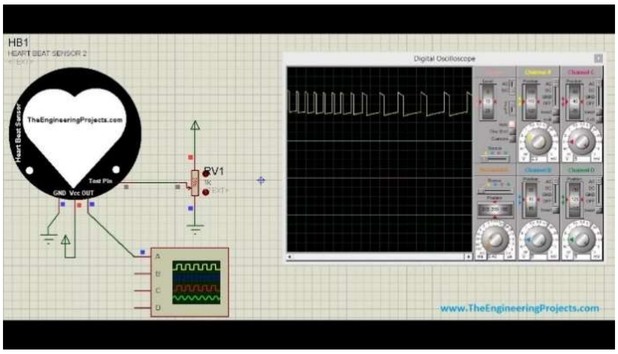

Fig. 5: The output signal by Oscilloscope on Proteus for heart sensor

Comparing the ECG waveform in Fig. 2 with the one in Fig. 5, it was observed that the output signal was well-suited for transmission to the microcontroller.

The ADC channel of the microcontroller was subjected to sinusoidal waveforms with frequencies ranging from 1 HZ to 3 HZ, and the corresponding beats per minutes were recorded. These tests were carried out in both a simulated environment (using Proteus) and the actual world. Table 2 displays the identical results observed in both settings. The negligible disparity between the two documentaries could be attributed to design error.

TABLE 2: MEASURING FREQUENCY OF SINUSOIDAL SIGNALS

Frequency (Hz)	**Result on Proteus (bpm)**	**Result on real world (bpm)**
1	55	59.52
2	105	120.15
2.7	142	163.33
3	160	179.52

ii. USER HEART BEAT PULSE TESTING

After the device's circuitry and display were validated, the user's heart beat pulse was used to ensure the device was functioning properly. A total of five human subjects, male and female, were employed to test this model. The user paused for one minute, then places the finger on the center of the infrared sensor, and the software began to execute based on the programmed algorithm. The infrared sensor picked up the pulse of the heart, the circuit amplified and filtered it, and the microcontroller converts it to a digital signal within 5 seconds, and the controller then spends another 9 seconds performing the Fourier transform on the signal. When successful, the controller needs about 4 seconds to locate the frequency, this includes the time needed to setup the system and collect user information, the entire procedure took less than a minute.

The Electrocardiogram (ECG) data from the patient's fingertip sensor is used to evaluate the Heart Rate Monitor (HRM) device's functionality on an oscilloscope. The percentage error was determined by:

$$E = \frac{(A - M)}{A} \times 100 \qquad (6)$$

Here, A = Actual heart rate
M = Measured heart rate
E = Error rate

TABLE 3: HEART RATE AND TEMPERATURE RESULT

Activity	**Patient A**		**Patient B**		**Patient C**	
	Heart (bpm)	Temp (^{0}F)	Heart (bpm)	Temp (^{0}F)	Heart (bpm)	Temp (^{0}F)
Resting	80	98	75	98.2	70	98.4
Running	130	99.2	170	99.4	135	99.3
Walking	90	98.5	95	98.6	100	98.8

The result of the testing process is represented in Table 3 as three patients' (Patient A, Patient B, and Patient C) resting, running, and walking heart rates and temperatures are displayed. This information was presented in the context of an enhanced wearable medication reminder system for people with arrhythmia. This system employs a Peripheral Interface Controller (PIC) to provide medication reminders and heart rate monitoring. The findings show that heart rate and temperature fluctuate considerably across a wide range of demographics, including age, gender, health, and physical activity. However, the given heart rate data demonstrates that the wearable medication reminder device was successful in keeping tabs on the patients' heart rates throughout the day for three respective patients.

All three patients' resting heart rates were within a healthy range, with Patient (A) having the slowest heart rate and Patient (C) having the fastest, both when the patients were sitting still and while they were walking. There was no abnormality in any of the three patients' temperatures, keeping a steady heart rate during less strenuous activities may have been made easier thanks to the medication reminder system. However, Patient (B's) heart rate reached 170 bpm while running, which was much greater than that of the other patients. It's also possible that the runner's elevated heart rate had nothing to do with the wearable reminder system. Patient (B) may have been too preoccupied during the runs for the medication reminder system to be as efficient as it was during the walks and rests scenario, this emphasizes the significance of taking into account the influence of physical exercise on heart rate and the efficacy of the medication reminder system when engaging in a variety of activities.

Furthermore, the data in Table 3 suggests that the enhanced wearable medication reminder system with a Peripheral Interface Controller was useful for monitoring heart rate during less strenuous activities like sleeping and walking. The system's efficacy may be diminished, however, during more strenuous sports like jogging due to factors including physical exertion and the patient's compliance with the system developed.

TABLE 4: MEDICATION ACTIVITY STATUS

Activity/Feedback	**Patient**	
	Yes	**No**
Medication Taken	Alert: Okay	Alert: Please Take your Medication
Medication Not Taken	Alert: Please Take your Medication	Alert: Okay

Patient reactions to an enhanced wearable medication reminder systems are shown in table 4. In order to ensure that patients with arrhythmia take their medication at the right times, the system makes use of a Peripheral Interface Controller (PIC) and GSM module to communicate the patient’s activities from cloud. There were two types of patient feedback recorded: "Medication Taken" and "Medication Not Taken."

There were two possible outcomes in the "Medication Taken" section: either the patient took the medication after being reminded ("Alert: Okay") or the patient did not need to be reminded ("Alert: Please Take your Medication"). Both "Alert: Please Take your Medication" and "Alert: Okay" fall under the "Medication Not Taken" heading, indicating that the patient has either ignored the reminder and hence not taken the prescription, or has taken the medication but was just not responding to the reminder.

Based on the data in the Table 4, it appears that the upgraded wearable medication reminder system was successful in getting the patient to take the medication when it is due. The "Alert: Please Take your Medication" response indicates that the system was successful in reminding the patient to take their prescription. Patients with arrhythmia may have a better chance of taking their medications as prescribed with this system implementation.

TABLE 5: MEDICATION ACTIVITY COMPARISON RESULT

Gender	**Age**	**HR on Display Device**	**HR on Oscilloscope**	**Error rate (%)**
Male	22	97	96	1.03
Male	22	83	81	2.41
Male	20	78	78	0
Male	22	90	87	3.33
Male	20	80	79	1.25
Female	22	77	77	0
Female	22	104	103	0.96
Female	19	75	75	0
Female	20	69	71	2.081
Female	22	83	85	2.35

In Table 5, the device precision was approximately 1.414 but changes depending on the results of the tests. Women typically have a greater HR than men, where there was a significant weight or lifestyle difference such as kind of work, health, inheritance of heart disease, and doing exercises.

In another test, two male heart rates were measured before and after a five minutes run. The resting heart rates were taken after the volunteers had rested for about two minutes. Comparing the device measurement to human measurement, which is done by counting pulses at the wrist as in Table 6.

TABLE 6: MANUAL AND WEARABLE SYSTEM MODEL COMPARISON TEST

Age	**Case**	**HR on Display Device**	**HR by Manual Measurement**
24	Before Exercise	65	64
	After Exercise	90	88
15	Before Exercise	91	88
	After Exercise	110	100

The test results indicate that different types of people have varying resting heart rates; the first test subject was a young man who regularly engages in physical activity, and the recorded resting heart rate was the lowest of all the test subjects. The other young man whose resting HR was recorded to be the highest of the two. Being aware that the healthy heart rate is between 60 and 100 beats per minute, it was assumed that anything above or below this indicates a health problem prior to testing. The research revealed a more accurate range of 60 to 120 bpm as the healthy range for heart rate. Therefore, it is very necessary to provide users with more response information of body condition, such as heart rate, to help know the healthy condition and prevent risk of disease.

iii. NOTIFICATION

There were also other tests done to guarantee that the alert mechanisms are activated if the HR was found to be too high. By providing false information about the user's age and gender, the MAXHR was reduced so that it was easily exceeded.

The result obtained was an efficient and reliable wearable medication reminding system that helps persons with arrhythmia to remember to take their medication at the right time. By using the Discrete Fourier Transform (DFT) algorithm on the PIC microcontroller, the system performed real-time signal processing and provided accurate heart rate measurements for medication reminders.

IV. CONCLUSION

The primary goal of the system model was to alert the patient's medical advisors via short message service on the case of arrhythmia on a monitored patient with wearable device and also notifies the medical advisor on the patient’s adherence to medical prescription from the medical advisor using a two-way communication channel enabled by the GSM modem. The system was tested with its performance evaluated to ensure optimum results. This device is deployable in hospitals, private homes, and emergency vehicles. The data presented in the research work indicates that the upgraded wearable medication reminder system was helpful in increasing medication adherence among patients with arrhythmia, but that further work could be needed to identify when medication has been given to prevent needless reminders.

ACKNOWLEDGMENT

Sincere gratitude to everyone who contributed to the development of the wearable medication reminding system for persons with arrhythmia using PIC microcontroller. Thank you all for your contributions to this research work, which has the potential to improve the lives of those with arrhythmia through the use of technology.

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