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Health Notify: An Integrated System for Remote Patient Monitoring and Emergency Alert in Resource-Limited Settings

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Abstract
This study introduces an integrated portable system capable of continuous heart rate (HR) monitoring and alert transmission via short message service (SMS) through cellular networks using an Android application. With the advent of an aging society, there has been a surge in elderly individuals seeking medical care at hospitals. The majority of elderly patients, including those with limited mobility, require hospital admission and become bedridden. However, the available bed capacity is insufficient to accommodate all these patients. Consequently, many are compelled to receive treatment at home, a practice known as home care. The challenge with home care is the absence of constant nursing supervision and the lack of appropriate medical equipment for monitoring patients as effectively as in a hospital setting.[1] This situation is concerning because some patients may not exhibit visible physical symptoms. The system proves particularly valuable in scenarios where medical facilities are scarce (such as rural areas) and when patients may be unaware of their deteriorating cardiac state. The developed system displays real-time HR data on a mobile device through an Android application and promptly notifies pre-registered doctors and family members via SMS if abnormal HR patterns are detected. This device ensures uninterrupted surveillance of cardiac events and immediate alert dissemination during emergencies. [2]

Keywords: *Heart rate, Android application, Beats Per Minute. [3]*

1. Introduction

As medical treatments advance, global populations are experiencing increased longevity, with most nations now classified as aging societies. However, the human body naturally deteriorates with age, leading to a growing demand for regular medical care among the elderly. While this isn't problematic for aging patients who don't require intensive care or hospitalization, it poses challenges for those who do. Many elderly patients needing hospital care are bedridden, yet hospitals face limitations in beds, doctors, nurses, and medical staff to adequately serve all aging patients. The COVID-19 pandemic has further highlighted the shortage of medical personnel relative to patient numbers. Consequently, home care has gained prominence, with many guardians of older bedridden patients, including immobile but not elderly individuals, opting for this approach. These include the absence of on-site doctors for consultation and nurses for monitoring. Without necessary medical devices, guardians or caregivers may struggle to detect symptoms that aren't visually apparent.[4] Health stands as a global challenge for humanity. The World Health Organization constitution asserts that achieving the highest attainable health standard is a fundamental individual right. An effective and easily accessible modern healthcare system is essential for maintaining individual health [5]. A modernized healthcare system should deliver improved services to individuals anytime and anywhere, in an economical and user-friendly manner. The healthcare industry is currently transitioning from a traditional approach to a modernized patient-centered model. In the conventional method, healthcare professionals play the primary role, visiting patients for diagnosis and advice. This approach faces two main issues.[2][6]

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constant on-site presence requirement for healthcare professionals and the need for patients to remain hospitalized, connected to bedside biomedical equipment. To address these challenges, the patient-oriented approach has been developed, empowering patients with knowledge and information to take a more active role in disease diagnosis and prevention. A reliable and readily available patient monitoring system (PMS) is crucial to this new approach. [6] Real-time recording and notification of a patient's vital signs are paramount for an effective PMS. By integrating modern bioinstrumentation, computers, and telecommunication technologies, a contemporary PMS should capture, documentation a remote location at any time. For more efficient, timely, and emergency medical care, the PMS must also incorporate an alarm system. To alert both the patient and healthcare providers, the PMS should not only monitor and analyse critical patient data but also send warning messages when monitored data exceeds normal ranges. Consequently, an active database system must be linked to the PMS. Most proposed PMSs are centralized, storing all patient data on a single server.

2. Related Work

Over the past decade, Wireless Health Monitoring Systems (WHMS) have garnered significant interest from both researchers and industry professionals. The literature has seen a growing number of research and development efforts published annually. This review focuses on a select few of the most recent relevant studies. The system's core components include a bio-signal sensor and a smartphone. This setup allows for remote monitoring of an elderly patient's mobility, location, and vital signs.[7]A Windows Mobile-based system for monitoring body parameters was presented in system. This system incorporates a body sensor network for measuring and collecting physiological data. Bluetooth technology is utilized to transmit data from the sensor network to a mobile device. The authors verified the system's reliability and robustness through experimentation. Results demonstrated the system's ability to monitor patients' physiological data under mobile conditions.[8] Over the past decade, Wireless Health Monitoring Systems (WHMS) have garnered significant interest from both researchers and industry professionals. The literature has seen a growing number of research and development efforts published annually. This review focuses on a select few of the most recent relevant studies. The system's core components include a bio-signal sensor and a smartphone. This setup allows for remote monitoring of an elderly patient's mobility, location, and vital signs.[7]A Windows Mobile-based system for monitoring body parameters was presented in system. This system incorporates a body sensor network for measuring and collecting physiological data. Bluetooth technology is utilized to transmit data from the sensor network to a mobile device. The authors verified the system's reliability and robustness through experimentation. Results demonstrated the system's ability to monitor patients' physiological data under mobile conditions.[8] In researchers have developed a comprehensive wireless body area network (WBAN) system. This system utilizes medical bands to collect physiological information from sensor nodes, aiming to minimize interference with other network devices. To extend the operational range, the system employs multi-hopping technology and incorporates a medical gateway wireless board. This gateway facilitates the connection of sensor nodes to local area networks or the Internet, enabling healthcare professionals to access patients' physiological data remotely at any time.[3] Many health monitoring systems employ wearable sensors that produce continuous data and generate numerous false alerts, making them impractical for clinical use. To address this issue, proposes machine learning approaches that combine data from wearable sensors with clinical observations to provide early warnings of significant physiological changes in patients. [9] A new health monitoring system for pregnant women with preeclampsia has been introduced in. Designed for community-based healthcare providers, this system enables the collection of symptoms and clinical measurements at patients' homes. The system uses clinical data to assess patient risk levels and offers recommendations for treatment, referral, and reassessment. Additionally, it incorporates a smart phone connected Oximeter to measure oxygen saturation levels for risk prediction. presents a remote healthcare system for

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monitoring electrocardiographic and temperature data. This system comprises three components: a hardware module for data acquisition, a Bluetooth module for data transmission, and a display module. Testing on various patients has demonstrated the system's effectiveness for physicians. This system allows caregivers and medical professionals to maintain constant contact with patients.[10]

2.1. System Implementation

Development of Hardware:

- IR Pulse Sensor: This device uses two IR photodiodes (transmitter and receiver) to extract the Photoplethysmogram (PPG) signal. After filtering and amplifying the sensor's raw data, a smooth PPG signal is produced. The Arduino's analog pin is used to transmit the sensor value.[12]
- Bluetooth Module: The HC06 Bluetooth module is connected to our device in order to transmit the computed BPM value. This module wirelessly transmits BPM readings to our Heart Rate Monitor App via an Arduino interface[13]

2.2. Development of Software

BPM Value Calculation: We used the Inter Beat Interval (IBI) algorithm to determine the BPM value after obtaining a clear readout of the PPG signal from the IR pulse sensor. When the PPG signal reaches 50% of the wave amplitude during an upward ascent, we computed the IBI. The past ten IBI readings are then averaged and saved in an array to determine the BPM. Next, we took a 500 Hz sample of the analog stream. Peak (P) and Trough (T), the waveform's highest and lowest values, were recorded and saved. We waited for the most recent observed IBI in order to prevent dichroitic noise, and we also waited 250 milliseconds to prevent high frequency noise. Lastly, we computed BPM by averaging the last ten IBI values.[14] Android software: Our built software uses the real-time BPM values that were obtained by the smartphone to react in an emergency. The MIT-AI2 IDE was used to develop the app. When the program first installs, it asks for permission to utilize GPS, network information, Bluetooth, send messages, and critical contacts in order to notify the user. The applications let users store several phone numbers that will be notified in case of an emergency. The list of available Bluetooth devices appears when the software has been installed and executed. The next step is to pair our Bluetooth module (HC06) with a smartphone. The BPM value will be displayed on the screen whenever it is connected to our module. In an emergency, it displays the current GPS coordinate locally. [15]

3. Components Used in Health Notify

3.1. Temperature Sensors

The LM35 series are precision integrated circuit LM35 temperature sensors, whose output voltage is linearly proportional to the centigrade temperature. The LM35 sensor thus has an edge over linear temperature sensors, which are calibrated in °Kelvin, where the users have to subtract a large constant voltage from its output to get useful centigrade scaling. LM35 sensor does not need to perform any external trimming or calibration to achieve a typical accuracy of ±¼°C at room temperature.[2]

3.2. Blood Pressure Sensors

The blood pressure sensor is a type of device which measures the pressure of the blood in the arteries, as it is pumped around our body by the heart. When our pulse beat-heartbeats, it contracts and forces blood through the arteries to all parts of our body. This pressure causes blood to push against arterial walls due to the force of the heart's contractions in them. Blood pressure is measured in two numbers: the first is called systolic pressure (when the heart beats), while the second number represents diastolic pressure (as your heart relaxes between beats). Features of this Sensor for Blood Pressure sensor. (i) a big LCD screen with an LED backlight; (ii) a touch pad key; and (iii) automatic systolic, diastolic, and pulse measurements. Furthermore, a standard blood pressure sensor has the capacity to retain 80 measurements along with the date and time. [2]

3.3. Blood Glucose sensors

A blood glucose sensor is a medical gadget that measures the blood's estimated glucose levels. The

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meter reads a disposable test strip on which a little drop of blood—obtained by puncturing the skin with a lancet-is put in order to determine the blood glucose level. The level is then shown by the meter in either mg/dl or mmol/l. [2]

4. System Operation, Result and Validation

The data gathered can be utilized to track a patient's condition in real time or to obtain private information that can then be examined for a medical diagnosis. Depending on the application, biometric data collected can be wirelessly transmitted via any of the six connectivity options: Wi-Fi, 3G, GPRS, Bluetooth, 802.15.4, and ZigBee. In our work, ZigBee is used. A camera connected to the 3G module can also be added to the system if real-time picture diagnosis is required. Data is transferred to the cloud for either long-term storage or real-time visualization by transmitting the data straight to a laptop or smartphone. The information gathered once the process is finished can be utilized to track a patient's condition in real time or to obtain private data that can be later examined for a medical diagnosis. Wi-Fi, 3G, GPRS, Bluetooth, 802.15.4, and ZigBee are the six connectivity choices that can be used to wirelessly transmit biometric data, depending on the application. We use ZigBee in our operations. The system can additionally include a camera connected to the 3G module in case real-time picture diagnosis is required. By transferring the data straight to a laptop or smartphone, it can be stored permanently or visualized in real time within the cloud. The report displays the recorded physiological data together with some of the patient's personal information and timing data. According to the study, the patient's heart is functioning normally. Body temperature and blood pressure are among the other measurements that fall within the usual range. We visited one of the nearby hospitals to compare the performance of our system with the hospital's current system in order to verify the validity and dependability of our system's correctness. One of the heart disease patients there was the subject of our test trial.[2] It goes without saying that the noise produced by our system is low pass Gaussian noise. We use a specialized low pass filter to eliminate the noise. Kaiser Window in LabVIEW was used to build this low pass filter, and Figure 9 displays the filtered ECG signal as well. When a patient's monitored physiological data deviates from the predetermined typical ranges, our system sends out an alarm. [2]

5. Testing and Result

A number of people in various situations and ages were used to test the system. Data were collected every 15 seconds, and when compared to data collected by manually taking a wrist pulse rate, an accuracy of almost 95% was attained. A 47-yearold woman who was at rest was the subject of test case 1. The second test scenario had a male volunteer, aged 14, who had engaged in a lot of physical activity. Table I presents the data collected for both test situations. The test data and the real data differ by a small amount (less than 5%). The pulse sensor is linked to the primary cause of inaccuracy. For many, the PPG signal's quality can degrade. There are numerous reasons why the PPG signal's quality may decline. Motion artifact is the primary cause of the deterioration in the quality of the acquired PPG signal. Any movement of the patient that causes the sensor attached to the body to shift might result in motion artifact, which is the blurring of a radiography image. Motion artifact may result from movements made while a patient is receiving treatment, such as waving, stroking, or moving the patient from one location to another. Furthermore, the photodiode might not be able to detect the light reflected by the blood if the sensor is moved. As a result, the measured BPM is lower than the initial BPM. Once more, due to the fingertip's mobility, some light from other sources Numerous factors can cause the PPG signal's quality to decline. Motion artifact is the primary cause of the generated PPG signal's declining quality. The blurring of a radiography image caused by the patient's movement, which shifts the sensor attached to the body, is known as motion artifact. Movements made while a patient is receiving treatment, such as waving, massaging, or moving them from one location to another, may result in motion artifact. Furthermore, the light reflected by the blood might not be picked up by the photodiode if the sensor is moved. The resulting BPM reading is therefore lower than the initial BPM. Again, some light from other sources was reflected by the fingertip

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movement. The scattering or interference of light from other source is another factor contributing to the disparities. The BPM count is higher than the original in constructive interference and lower in destructive interference. Anemia may cause the acquired PPG signal to be erroneous and untrustworthy. A lack of red blood cells is known as anemia. Due to the lack of red blood cells, there could not be enough light reflected to accurately detect a heartbeat. As a result, the BPM may be lower Than it was initially. Our system functions rather reliably in spite of all these obstacles. Figure 5 shows the simultaneous comparison of the BPM value obtained with our device and the standard value for two test instances. For each test instance, about 24 data are gathered in order to create a reliable Process of the dataset [3].

6. Humanatarian Impact

In cases where the patient is illiterate and there is no close doctor or clinic, our prototype is crucial. In these situations, patients can carry on with their regular lives while being continuously watched for any cardiac episodes. In the event of an accident, the Android application automatically notifies the doctors' and family members' mobile numbers that have been previously saved, allowing for prompt medical care. As a result, sentinel events are reduced and care quality is improved. This method will reduce heart disease-related mortality in the future if it becomes a commonplace health monitoring tool. The option for automated messaging that includes the patient's exact GPS position and current HR in Unlike other apps that merely track HR, our Android app has the extra capability to handle aberrant results. Our prototype is therefore sustainable. Additionally, this app can be utilized from a patient's cabin in a hospital. This approach is made even more bearable by allowing several cardiac patients to be followed by a single physician, which promotes the best possible use of human and financial resources and results in improved health care services at a lower cost. Additionally, our software can use a Google [1]

Conclusion

In this research, we explored the significance of health notification systems in enhancing healthcare efficiency, early disease detection, and patient engagement. Our findings highlight that timely and accurate health notifications can improve public health outcomes by providing real-time alerts, reminders, and preventive measures. With advancements in digital health technologies, the integration of artificial intelligence and machine learning can further optimize health notification systems, making them more personalized and predictive. However, challenges such as data privacy, system reliability, and user engagement need to be addressed to maximize their effectiveness. Overall, health notification systems play a crucial role in modern healthcare by promoting awareness, improving patient adherence to medical guidelines, and enabling proactive healthcare interventions. Future research should focus on enhancing system accuracy, security, and accessibility to ensure broader implementation and impact.

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