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Designing of Portable Health Monitoring System using ATmega328P Microcontroller

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Narjis M. Khalafullah[1], Najib E. Omran[2], Marwa Alfordogh[3], Retaj Almorabit[4],

Malek karaim[5]

1, 2 Libyan Center for Electronic System Programming and Aviation Researches
1,3,4,5University of Zawia, Faculty of Engineering-Libya

narjesmohammed3@gmail.com

Abstract

A portable, compact, and conveniently used emergency health monitoring system, that allows individuals to monitor their health status in real-time, this integrated system includes a few sensors that can measure vital health-related signs such as heart rate, blood pressure, oxygen saturation in blood, and body temperature features a liquid crystal display (LCD) interface, facilitating seamless interaction for individuals. Using an Arduino nano microcontroller.

One unique aspect of this emergency healthcare monitoring system is its capacity to recognize critical situations and to automatically send out emergency condition notifications. For example, if the device recognizes a sudden increase in heart rate or a significant drop in blood oxygen levels, it can send a notification to the user and/or healthcare institutions wirelessly to the phone number that are registered with it. The system has a successful performance compared to other commercially available devices and hospital-grade equipment that has been tested on multiple human subjects.

Keywords: Wearable device, vital signs, biosensors, GSM, microcontroller.

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تصميم نظام محمول للمراقبة الصحية باستخدام المتحكم الدقيق ATmega328P

نرجس خلف الله[1]، نجيب الكوني[2]، مروة الفردغ[3]، رتاج المرابط[4]، مالك كريم[5]

1، 2 المركز الليبي للمنظومات الالكترونية والبرمجيات وبحوث الطيران
1، 3، 4، 5 جامعة الزاوية كلية الهندسة-ليبيا

narjesmohammed3@gmail.com

الملخص

نظام محمول صغير الحجم وسهل الاستخدام لمراقبة الحالة الصحية في حالات الطوارئ، يسمح للأفراد بمراقبة حالتهم الصحية في الوقت الفعلي، ويتضمن هذا النظام المتكامل بعض أجهزة الاستشعار التي يمكنها قياس العلامات الحيوية المتعلقة بالصحة مثل معدل ضربات القلب وضغط الدم وتشبع الأكسجين في الدم ودرجة حرارة الجسم ويتميز بواجهة عرض بلورية سائلة (LCD)، مما يسهل التفاعل السلس للأفراد. باستخدام متحكم دقيق من نوع Arduino nano.

إن أحد الجوانب الفريدة لنظام مراقبة الرعاية الصحية في حالات الطوارئ هذا هو قدرته على التعرف على الحالات الحرجة وإرسال إشعارات الحالات الطارئة تلقائياً. على سبيل المثال، إذا تعرّف الجهاز على زيادة مفاجئة في معدل ضربات القلب أو انخفاض كبير في مستويات الأكسجين في الدم، يمكنه إرسال إشعار إلى المستخدم و/أو مؤسسات الرعاية الصحية لاسلكيًا إلى رقم الهاتف المسجل لديه. ويتمتع النظام بأداء ناجح مقارنةً بالأجهزة الأخرى المتاحة تجارياً والمعدات المتوفرة في المستشفيات والتي تم اختبارها على العديد من الأشخاص.

الكلمات المفتاحية: جهاز قابل للارتداء، علامات حيوية، جهاز استشعار حيوي، جهاز GSM، متحكم دقيق.

Introduction

The demand for health services and systems is at an all-time high. [1] with biomedical sensors playing a key role. These electronic devices capture and convert biological signals into measurable data. [2] forming the foundation of various medical diagnostics tools. Biomedical sensing technology aims to enhance understanding of biological processes and improve health monitoring and treatment. Applications are vast, including molecular detection sensors, drug analysis sensors, and micro-implantable probes.

Moreover, biomedical sensors have been widely applied in medical image analysis and diagnostics, portable and clinical diagnostics, and laboratory analytical applications. [3]

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Here we show a portable emergency health monitoring system, where the system is a noninvasive smartly integrated device that encompasses a few different biomedical sensors that could be used to assist pediatric personnel in filed and triage rooms. The system logs data and displays medical measures instantaneously to help provide first aid services on the spot. The medical parameters targeted in this work are comprises of several segments which are heart pulse rate and oximetry measurements using MAX30100 sensor module, body temperature measurements using MLX90614 sensor module, blood pressure measurements using a MPS20N0040D-S sphygmomanometer pressure sensor, and a cuff including DC mini air pump with solenoid valve and L9110 motor Driver, SIM900A GSM Module, Nokia 5110 Graphic LCD Display and Arduino Nano (ATmega328P).

The Arduino Nano is breadboard-friendly board based on the ATmega328P, it is small size and wide range of applications make it an excellent choice for portable devices where space is a premium. Its ability to communicate with other controllers and computers, along with its I2C communication protocol, further enhances its suitability for portable applications. [4]

The system was tested on 10 individuals, and its performance was compared to hospital-grade equipment at Al-Zawiya Hospital and Libyan Foreign Hospital to validate its accuracy and reliability." It was found that device provide those measurables with improved accuracy, quicker access, expedited results and easiness to use. Additionally, if any abnormal changes occur in a patient's health based versus standard values, the device will alarm the user using the mentioned GSM module by sending an alert and sending a message to emergency facility carrying vital information to speed up the first aid process.

Many health individuals and patients require regular health monitoring and observation during emergencies or normal sport activities. [5] Health monitoring devices are becoming more popular, but they are still expensive to afford or big in size or not easily accessible. [6]

Here, we aim to use technology more efficiently to make patients’ lives easier by providing prompt diagnosis and health condition analysis. The portable emergency health monitoring system introduced here prevents frequent visits to doctors and reduces meetings between patients and medical professionals. The system provides monitoring of blood pressure, heart rate, oxygen level, and temperature readings of a person using one compact and affordable device.

Workflow of the health monitoring system

In figure1 a flowchart illustrates the procedure of monitoring a patient's vital signs using the sensors and sending medical alerts using Arduino Nano and cellular technology. It outlines the process of initializing modules, processing sensor data, and displaying it. Actions are triggered based on the patient's vital signs, notifying relevant doctors if

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necessary. The flowchart also includes a step for transferring data to a specified number for storage.

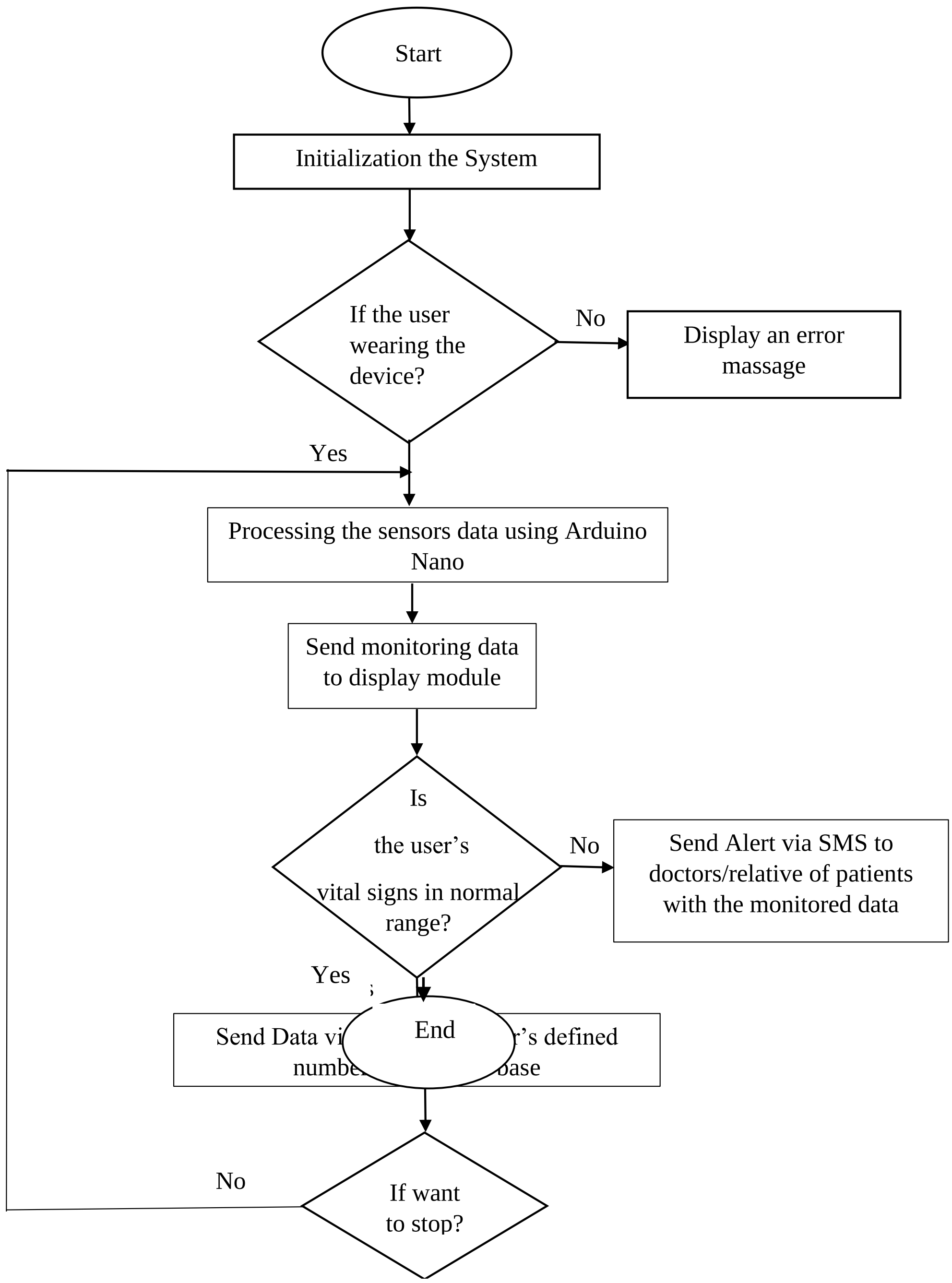

Figure1. Flowchart of the presented system

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The whole process is started by pressing a button as it is demonstrated in figure2 The pulse oximeter and heart rate and oximetry sensor, temperature sensor, and pressure sensor are the three sensors from which the main control unit (MCU) gathers data. [7] However, the MCU instructs H-bridge to initialize the motor before receiving data from the pressure sensor. The cuff is then inflated by a pump, enabling accurate pressure measurement. Following its acquisition, the calculated values are then displayed on a screen and transmitted wirelessly via SMS to another device using GSM.

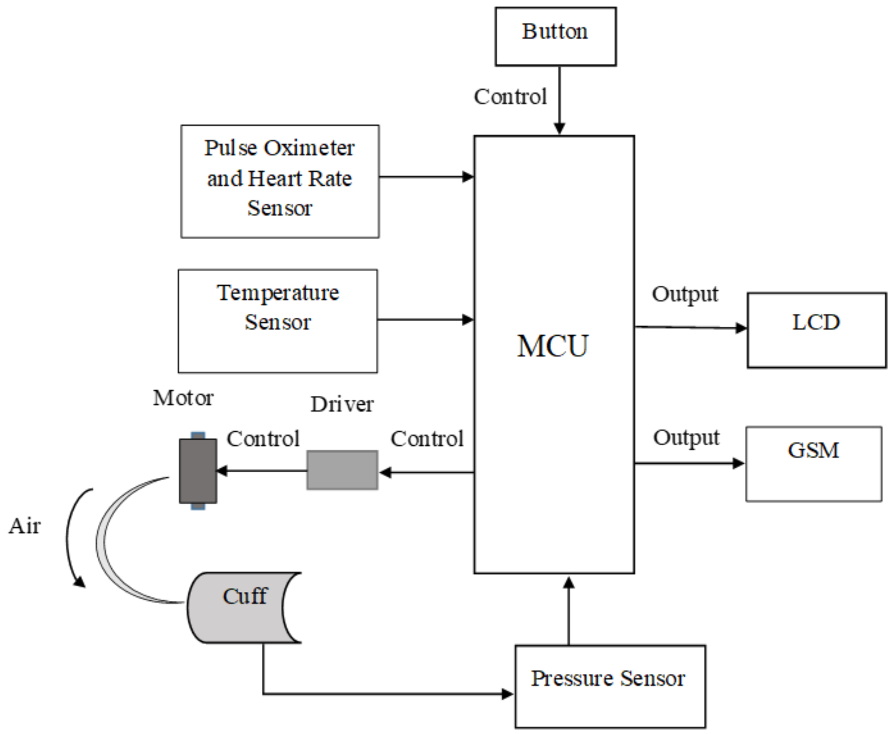

Figure2. Block diagram of the presented system

System implementation

The system proposed here was implemented precisely, as we have three nodes to measure the four vital signs the pressure, heart rate, oxygen saturation and temperature. As the heart rate and oxygen saturation are considered a one node because they are measured with same sensor. This works by wrapping the cuff around the wrist, where we have the pressure and temperature sensor and for these infrared thermometers, the best place to measure temperature for accurate results is the wrist as they are less exposed to the external environment. [8] While the heart rate sensor is placed on the fingertip (or essentially anywhere where the skin isn't too thick, so both lights of the two LEDs on the sensor can easily penetrate the tissue). [9] A schematic diagram of the measurement units is given in figure3.

The complete system

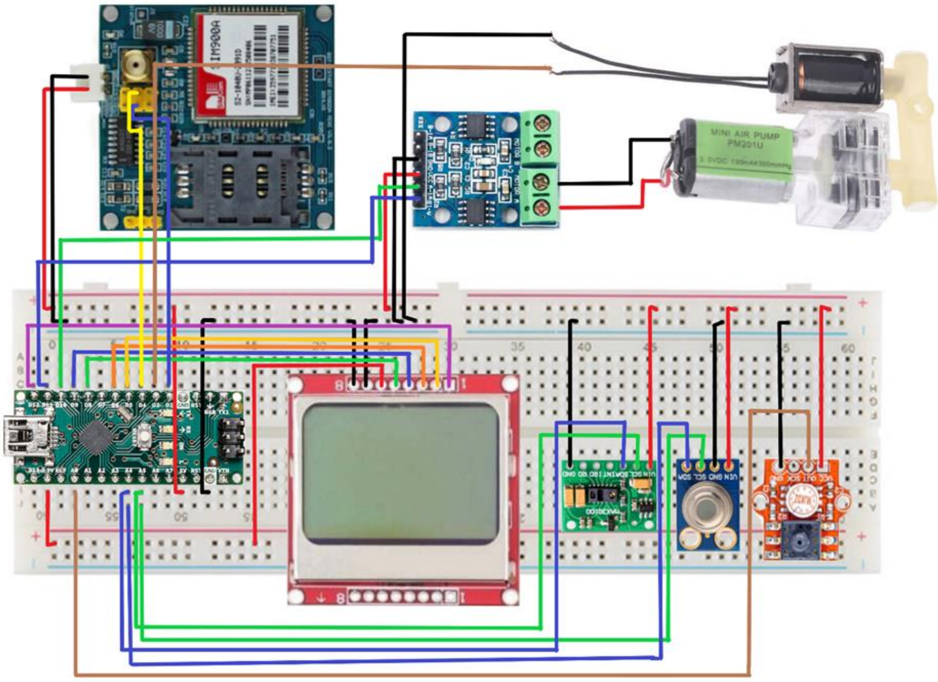

Figure3. Complete system implementation

The system was highly compact and did not create any mentionable problem. The whole system layout is shown in figure4.

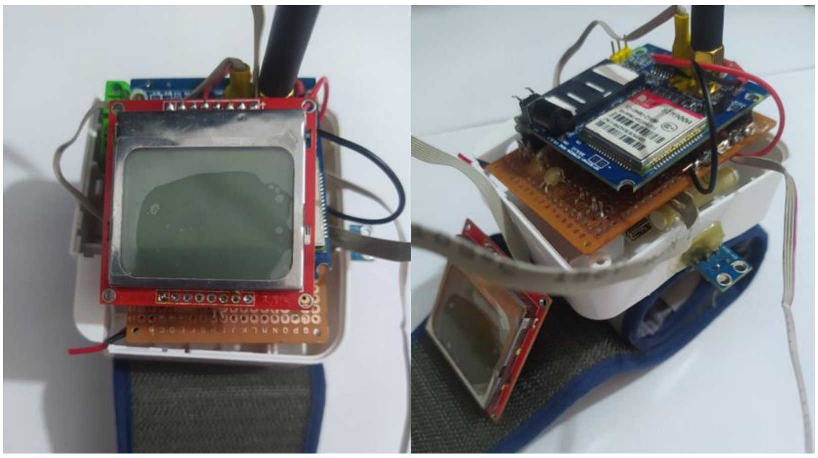

Figure4. Complete system design

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System output

For blood pressure, both systolic and diastolic readings were shown on the LCD display. Also, the body temperature in Celsius scale, heart rate in beat per minute and the percentage of oxygen saturatio were displayed on the screen. Both ouputs were experimented with the 10 patients to present the mentioned vital signs. Figure5 (a) shows the display of a phone device used to get the measured readings while figure5 (b) presents the readings on the LCD.

(a) (b)

Figure5. (a) Screenshot of the displayed reading using the GSM

(b) Display readings on the LCD

Results and discussion

Heart rate fluctuates for different age groups. For a human adult of age 18 or more years, a standard inactive heart rate is about 72 (bpm). A lower heart rate at relaxation infers more efficient heart function and healthier cardiac system [10]. The 10 mentioned patients were from a different ages ranging from 5 years old to 47 years, for each age, the accuracy of each sensor will be presented.

The system shows a very high accuracy, A graphical representation of differences between the presented system and commercial device readings is shown in figure6.

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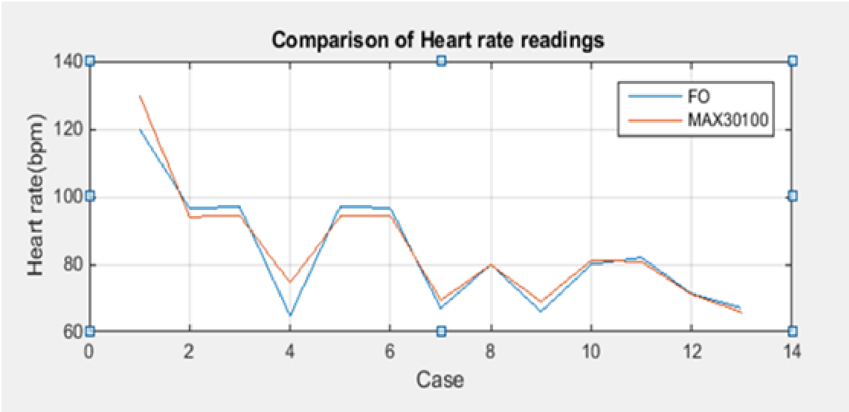


Figure6. Heart rate reading comparison

The temperature is a clear mien of its molecular excitation. The human body's essential temperature varies from time to time, but these variations are slight, habitually no more than 1.0ºC. Human body temperature is delimited at about 37ºC ±1ºC. Exterior and interior heat affect body temperature which vicissitudes the overall reading [11]. Evaluations had been recorded from different patients by using a thermometer. Then those readings were compared to MLX90614 sensor interpretations. Graphical representation of differences between thermometer reading and sensor reading is shown in figure7.

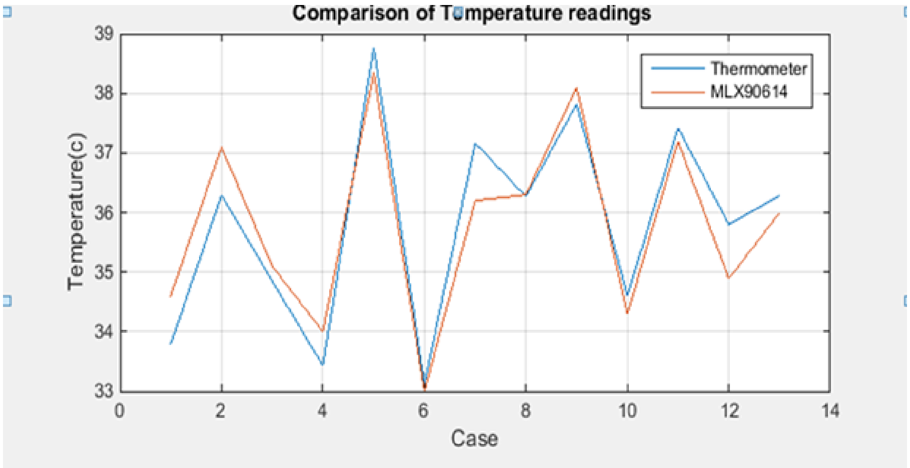
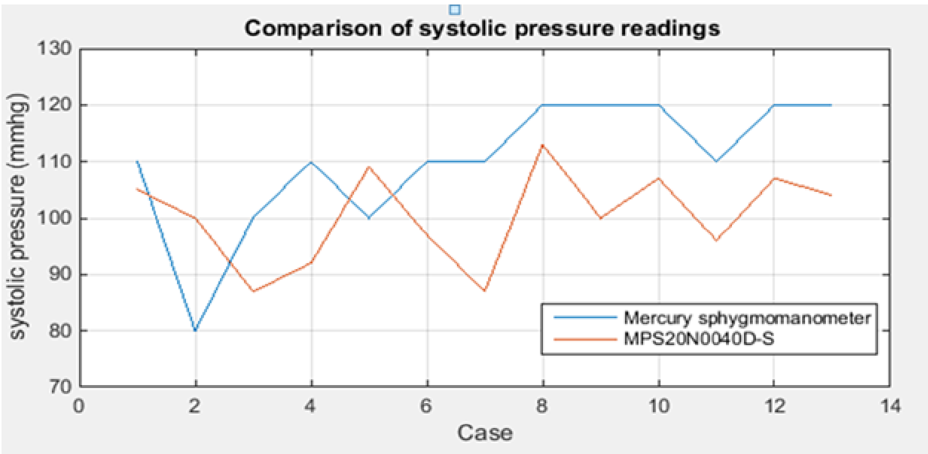
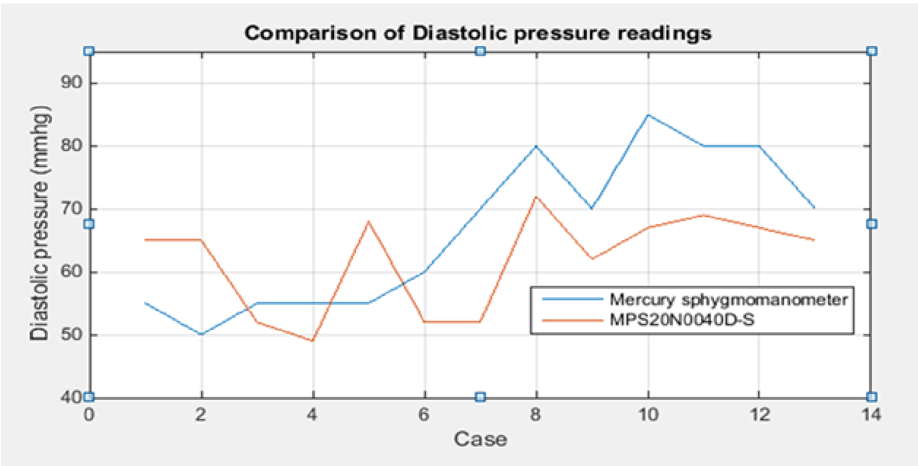


Figure7. Body temperature readings comparison

Pressure sensor was utilized in this resolution. A pressure sensor performs as a transducer, it generates an electrical signal as a function of the pressure imposed. Readings were recorded using the traditional method and then compared to the sensor readings. Negligible deviation was observed between the sensor and traditional device because some patients was not very cooperative to follow the instructions of the right use manual. One of these instructions is to make sure the heart and wrist are kept at the same level to avoid the effects of hydrostatic pressure. A graphical assessment of systolic and diastolic pressure readings is revealed in figure8.



(a)



(b)

Figure8. (a) Systolic pressure readings assessment

(b) Diastolic pressure readings assessment

All the readings recorded from different patients using both the presented system and the traditional used devices is given in Table 1.

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Table 1. COMPARISON OF HEART RATE, BODY TEMPERATURE AND BLOOD PRESSURE READINGS

Patient's details		Heart rate		Body temperature		Blood pressure	
Number	Age (years)	Sensor (bpm)	Oximeter (bpm)	Sensor (°C)	Thermometer (°C)	Sensor (mmHg)	MS (mmHg)
01	05	130	120	34.6	33.79	105/65	110/55
02	27	94	96.6	37.1	36.29	100/65	80/50
03	23	94.4	97	35.1	34.85	87/52	100/55
04	39	74.55	64.75	34	33.43	92/49	110/55
05	23	94.2	97.2	38.35	38.77	109/68	100/55
06	18	94.4	96.6	33.0	33.13	97/52	110/60
07	28	69.37	67	36.2	37.17	87/52	110/70
08	24	79.84	80	36.3	36.27	113/72	120/80
09	25	69	66	38.1	37.82	100/62	120/70
10	47	81.12	80	34.3	34.6	107/67	120/85

Conclusion

The developed health monitoring system demonstrated effective functionality by providing real-time tracking of vital health parameters, including heart rate, oxygen saturation, body temperature, and blood pressure. Each reading was evaluated for accuracy, with specific findings highlighting strengths and areas for improvement.

Heart rate and oxygen saturation readings showed consistent accuracy across various tests, Temperature readings, in particular, proved to be the most reliable, with results matching traditional clinical thermometers with minimal deviation. However, blood pressure measurements showed some deviation when compared to standard sphygmomanometers. While this is common in non-invasive, digital blood pressure monitoring systems, the right use of the device, ongoing calibration and refinement are needed to reduce this gap and improve overall reliability. The deviations observed are within acceptable limits.

A notable limitation of the system is its reliance on SMS notifications in emergencies, which may fail to be delivered due to poor mobile signal reception in some areas. To mitigate this issue, alternative communication methods such as integrating Wi-Fi or Bluetooth, utilizing cellular networks with enhanced coverage, or developing a mobile app that uses internet-based messaging could be considered to ensure critical alerts reach emergency services reliably.

Another point to be reached is the use of GPS with SMS notifications so that when an emergency situation occurs and the readings are abnormal, a message containing the measured vital value associated with the location of the user (patient) is sent.

Using autoregression models that predict the future behavior of sensor outputs based on past behavior would be a great addition. Autoregressive modeling uses only past data to predict future behavior, this can improve the accuracy of various sensors.

The proposed system is an appropriate solution for densely populated countries, where doctors are not easily obtainable all the time. The expectation is that, this scheme will bring a constructive change in our conventional medical sector.

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