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# Patients Monitoring and Data Management System for Hospitals

**Shahad Abdulrahman Khuder, Sura Nawfal Abdulrazzaq***
Computer Engineering Department, Mosul University, Mosul, Iraq

Correspondance
*Sura Nawfal Abdulrazzaq
Email: sura.nawfal@uomosul.edu.iq

**Abstract**
***This work concerns creating a monitoring system for a smart hospital using Raspberry Pi to measure vital signs. The readings are continually sent to central monitoring units outside the room instead of being beside the patients, to ensure less contacting between the medical staff and patients, also the cloud is used for those who leave the hospital, as the design can track on their medical cases. Data presentation and analysis were accomplished by the LabVIEW program. A Graphical User Interface (GUI) has been created by the Virtual-Instrument (VI) of this program that offer real-time access to monitor patients' measurements. If unhealthy states are detected, the design triggers alerts and sends SMS message to the doctor. furthermore, the clinicians can scan a QR code (which is assigned to each patient individually) to access its real-time measurements. The system also utilizes Electrocardiography (ECG) to detect abnormalities and identify specific heart diseases based on its extracted parameters to encourage patients to seek timely medical attention, while aiding doctors in making well-informed decisions. To evaluate the system's performance, it is tested in the hospital on many patients of different ages and diseases as well. According to the results, the accuracy measurement of SpO2 was about 98.39%, 97.7% for (heart rate) and 98.7% for body temperature. This shows that the system can offer many patients receiving health services from various facilities, and it ensures efficient data management, access control, real-time monitoring, and secure patient information aligning with healthcare standards.***

**Keywords**
**Health Monitoring, Smart Hospital, SPO2, ECG, Raspberry Pi, LabVIEW.**

## I. Introduction

Nowadays, many industries and companies can employ the Internet of Things (IoT) in many needs to improve different processes [1] [2]. In fact, there are relatively fewer IoT implementations in healthcare compared to some other sectors like smart cities or manufacturing. Fig. 1 shows the emerging of the top 10 IoT applications across 7000+ technologies in 2023 [1].

Increasing IoT adoption in healthcare requires a strategic and collaborative approach. Working closely with healthcare professionals, understanding their needs, and addressing concerns will contribute to the successful integration of IoT technologies in the healthcare sector. Cloud computing and edge computing have transformed conventional healthcare systems and given rise to the possibility of replacing in-hospital medical systems with Internet-connected electronic health (eHealth) care systems [3]. As a result, the IoT can assist a variety of medical applications, as remote patient monitoring, chronic illnesses, exercise routines, and elder care [3] [4].

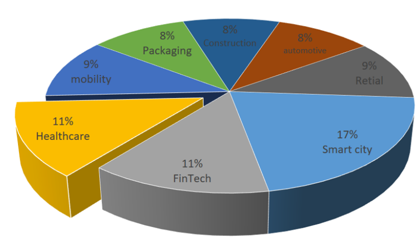



Fig. 1. Impact percent of IoT on healthcare technology.

Wearable IoT devices can function as biosensors to track physical activity [5].The majority of these sensors are adaptable and non-invasive, and they continuously track the patient's physiological parameters using a wireless network to gather data from the body, these data like blood pressure, SPO2, BPM (Beat Per Minute) and ECG can be monitored using IoT nodes [6].
ECG is considered one of the most important vital signs since it plays a crucial role in diagnosing specific heart conditions. It records the electrical activity of the heart, recording components like the P-wave, QRS-complex, and T-wave in the heartbeat.Fig. 2 illustrates a waveform of a normal ECG signal. Each wave in it has amplitude and duration characteristics, with positive and negative peaks or amplitudes grouped accordingly Table V. The abnormal changes in any of these amplitudes and duration can induce a special heart condition and so, a unique ECG pattern for each, where a hyperkalemia may result in peaked T wave, long PR, QT depression, and wide QRS [7]. This work focuses on the automatic detection of many ECG features to early diagnose cardiac disorders. This is in addition to designing a complete real-time wireless design that collects and processes the biological parameters for multiple patients in the hospital, in addition to saving and displaying these signals on GUI monitors using the Laboratory Virtual Engineering Workbench (LabVIEW) environment. All hardware parts are combined with this program to show the doctor the data in real-time, preserve patient readings continuously, and record the patient's personal information. The created system enables the simultaneous monitoring of the SPO2, pulse rate, temperature and ECG. In addition to the room temperature and humidity. The rest of the paper is structured as follows: the related works are stated in the following section. Section 3 gives an overview of the hardware and software required in the system. Section 3 explains the proposed system. Section 4 shows the results and analysis of the developed system. Section 5 presents some conclusions and future works.

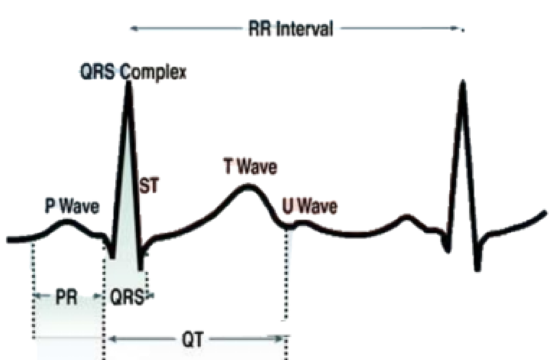


Fig. 2. Normal ECG signal [8].

TABLE I.
NORMAL VALUES OF ECG FEATURES [7, 9]

| Features | Normal limits | Amplitude | Possible disease |
|---|---|---|---|
| Heart rate | 60-100bpm | ... | Bradycardia Tachycardia |
| PR interval | 0.12-0.22 s 0.2 s for young adults | 0.1-0.2mv | AV block Atrioventricular |
| QRS width | 0.08-0.12 s | 0.8-2mv | Bundle Branch Block (R or L) |
| QT interval | 0.36-0.44s men 0.36-0.46women | .... | Hypocalcaemia Hyperkalaemia |
| ST segment | 0.08-0.12 s | 0.1mv | Hypokalemia coronary (CHD) L or R ventricular hypertrophy |
| T width | 0.1-0.25s | 0.1-0.5mv | ischemic stroke |

## II. RELATED WORKS

The medical science field has benefited greatly from the adoption of IoT to track patient health. A list of some related works to this field are discussed here. In [10], the authors suggested a fuzzy system design to decide the degree of risk according to the temperature and heart rate measurements. Many works like [11] and [12] use Arduino and DAQ micro-controllers to monitor health parameters, however, these systems need wired sensors connected to the patients. Other works [13] [14] used (python) text language that cant offer a visual GUI panel, instead it display the outputs on a small LCD.
The works [15] and [16] focus on patient data security and privacy, and provided a cloud-based safe architecture for a mobile healthcare system as well as inter-sensor communication security, offering good inter-sensor communication security. Data security was also taken into consideration [16] in addition to the cost and accuracy, where the real-time cardiac monitoring system is designed. The technology is designed to facilitate two-way communication between healthcare providers and patients, the study's major goal is to facilitate remote cardiac patients to obtain cutting-edge medical care that would otherwise be unattainable due to the low doctor-to-patient ratio. However, the previous two works employed only two sensors, including an inaccurate LM35 sensor leaving out any monitoring findings.
In other related works [17] [18] the Raspberry Pi was employed to track a patient's data. It could warn the doctor if these metrics reach an abnormal state. The patient would be dynamically monitored by the Raspberry cluster, and the data would be sent to the internet and kept on the medical

server. By using the server IP address supplied, a doctor and a patient can access patient data at anytime from anywhere in the globe. In the realm of ECG signals, prior works have explored limited approaches. Some authors utilized ECG monitoring over the cloud, displaying information on a small LCD screen [13] [19]. Another work combined IoT, Machine Learning, and an Android App for automated detection of heart defects among athletes [11]. Additionally, In [20] the authors used the ECG signal for authentication instead of eye or fingerprint. This involved feature extraction and noise elimination methods for signals with negative peaks. In a separate contribution [21], a QRS complex detection algorithm based on energy maxima computation in ECG signals was presented, allowing for cardiac frequency measurement and estimation of R peaks temporal positions. Notably, this algorithm was simulated in MATLAB, without practical implementation.
In contrast, this work introduces a secured patient monitoring model, integrating sensors for real-time vital signs tracking and continuous data reporting. The Raspberry Pi Module acquires the collected data and sends it wirelessly to a central node via a local Access Point (AP) inside the hospital, where this communication acts as fog computing to ensure the security of the patient data [22]. In addition to automatic detection and diagnosing cardiac disorders, the use of LabVIEW can ensure real-time monitoring of patient medical data especially for the ECG visualization.

## III. System Design

The proposed system utilizes some form of software and hardware parts. Below is a list of the basic components that is used to create a system.

### A. Hardware Implementation

The hardware elements that is employed in the proposed system are shown in Fig.3, where all of them are connected to the Raspberry Pi which is the central element of the design, it is a small low-cost computer, Model B+ is powered by a Micro USB 5V port, which has a two-core ARM11 processor and 512MB of SDRAM. The Raspberry Pi is chosen for this application due to its adaptability and energy efficiency. This system is easy to implement in any hospital, allowing the creation of a database to record extensive data. Moreover, the versatile features of the Raspberry Pi enable its use for various purposes [23].
The MAX30100 sensor is an integrated pulse oximetry and heart rate sensor and can also detect pulse oximetry. Its parts comprise a photo sensor, Infra-Red Light Emitting Diode (IR LED), better optics, a red LED, and low-noise analog signal processing. The MAX30100 sensor operates between 1.8V and 3.3V to save electricity while keeping an open connection at all times [24]. Fig.3.b illustrates the max30100 sensor.

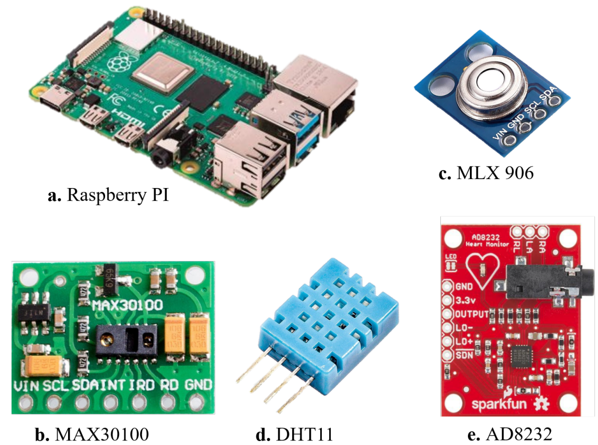



Fig. 3.
The hardware components (a) Raspberry Pi chip (b) Max30100 sensor. (c) MLX906 sensor. (d) DHT11 sensor. e.AD8232.

MLX90614 is a sensor that uses infrared to measure temperature without making physical touch. It can be used for many different things, such as detection and measuring body and environmental temperatures. This sensor's exceptional accuracy and resolution are a result of its robust DSP and internal 17-bit ADC [25].
Fig.3.c illustrates the MLX sensor. The DHT11 sensor, which is frequently used, measures temperature and humidity. The sensor has an 8-bit microcontroller for processing temperature and humidity readings serially and a specialized NTC for temperature measurement. It is simple to integrate with other microcontrollers because the sensor has been calibrated at the factory as well [26]. Fig.3.d illustrates the DHT11 sensor. Finally, the AD8232 sensor is also used for heart rate monitoring such as arrhythmia detection, stress level monitoring, and sleep quality analysis.

### B. Software Implementation

Many industries nowadays use a variety of systems to manage their operations, however, hospitals need more automation to improve their work. The LabVIEW front panel offers interactive visualizations for the obtained data, enabling doctors and patients to read and comprehend the parameters.
IoT and LabVIEW together can offer effective ways to monitor eHealth. It has a great graphical user interface that allows for the simultaneous monitoring of multiple parameters, which is typically not achievable with mobile-based applications. The system design platform and development environment for a visual programming language from National Instruments company. It makes use of a graphical programming language to let users create test, control, and measurement applications. Applications are made without lines of text and instead, use

icons. It is a virtual instrument. Block diagrams and a front panel make up the LabVIEW programming element that represents the program. The user-facing controls and indicators are displayed on the front panel, while the code for the VI is contained in the block diagram [27].
At the client side, Python programming is used for a Raspberry Pi. Python holds a first-class status on the Raspberry Pi, Python was chosen as the basic language by the Raspberry Pi Foundation specifically because of its ability and versatility [28].

## IV. Description of the Proposed System

The basic concept of the suggested system is to monitor the patients via network in addition to process their vital signs to diagnose some cardiovascular heart diseases, Fig.4 displays the overall diagram of the proposed system inside and outside the hospital, where we can divide the system into four parts, the details of the preceding two figures are discussed below:

### *A. Sensors module*

The wireless sensors are attached to the patients as a part of the monitoring system, these sensors can capture medical measurements from the patient's body.
At the other end, these sensors are connected to a Raspberry Pi, which stores the data collected by them then, transmits it wirelessly via User Datagram Protocol (UDP) to LabVIEW at the processing unit, which is connected wirelessly to the same router at the hospital, this local connection can give the system certain security advantages. Dynamic Host Configuration Protocol (DHCP), can be used to assign Internet Protocol (IP) addresses to each host. Using the acquired IP address and the PuTTY settings program the Pi desktop is opened. The Python code is thence executed in LX Terminal.
Once LabVIEW and Raspberry Pi wireless connection is run, the establishment of a UDP connection begins, where the UDP socket listens for incoming data from the sensors.
The Python side can be considered as a server that acquires

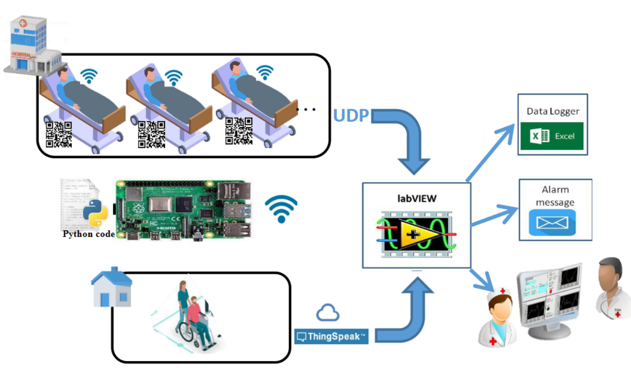


Fig. 4. Basic diagram of the proposed system.

data from the sensors, then sends it via UDP Python code to LabVIEW, which in turn receives the data, and prepares it for the next steps for display, storage, and processing. so it is the client side. Fig.5 displays the block diagram of the wirelessly received data (as heart rate here) from Raspberry PI.

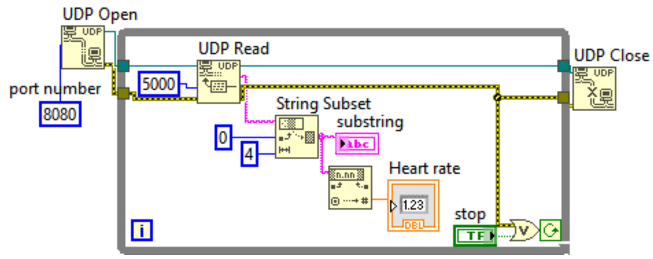


Fig. 5. wireless communication block diagram.

### *B. Data processing module*

The acquired data are then sent to the monitoring units via a Raspberry to LabVIEW for present and process these medical data as shown in the flow chart (Fig.6) of the designed system. This stage can be divide into two parts:

#### *1) Notifications:*

The first part, for notifications and alarms to doctors or physicians, when one of the vital signs is out of range (as shown in 5, an alarm is set on and an automated email system will send a notification message to the specialty doctor via email. That in turn, can propose medicament or modify the patient's prescription after reviewing the patient's prior archives. The GUI unit is equipped to generate an audible alert through a beep sound, notifying the medical staff about the abnormal case of the specific patient.

#### *2) ECG Feature Extraction:*

In this part, ECG signal is processed to elicit the important features that can give patients insights for their heart health before a doctor's diagnosis. These features (illustrated previously in V are extracted using a set of functions and algorithms provides by LabVIEW's Biomedical Toolkit and also signal processing and analysis toolkit.
In the beginning, the acquired ECG signal from the Raspberry is read and displayed on LabVIEW, then the features are obtained from each segmented heartbeat to analyse its morphology and derive the features: QRS Complex, P and T wave, total number of heart beats, PR, ST, Iso and QR level mean and standard deviation for statistics analysis. Finally, the abnormal ranges of these parameters are computed using basic LabVIEW blocks and based on Table V to facilitate the diagnosis of certain heart ailments.
By this design, patients can recognize irregularities and seek timely medical attention, fostering a proactive approach to

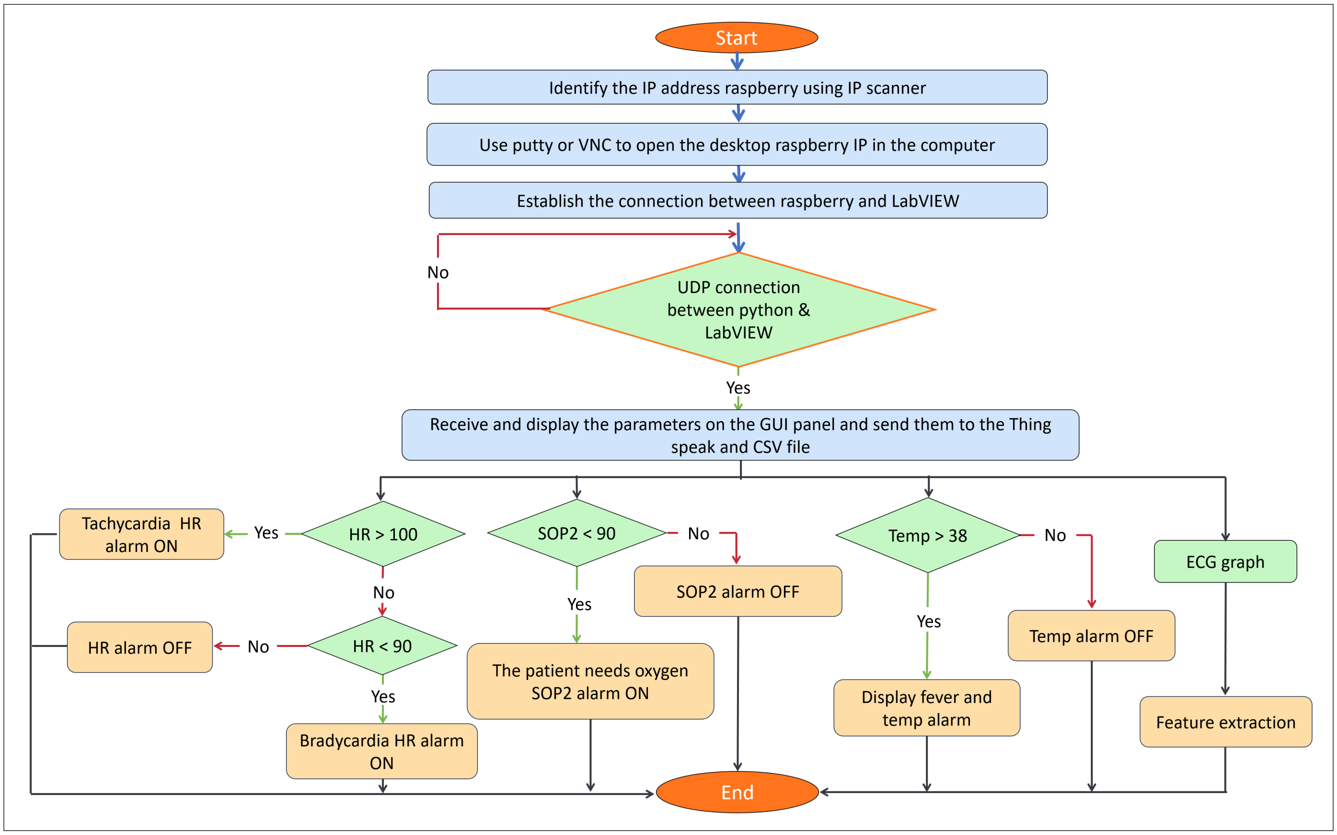



Fig. 6. Front panel of monitoring and control system

their cardiovascular well-being. On the other hand, it can aid the doctor's ability to make well-informed decisions about patient health, thereby enhancing the quality of overall health-care in hospital settings.

### *C. Data management module:*

The main part is at the hospital side, where a QR code is assigned to patients as they enter the hospital to protect sensitive patient information. These codes are acquired using chart.googleapis site and data socket VIs, In addition to that, the logged data execution is saved as (.csv) in Microsoft Excel offering a digital alternative to handwritten patient reports. Once LabVIEW has been run, the row entry of eight columns in the CSV file will be created to save the Patient's vitals. This file is stored locally in the hospital for each room. Fig.7 and Fig.8 illustrate the designed diagrams of the data management part.

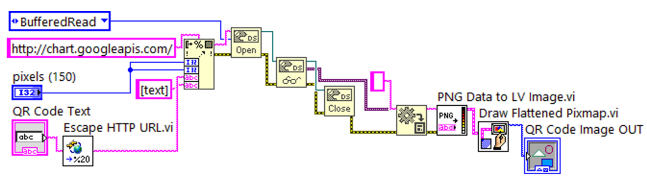



Fig. 7. The QR code block diagram.

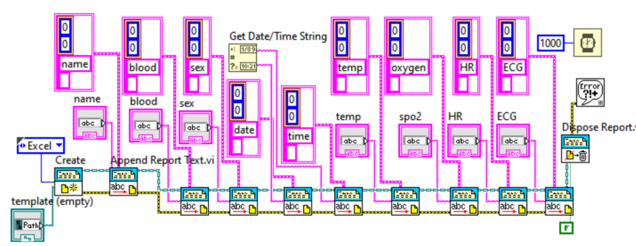



Fig. 8. Report generation block diagram.

### *D. Graphical User Interface module:*

The most attractive addition to this design is a friendly user interface to display the monitored data in real-time, this GUI is designed according to patient and hospital specialists and can be easily expanded or modified based on the number of patients or specific requirements in the hospital. For rapid diagnosis, online monitoring of crucial data is necessary, especially for ECG monitoring which can be challenging to discern on small Liquid Crystal Display (LCD) screens as in

traditional approaches.
Combining LabVIEW with IoT in this paper adds more enhancement to the health monitoring. The acquired data are sent to, displayed on, then saved in a hospital's central units. also, The doctor can launch these unit via its computer or mobile. On home side, when the patients leave the hospital, cloud-based monitoring is added to the design to provide continuous care and ensure their well-being.

## V. System Testing and Results

The complete GUI monitoring and control system's front panel is depicted in Fig.9, this program is designed for each room and many patients can be added on the upper tab control. As shown, the design is simple for doctors to monitor and manage the parameters related to patient care.
For the testing process, the UDP communication and the file path are initialized before running LabVIEW. The Raspberry Pi has the IP address 192.168.1.10 and connects to the wireless router via port 8080. In this illustration, the time is set for data execution every second (for ECG ) and a longer time for other parameters, also the file path will record and store the data in a file with the specified patient's name.
After this initialization, the designed system is tested on multiple patients having different ages and under various critical conditions at hospital. The observed data have been measured from the designed system by many scenarios for sensors measuring the important vital signs, then, these values are compared with manually measured real values using traditional tools that are currently used in the hospital.
Tables.II, III, and IV show the manual and automated obtained data for the heart-rate, body temperature, and oxygen level (SPO2) sensors respectively, each value represents the average result after many tests. The error values are obtained by dividing the differences by the actual values. From these

TABLE II.
The Actual and Obtained BPM

| Name | Age | Actual heart rate(bpm) | Observed heart rate(bpm) | %Error |
|---|---|---|---|---|
| Rania | 28 | 70 | 72 | 2.58 |
| Omer | 35 | 80 | 83 | 3.75 |
| Rand | 20 | 67 | 68 | 1.49 |
| Ahmad | 45 | 73 | 72 | 1.36 |

TABLE III.
The Actual and Obtained Body Temperature Measurements

| Name | Age | Actual temperature(C) | Observed temperature(C) | %Error |
|---|---|---|---|---|
| Rania | 28 | 37.2 | 37.8 | 1.34 |
| Omer | 35 | 36.7 | 37 | 0.81 |
| Rand | 20 | 37.3 | 37.8 | 1.34 |
| Ahmad | 45 | 37.9 | 38.5 | 1.58 |

tables and its measurements, the accuracy of the design can be approximately calculated from the % error values as follows:

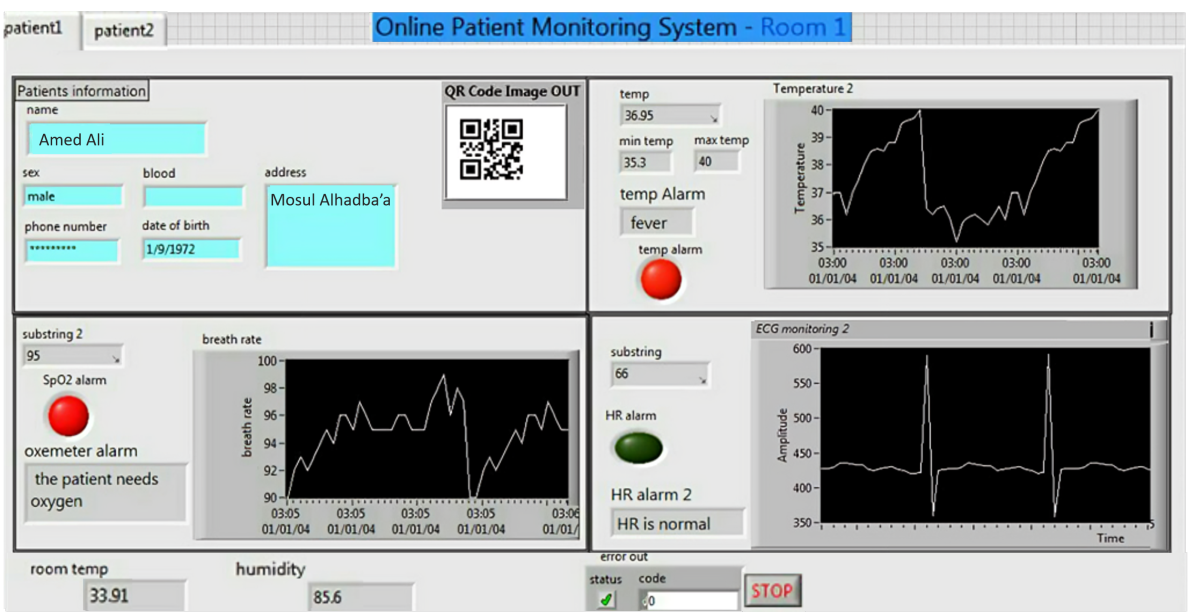


Fig. 9. Front panel of monitoring and control system.

TABLE IV.
THE ACTUAL AND OBSERVED SPO2 MEASUREMENTS

| Name | Age | Actual (SpO2) | Observed (SpO2) | %Error |
|---|---|---|---|---|
| Rania | 28 | 98 | 100 | 2.04 |
| Omer | 35 | 100 | 101 | 1.00 |
| Rand | 20 | 99 | 97 | 2.02 |
| Ahmad | 45 | 98 | 99 | 1.02 |

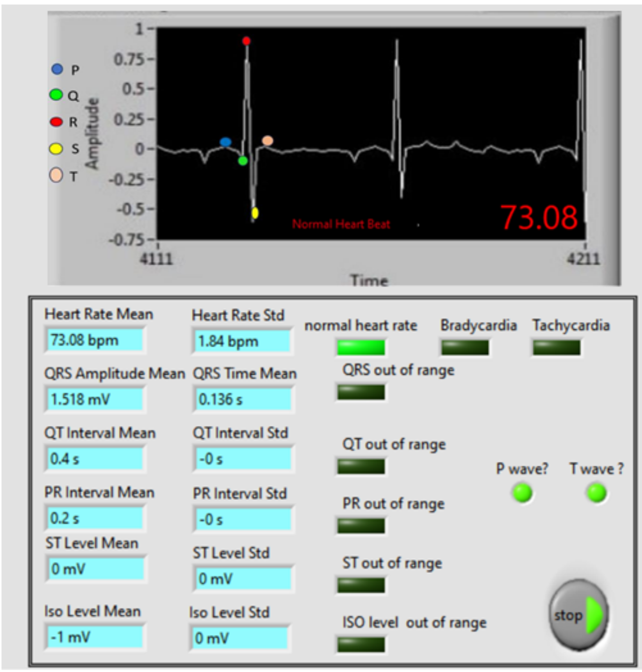
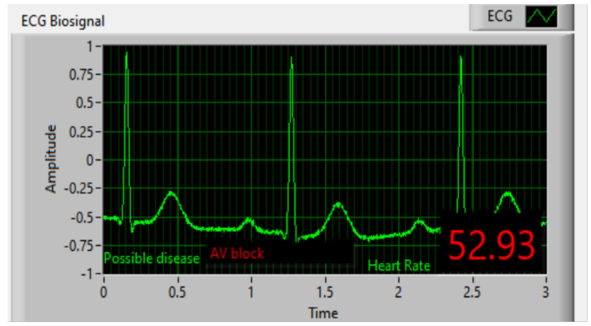
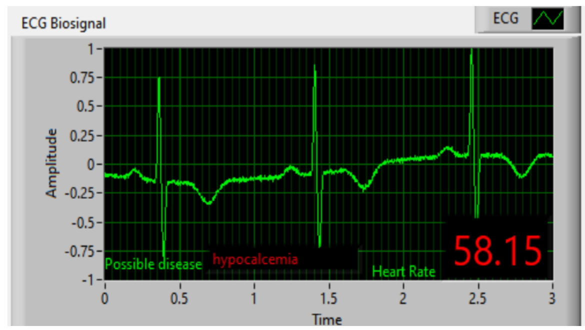



Fig. 10.
ECG features of the imported signal measured from ADS1115.

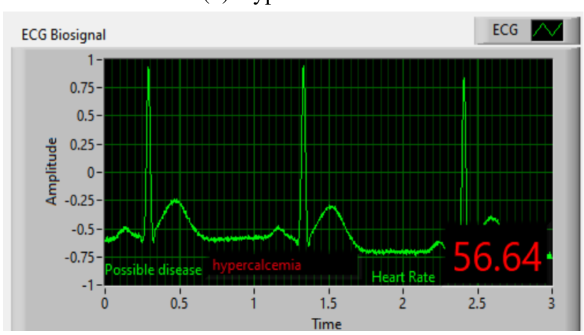
97.7% for heart rate, 98.7% for temperature readings, and 98.39% for SPO2 measurements.
For the ECG signal, detailed information is extracted using another sub-VI inside the previous one, where the QRS complex, other peaks and durations are extracted and displayed, then, the values are checked to determine if they fall within the range, display the decision on LED indicators on the GUI, as in Fig.10, where the signal acquired from the ADS1115 for a patient exhibiting normal heart health. To test the abnormality features, additional measurements are obtained from simulated signals (.tdms format) because these cases were not be encountered in a hospital setting. Our design can detect some heart diseases as shown in Fig.11.



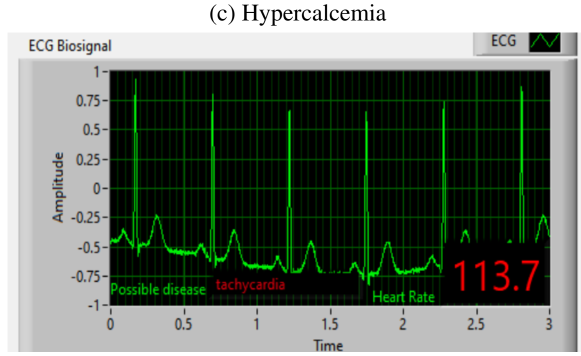

(a) AV Block




(b) Hypocalcaemia




(c) Hypercalcemia

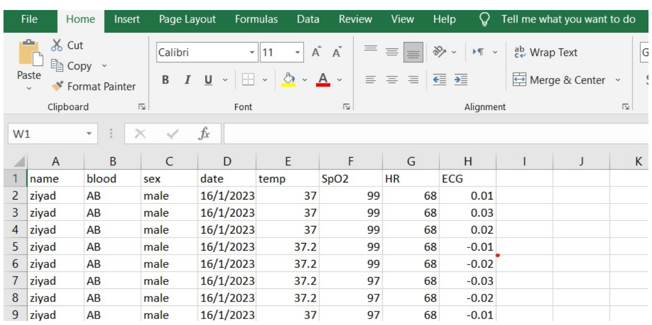



(d) Tachycardia

Fig. 11. Discovered diseases for abnormal ECG signals.

AV Block can be detected for increased PR interval, Hypocalcaemia or Hypercalcemia according to QT interval, Tachycar-

dia, Bradycardia as a relation of heart rate speed, and so on for other diseases. The graph displays the name of the possible disease and its corresponding out-of-range LED is also activated. Achieving accuracy is vital for doctors, recognizing that some diseases may not be easily detected.
For data management, the csv file is created by the designed sub VI in Fig.8, the output of this program will be opened directly once LabVIEW is run, and the table data will be filled as long as the sensors are working and the data is recorded according to the customized time interval that can be set in the design according to the hospital needs, Fig.12 shows a snapshot of the logged data presented in a tabular form containing eight columns for the patient's measurements and personal information, this file can be logged on the front panel or using an excel program.
All the previous measurements and recorded data are stored locally at the hospital to ensure it being secure. On the cloud side, the ThingSpeak is utilized for those patients who leave the hospital, where this design can also go ahead on their cases. The patient data is safe because the accessing to it requires passing via a password-protected system, which means that only authorized persons may monitor the system. Fig.13 depicts a snapshot of the real-time measured data in this web server.



| name | blood | sex | date | temp | SpO2 | HR | ECG |
|---|---|---|---|---|---|---|---|
| ziyad | AB | male | 16/1/2023 | 37 | 99 | 68 | 0.01 |
| ziyad | AB | male | 16/1/2023 | 37 | 99 | 68 | 0.03 |
| ziyad | AB | male | 16/1/2023 | 37 | 99 | 68 | 0.02 |
| ziyad | AB | male | 16/1/2023 | 37.2 | 99 | 68 | -0.01 |
| ziyad | AB | male | 16/1/2023 | 37.2 | 99 | 68 | -0.02 |
| ziyad | AB | male | 16/1/2023 | 37.2 | 97 | 68 | -0.03 |
| ziyad | AB | male | 16/1/2023 | 37.2 | 97 | 68 | -0.02 |
| ziyad | AB | male | 16/1/2023 | 37 | 97 | 68 | -0.01 |

Fig. 12. Data logger.

Finally, Table IV. compares the work with other previous ones, it evidences that the current design incorporates five crucial characteristics: the interactive front panel, local storage for most data, selective cloud storage, detected heart diseases, and the central unit protected by a QR code. The present study introduces an inventive concept by designing a comprehensive system tailored for a smart hospital, to provide many facilities for both patient relations and medical staff.

## VI. Conclusions and Future Works

In conclusion, the designed system can be easily expanded to handle hundreds of patients to receive many health monitoring services. The percentage accuracy between the observed (automated) data and the actual (manual) data is roughly more

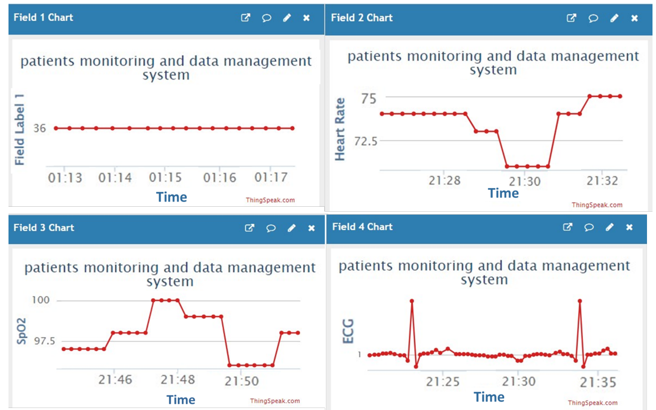



Fig. 13. Data logger.

than 98%. In times of epidemics or emergencies, this technology can also help medical professionals and nurses.
Utilizing local storage for most data and employing cloud storage selectively, strikes a balance between data security and accessibility, also the implementing a QR code-based health data management system in a hospital introduces an extra layer of security. This work gives the advantage of reducing or eliminating the need for wires near the patient in a hospital setting, consequently, patients can move more freely without being tethered to monitoring equipment by wires, which can improve their comfort and quality of life during hospital stays.
Analyzing and processing the ECG pattern provides valuable insights for doctors to identify and diagnose the electrolyte imbalances, additionally, it serves to inform patients about their health.
As for future development, for greater measurement accuracy, high-quality temperature, heart rate, and oxygen sensors are advised. Although the system appears to be relatively large, competent manufacturing will reduce it to a compact device. For face-to-face consultations between patients and doctors, a video component can be introduced.

## Conflict of Interest

The authors have no conflict of relevant interest concerning this article and the published research findings.

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TABLE V.
COMPARISON OF THE PROPOSED METHOD WITH STATE-OF-THE-ART METHODS

| [Ref.] | measured parameters | hardware model/user interface | Average accuracy | Storing form | ECG Features extracted | Main Contribution |
|---|---|---|---|---|---|---|
| [14] 2015 | SPO2 | ECG Microcontroller/no user interface | X | X | X | ECG control the flow meter vacuum to deliver the necessary oxygen to the patient |
| [20] 2018 | ECG | Simulink Matlab only | X | X | ✓ | convert a time-domain ECG signal to a colored image in a particular pattern |
| [10] 2020 | Temperature, HR | Arduino Uno / Smartphone | X | Cloud (Ubidots) | X | Design a fuzzy system to decide the degree of risk |
| [18] 2021 | Heartbeat, Blood pressure, temperature | my RIO/PC only | 98.4% | X | X | Using the real-time hardware platform NI MYRIO |
| [19] 2022 | ECG, temperature, pulse rate | NI-myRIO /PC only | 97% | cloud | X | Deep learning model |
| [13] 2023 | ECG, heart rate, temperature, SpO2 | Esp32/small OLED display or smart phone | X | cloud ThingSpeak | X | mobile and GSM application for continuous monitoring of patients |
| current work | ECG, heart rate, temperature, SpO2 | Raspberry Pi/smart phone and PC | 98.3% | cloud /local server | ✓ | Real-time Interactive GUI based secure management system automatic detection for heart diseases |

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