Al-Khwarizmi Engineering Journal, Vol. 16, No. 4, December, (2020)
P. P. 41- 51

Al-Khwarizmi Engineering Journal

Remote Patient Healthcare Surveillance System Based Real-Time Vital Signs

Qunoot N. Alsahi* **Ali F. Marhoon****
Ali H. Hamad***

**Department of Computer Science/ University of Basrah /Iraq*
***Department of Electrical Engineering/ University of Basrah /Iraq*
****Department of Information and Communication Engineering / Alkhwarizmi College of Engineering / University of Baghdad*
*Email:Qunootalsahi@gmail.com
**Email: ali.marhoon@uobasrah.edu.iq
**Email: ahamad@kecbu.uobaghdad.edu.iq

(Received 16 August 2020; accepted 20 October 2020)
https://doi.org/10.22153/kej.2020.10.003

Abstract

Today many people suffering from health problems like dysfunction in lungs and cardiac. These problems often require surveillance and follow up to save patient's health, besides control diseases before progression. For that, this work has been proposed to design and develop a remote patient surveillance system, which deals with four vital signs (temperature, SPO_2, heart rate, and electrocardiogram ECG). An adaptive filter has been used to remove any noise from the signal; also, a simple and fast search algorithm has been designed to find the features of ECG signal such as Q, R, S, and T waves. The system performs analysis for medical signs that are used to detected abnormal values. The acquire data from different sensor are sent to the Base-station if it have some medical issues, otherwise new data window are taken for analysis. In addition, it generates an alarm to the physicians via ringing up mobile and SMS to overcome the internet disconnected. The system has been designed to achieve precision, small size, and low energy consumption. Three types of sensors have been used in this work, ECG, SPO_2, and temperature sensors. Also, a sim800L GSM module has been used for communications, the main controller in this work is ESP32 unit.

Keywords: *Remote Healthcare, ECG, SPO_2, adaptive filter, QRS features, GSM.*

1. Introduction

Recently, health issues have increased day by day in our life, Where chronic diseases such as (heart disease, lungs, hypertension) that need continuous monitoring. In addition to epidemics like (COVID-19, SARS), etc. constitutes great concerns for people due it often leads infection transmitted and disease spread then causing death. So like that cases need to provide telemedicine concepts including tracking and real-time monitoring to health conditions, hence they need frequent visits to clinics and hospitals[1],[2]. However, healthcare constitutes an essential and important part of life. Which require an attention to the health system and making it smarter. The traditional health systems suffering from many issues such as lack of medical staff and medical equipment, in addition to the effort made by physicians and patients and the cost of money and time. So, smart healthcare systems prepare means of low cost and small size to surveillance an individual's health[3].

ECG measures the rhythm and rate of a pulse, also introduces indirect proof on the flowing blood to the heart [4]. Besides, it gives a perfect picture of the effectiveness and activity of the individual's heart muscle. Many abnormalities can be observed as the electrical signal analyzes each heartbeat. The ECG signal consists of some basic features such as P, QRS, and T, where the ECG signal can be cut into segments are PQ, QRS, and ST-segment as shown in Fig.1. So, the period of each segment should be computed to determine the heart conditions precisely.

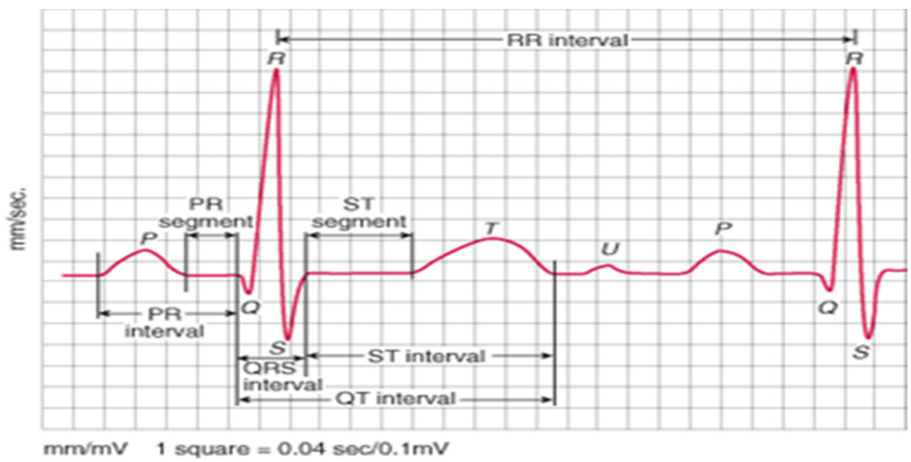


Fig. 1. Structure of the ECG signals [14].

In this work, a proposed telemedicine system monitors the 3-physiological parameters of the patient's body (ECG, SPO_2, and Temperature). These physiological parameters are analysed to notify physicians about any abnormal conditions, besides, these abnormal states are stored in a system database. The proposed system uses an alert system based SIM800L GSM module to inform the physician about the abnormal status of patients.

The rest of the paper is organized in the following sections. In section 2, background and related works are discussed. In section 3, proposed system design. In section 4, proposed system software design. In section 5, result and discussion. In section 6, conclusion.

2. Related Work

Studies view some papers for healthcare systems. In 2016, Hossein and Shaikhan [5] proposed an android application to monitor the patient's health and medical-application to show the patient's information based on NFC tags, and it utilized a web server to store patients data. In 2017 kale et al [6], proposed a system aimed to monitor the patient outside the hospital in a cost-effective manner. The system handles two vital signs (heart rate, temperature) besides track patient activity via an acceleration sensor. Also in 2017 Kaur and Jasuja [7] proposed a system looking for heart rate and temperature using raspberry pi and IoT platform, but it focuses on the cost and accuracy and discards real visualize of patient's health that requires more vital signs such as(respiratory rate and regularity ECG signal, etc.). In 2017, Alamelu and Mythili [8], designed the Internet of Health Thing architecture (IoHT) for a healthcare system that used wireless sensor networks in IoT environment for a health monitoring system. The system consists of a source node that acts as a sensor node and a sink node represent in Personal Digital Assistants PDA. The weakness in this work is the energy consumption of health monitoring applications. In 2018, Mehmet Taştan [9] proposed a system to handle heart rate variability and temperature besides, a real-time location of the patient. The system sends E-mail notification if the values exceeded normal conditions, this work dependent on the internet in alarm. Also In 2019, Shaown et al [10] designed a system that is frequently monitoring the ECG signal by using wearable sensors. Where it notifies the users and physicians via Email when found any malformation in ECG which makes [9], [10] useless in case of internet disconnect. In 2019, Tamura [11], proposed a system to monitor blood pressure depended on the IoT platform to facilitate home-based healthcare. Also in 2020, Acharya and Patil [12], proposed a system to monitor the vital signs of people to predict their health using Arduino UNO and raspberry pi.

3. Proposed System Design

Generally, the proposed system is smart enough to collect vital signs from patient's body and analyzed it to predict when abnormalities occur, then alert physicians and opened a connection to send data to the Base-station to save it in patient's medical record. Basically, the proposed system composes of three layers that are sense layer, transport layer, and application layer as shown in Fig.2

Sensing layer: consists of a wearable wireless body area sensor network that responsible for data collection from the patient's body then send to be processed and analyzed in the processing unit (ESP32).

Transport layer: represented by the communication protocols (HTTP) that is responsible for the connection between the patient side and the server-side.

Application layer: this layer responsible for the system data view process. This layer is represented by the web application, which allows physicians to access and view the health conditions of their patients.

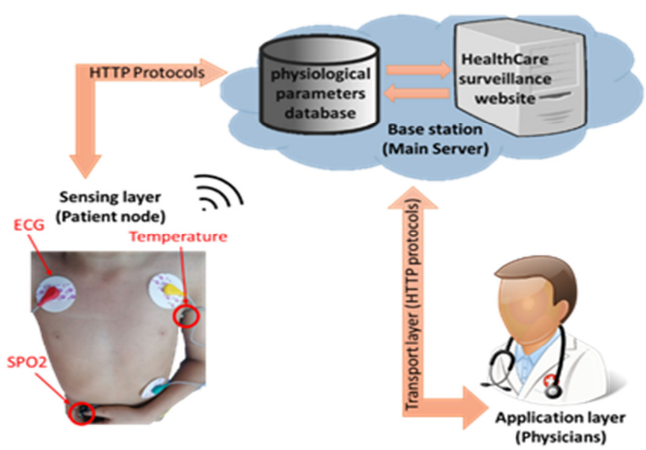


Fig. 2 General architecture of the healthcare system

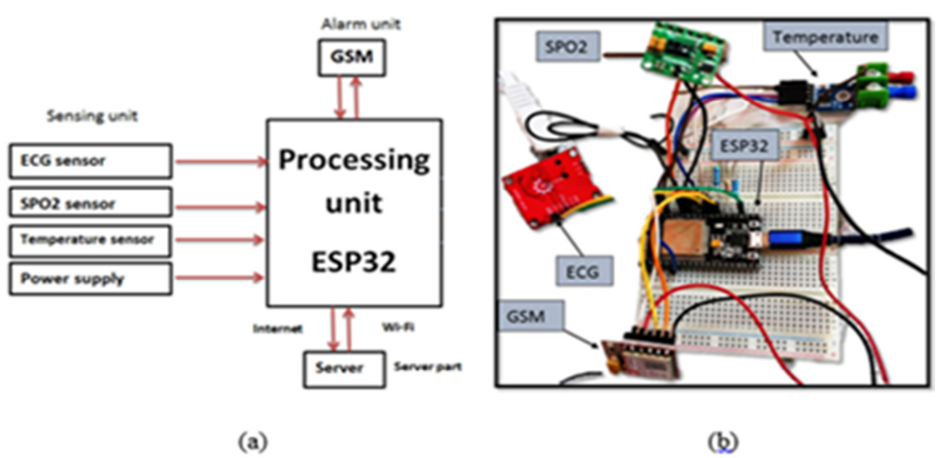


Fig. 3 (a) Patient-Node schematic diagram, (b) Patient-Node hardware design.

The system consists of hardware and software that works and interacts in synchronized with each other.

1) Patient-node: the patient node composes of many units that are connected to achieve the system-required tasks. Fig.3 shows a patient unit schematic diagram, these units consist of:

1.1 Sensing-Unit (WBSN): this unit consists of several sensors that form Wearable Body Area Sensor Network (WBASN). This sensor network attaches to the patient's body to gather the physical parameters (ECG, SPO_2, and Temperature). This sensor network should be configured with a microcontroller to control the network jobs.

1.1.1 Heart Respond Measurement: The AD8232 ECG monitoring sensor utilized in this work is connected with the ESP32 microcontroller through an Analog-to-Digital Converter (ADC). It has 3-leads (RA: Right arm, LA: left arm, LL: Left leg) that are fixed on the various points of the human torso as shown in Fig. 4. The ECG signal processing passes via three stages shows in Fig. 5:

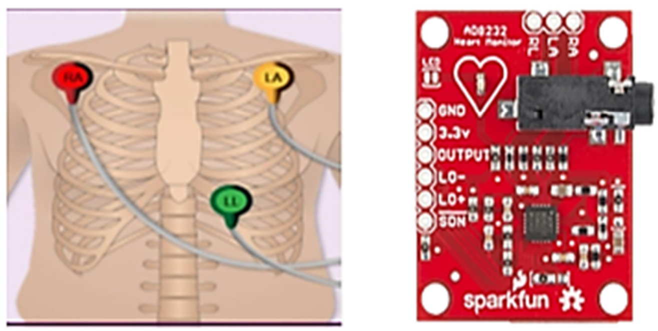


Fig. 4 (a) Proper placement of the electrodes, (b) ECG sensor.

Fig. 5. ECG signal-processing stages.

In the Pre-Processing stage, the digital value of the built-in ADC (Successive Approximation Register 12 bit type) in ESP32 microcontroller is calibrated into its original values. The following formula is used to convert

the digital code into a millivolt values [13].

$$\text{ECG signal in mV} = \frac{(\text{ADC output} - \text{ADC offset}) * \text{ADC sensitvity}}{\text{Gain}} \quad \ldots(1)$$

Where:

$$ADC\ \text{sensitivity} = \frac{\text{Vref.}}{\text{ADC max}} = \frac{3300\ \text{mV}}{4095} \quad \ldots(2)$$

Where ADC output= ECG data in digital form, ADC offset = 2060, and Gain =100.

.b In the Filtering stage, an adaptive filter is applied to eliminate several forms of noise that distorting the shape and features of the signal [13].

ecg_adp (nT) =α* ecg_adp (nT-T) + (1-α)* ecg _raw (nT) … (3)

Where ecg_raw (nT) is the current value of ECG signal.

ecg_adp (nT) is the filtered ECG signal.

n = 1 ……….∞.

α is the balance coefficient (default is 0.95).

c. In the Feature Extraction stage, a search algorithm is applied to detect ECG signal features[13]. The basic principle of the algorithm is based on a threshold value where the upper threshold used to find R-peak while lower threshold are used to find S-peak as shown in Fig.4 The following formulas are used to find thresholds:

R_threshold = (max data in 1000 sample/2) …(4)

S_threshold = (min data in 1000 sample/2) …(5)

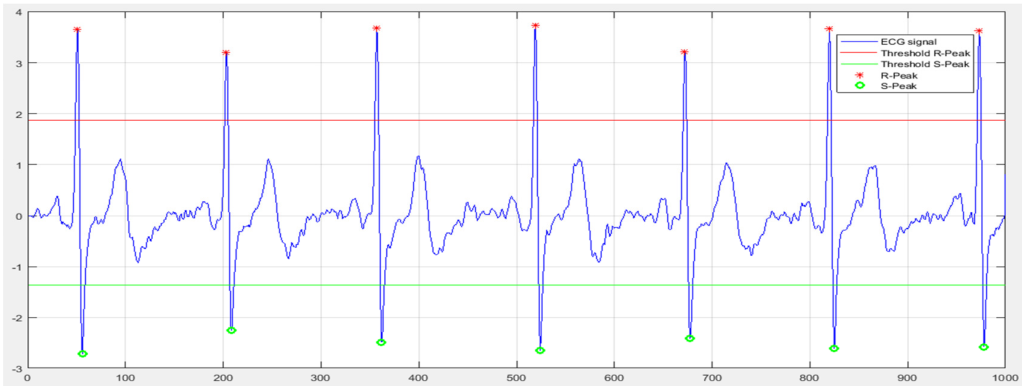


Fig. 6. Upper and lower threshold in ECG signal.

Then, applying a searching algorithm to find R-Peaks that satisfy the threshold of R-peak for 1000 samples of ECG data. According to the index of R-peak, the rest (P, Q, S, T) features are obtained such that: Q-Peak present at 10 points before R-Peaks and S-Peak at 10 points after R-Peak, so the search algorithm applies at the window of index[R-15] to [R] to find Q-Peak and index[R] to[R+١٥] to find S-Peak, hence QRS complex could be found. While P-peak and T-Peak present at 100 points of index R-Peak, then applying search routine at index[R-100] to [R -25] for finding P-Peak occurred before R-Peak and for finding T-Peak occurred after R-Peak applies search algorithm at index of [R+100] to [R+25]. Then the intervals of PR, QRS, and QTC are calculated, in addition to a heart rate that calculates from equation [14]

HR = Fs*60/ RR interval …(6)

Where **HR** is the heart rate, **Fs** = 200Hz is the sampling rate, and **RR** is the average RR intervals. Thus, if any of these parameters exceed the allowable values (normal value) classified as abnormal conditions by the system as shown in Table 1.

Table 1,
Normal values of the medical parameters.

Medical parameters	Normal value
Heart rate (HR)	60 – 100 pbm
PR intervals	120 – 200 m sec.
QRS duration	80 – 100 m sec.
QTc	390 – 450 m sec.
Temperature	36 ℃
SP$\mathbf{O_2}$	94 - 100%

1.1.2 Oxygen saturation monitoring: Blood oxygen (SP$\mathbf{O_2}$) is the mean percentage of oxygen ($\mathbf{O_2}$) that must be carried in the blood, where the normal values are in the range of (94 – 100) [14]. So it is important to measure the amount of $\mathbf{O_2}$ in the blood, since the raising or lowering ratio of $\mathbf{O_2}$ causes several diseases, for instance, an increase in $\mathbf{O_2}$ concentrations causes some cases of poisoning, and this is due to a defect in some vital signs of the lungs. Where the SP$\mathbf{O_2}$ can be measured using the Max30100 sensor as shown in Fig. , which is attached to the fingertip, and can be wired with the microcontroller via an $\mathbf{I^2C}$ protocol (SDA and SCL pins). So when the sensor reading the SP$\mathbf{O_2}$ value less than 90 or more than 100, the system classifies these reads as abnormal values.

Fig. 7. SPO_2 sensor.

1.1.3 Body temperature measurement: Temperature is one of the essential vital signs that aid in defining the health issues of the body vital functions. To measure the temperature there are four ways are Axillary, Oral, Tympanic, and Rectal [17,18]. In this work, the MAX6675 sensor is utilized to measure the temperature see Fig.8, which is connected with microcontroller via SPI protocol (SCK, CS, SO). The normal value of the human body temperature is 36 ℃, so when the sensor reading temperature less than 36 ℃ or more than 37.5 ℃, then it will be classified as an abnormal value by the system.

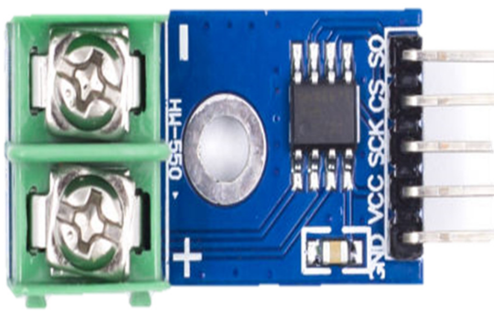


Fig. 8. Temperature sensor.

1.2 Processing-Unit (ESP32)

The embedded system that is used in the proposed system relies on a mini-board named the microcontrollers, which includes memory, processing units, and Input/ Output pin [17]. The microcontroller that is utilized in our work is ESP32; it is an open-source environment based on easy to utilize software and hardware [18]. ESP32 can be programmed via sending the instructions to the microcontroller to be stored in the memory. The ESP32 has two type of communication technologies, which are Bluetooth and Wi-Fi (which has been used in this work)

1.3 Alarm-Unit

This unit is an important and essential issue in the proposed healthcare system due to its usefulness in the alerting process of abnormal conditions. It mainly consists of GSM that is used to alerting physicians in the manner of calling and SMS that includes all vital parameters, containing an abnormal value. In this sense, the physician gets alert via call and SMS in real-time, anytime, and anywhere. The GSM SIM800L model utilized in our system and can be wired with ESP32 via the serial port as shown in Fig.9.

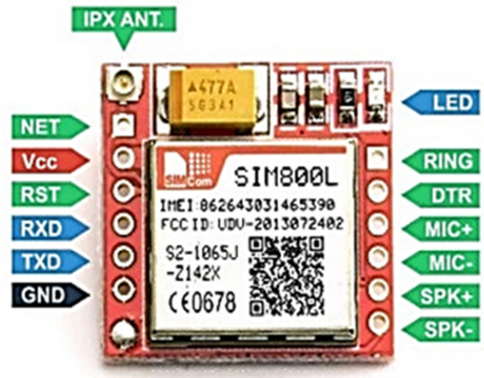


Fig. 9. SIM800L module.

2) Base- Station: Base-station coordinates the job of each part inside the proposed system. This part represents the intermediate node that connects all parts of the system see Fig. 2 .A Raspberry pi has been used as the main server, which is responsible for storing patients' node data in the hospital data centres, where it communicates with a patient's node through HTTP protocol. When abnormal conditions occurred, the patient node will send data to the Base-station to notify the physician via ringing his mobile, and then he requests the page that view vital signs of the patient from the server.

4. Proposed System Software Design

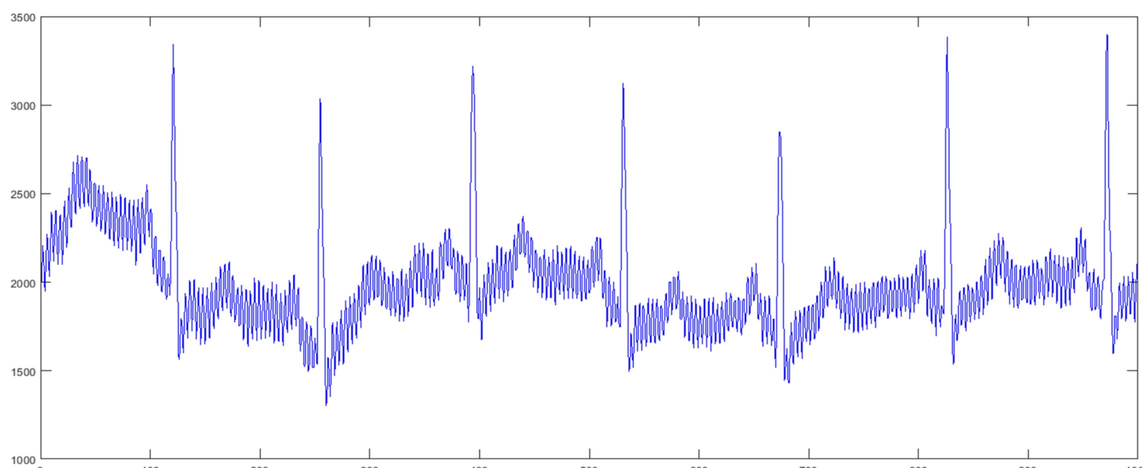
The proposed system software design is represented by Algorithm 1 where different sensors data are collected by patient-node which is wears by the patient himself, then process these data by the ESP32 unit to check if it is a normal or abnormal data as shown in Table1. If any abnormality occurs an alert message would be sent to the physician responsible to that patient. Algorithm 1 represents the details for the ECG signal since it considers the most important signal in the system.

Algorithm 1

Connected Wi-Fi
Read data from different sensors according to sampling rate (for each sensor)
While(True)
{
Read 1000 sample of ecg signal;
Call a routine to analyzed ecg signa;,
Find ecg features P, QRS, and T periods;
Compute heart rate;
***If** (all vital signs == normal)*
status = abnormal;
***Else** status = normal;*
***If** (status == abnormal) :*
Alert doctor by ringing up his mobile and send SMS contain medical data value.
Establish a connection and upload packet to Base-Station (Server)-show abnormal data in the web page.
***Else**:*
Discard the data packet
}

5. Results and Discussion

The developed prototype healthcare monitoring system has trends to be an effective and practical medical tool in most of the modes and conditions. This system allows monitoring the electrical activity of the heart and analyzed it. Fig. 8, Fig.10 (a) shows the raw data signal obtained from healthy personal, while 10 (b) shows the recorded signal after filtering the noise. The system records the window of ECG signal with 5 sec that is sufficient to record more than one pulse, and then check each pulse in this window to make a decision, which enhances the accuracy and response time of the proposed system. In order to give a chance for the physicians to diagnose heart diseases more precisely during real-time remote monitoring. The ECG recorded signal is provided to the physicians is essential to diagnoses in the ECG frame rather than depending only on the heart rate. Besides, provides essential vital signs like temperature and SPO_2 see Fig.11. Where providing this information in anytime-anywhere in the world, so it used the web page to achieve this aim. After collecting data from the patient's body, the system has been analysed and diagnosed whether they are abnormal conditions as shown in Table 2, where it makes a calls the doctor to inform him that there are emergency conditions. This alert is made using GSM technology in order to overcome the problem of internet disconnection. The abnormal data are transferred to the base-station (main server) to be stored using the HTTP protocol (server-client scheme). This analysing process is accomplished locally (patient's node), which reduces the communication time with the server that reduces the power consumed.



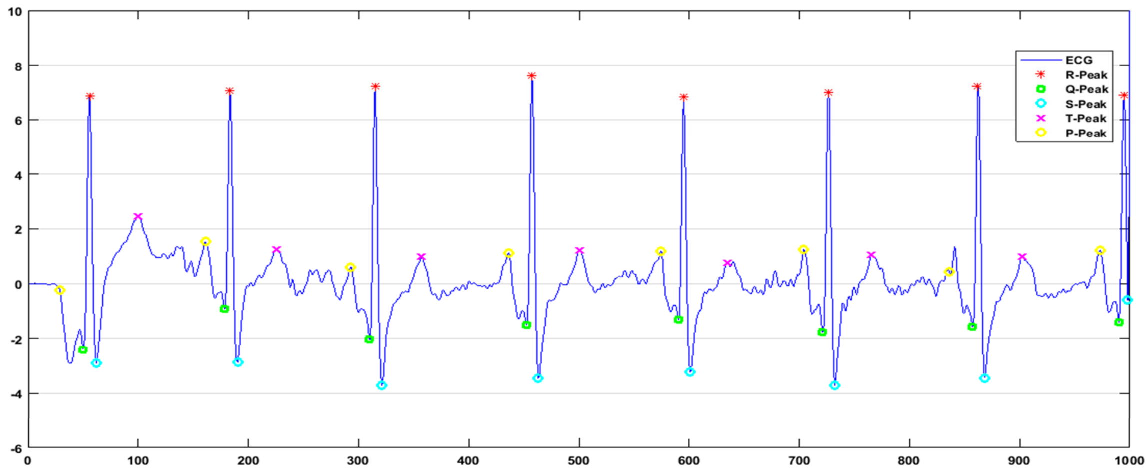


Fig. 10. (a) ECG signal before the filtering process. (b) ECG signal after applying filter and Feature extraction.

Fig. 11 Web-page of vital arameters.

Table 2,
Experimental results of real persons.

ID	Age	Gender	Temperature Normal 36 C̊	SPO_2 Normal 94-100%	HR Normal 60-100 bpm	Status
1	25	Mail	36.10	95.60	73	**Normal**
2	20	Female	36.03	97.50	65	**Normal**
3	42	Female	36.40	93.50	75	**Abnormal**
4	46	Mail	36.50	99.00	68	**Normal**
5	55	Female	38.00	96.05	86	**Abnormal**
6	63	Mail	36.50	98.20	78	**Normal**

The proposed system has been used practically in real-time with different patients with different status such elderly people, chronic diseases, infectious, and critical conditions (emergency). Table 3. shows different hardware used with their power consumption.

Table 3,
Power consumption of hardware design [18],[19].

Devices	Voltage	Current
ESP32	3.3v	0.5 A
AD8232	3.3v	170 μA
MAX30100	3.3v	20 mA
MAX6675	5v	50 mA
SIM800L	5v	131-216 mA

6. Conclusion

This work is an improvement of most existing health surveillance systems, where the designed system considers aspects of precision, size, energy consumption, and limited resource in health centres. The system has been designed to transition to smart systems to provide medical services better than the traditional form and to preserve the lives of people. As well as to reduce death rates because of delays in providing medical services or discovering diseases and its access to stages advanced. The system is smart enough to collect the vital signs from the patient's body and analysed to detect the abnormal condition (emergency). Hence, it can be deciding to alert physicians and transferring data to the server to enable the physicians to assess the patient's condition. The physicians can access the abnormal conditions via a designed web page for this purpose.

7. References

[1] M. M. Baig, H. GholamHosseini, and M. J. Connolly, "Mobile healthcare applications: system design review, critical issues and challenges," *Australas. Phys. Eng. Sci. Med.*, vol. 38, no. 1, pp. 23–38, 2015.

[2] K. Y.-C. Hsieh and A.-C. Tung, "Taiwan's National Pension Program: A remedy for rapid population aging?," J. Econ. Ageing, vol. 8, pp. 52–66, 2016.

[3] F. Leu, C. Ko, I. You, K. K. R. Choo, and C. L. Ho, "A smartphone-based wearable sensors for monitoring real-time physiological data," Comput. Electr. Eng., vol. 65, pp. 376–392, 2018.

[4] M. Pereira and K. K. Nagapriya, "A novel IoT based health monitoring system using LPC2129," RTEICT 2017 - 2nd IEEE Int. Conf. Recent Trends Electron. Inf. Commun. Technol. Proc., vol. 2018-Janua, pp. 564–568, 2017.

[5] H. R. Hossein and S. S. Shaikh, "SPHPMS: Smart personnel m-healthcare patient monitoring system," Int. Conf. Electr. Electron. Optim. Tech. ICEEOT 2016, pp. 1750–1753, 2016.

[6] S. Kale, S. Mane, and P. Patil, "IOT based wearable biomedical monitoring system," Proc. - Int. Conf. Trends Electron. Informatics, ICEI 2017, pp. 971–976, 2017.

[7] A. Kaur and A. Jasuja, "Health monitoring based on IoT using Raspberry PI," in 2017 International Conference on Computing, Communication and Automation (ICCCA), pp. 1335–1340, 2017.

[8] J. V. Alamelu and A. Mythili, "Design of IoT based generic health care system," 2017 Int. Conf. Microelectron. Devices, Circuits Syst. ICMDCS 2017, vol. 2017-Janua, pp. 1–4, 2017.

[9] M. Taştan, "IoT Based Wearable Smart Health Monitoring System," Celal Bayar Üniversitesi Fen Bilim. Derg., vol. 14, no. 3, pp. 343–350, 2018.

[10] T. Shaown, I. Hasan, M. M. R. Mim, and M. S. Hossain, "IoT-based Portable ECG Monitoring System for Smart Healthcare," *1st Int. Conf. Adv. Sci. Eng. Robot. Technol. 2019, ICASERT 2019*, vol. 2019, no. Icasert, pp. 1–5, 2019.

[11] T. Tamura, "Connected healthcare system to monitor the blood pressure of clients with an unobtrusive device," *Med. Meas. Appl. MeMeA 2019 - Symp. Proc.*, pp. 1–6, 2019.

[12] A. D. Acharya and S. N. Patil, "IoT based Health Care Monitoring Kit," *Proc. 4th Int. Conf. Comput. Methodol. Commun. ICCMC 2020*, no. Iccmc, pp. 363–368, 2020.

[13] A. F. Marhoon and A. H. Hamad, "A new real-time resource-efficient algorithm for ECG denoising, feature extraction and classification-based wearable sensor network," *Int. J. Biomed. Eng. Technol.*, vol. 18, no. 2, pp. 103–114, 2015.

[14] S. Ramakrishnan, "Design and Analysis of Feature Extraction Algorithm for ECG signals using Adaptive Threshold Method," *2017 Trends Ind. Meas. Autom.*, pp. 1–8, 2017.

[15] Q. N. and A. F., "Design Health care system using Raspberry Pi and ESP32," *Int. J. Comput. Appl.*, vol. 177, no. 36, pp. 33–38, 2020.

[16] M. A. Mahmoud, M. A. M. El-bendary, and M. Eltokhy, "Transfer Some of the Vital Signs of the Body by using Wireless Sensor Network," pp. 1665–1679, 2020.
[17] A. W. Brand, "Raspberry Pi for Dummies." John Wiley and Sons, New Jersey, 2013.
[18] M. Babiuch, P. Foltynek, and P. Smutny, "Using the ESP32 microcontroller for data processing," *Proc. 2019 20th Int. Carpathian Control Conf. ICCC 2019*, pp. 1–6, 2019.
[19] Shanghai SIMCom Wireless Solutions Ltd. "SIM800L Hardware Design V1.00", Shanghai, 2013.

نظام مراقبة الرعاية الصحية للمرضى عن بعد يعتمد على الإشارات الحيوية في الوقت الحقيقي

قنوت نايف الساهي* **علي فاضل المرهون****
علي حسين حمد**
قسم علوم الحاسوب/ كلية التربية للعلوم الصرفة /جامعة البصرة /العراق
***قسم الهندسة الكهربائية/ كلية الهندسة / جامعة البصرة /العراق*
****قسم هندسة المعلومات و الاتصالات/ كلية الهندسة الخوارزمي/ جامعة بغداد/ العراق*
*البريد الالكتروني: Qunootalsahi@gmail.com
** البريد الالكترونيali.marhoon@uobasrah.edu.iq:
*** البريد الالكتروني: ahamad@kecbu.uobaghdad.edu.iq

الخلاصة

في يومنا هذا الكثير من الناس يعانون من مشاكل صحية مثل مشاكل في الرئتين والقلب، وغالبًا ما تتطلب هذه المشكلات المراقبة والمتابعة للحفاظ على صحة المريض، إلى جانب السيطرة على الأمراض قبل تفاقمها. لذلك ، تم اقتراح هذا العمل لتصميم وتطوير نظام مراقبة المريض عن بعد، والذي يتعامل مع أربع علامات حيوية (درجة الحرارة، تشبع الاوكسجين، ومعدل ضربات القلب، وتخطيط القلب الكهربائي). حيث تم استخدام مرشح Adaptive filter لإزالة أي ضوضاء من الإشارة، بالإضافة الى ذلك تم تصميم خوارزمية بحث بسيطة وسريعة للعثور على ميزات إشارة ECG مثل موجات Q و R و S و T. حيث يقوم النظام بتحليل العلامات الطبية التي يتم استخدامها للكشف عن القيم غير الطبيعية. حيث يتم إرسال بيانات التي تم الحصول عليها من المستشعرات المختلف إلى المحطة المركزية في حالة كون هذه البيانات غير طبيعية ، وإلا فسيتم أخذ نافذة بيانات جديدة للتحليل هذه البيانات وصنع القرار حولها. بالإضافة إلى ذلك ، في حال كون الحالة الصحية غير طبيعية فإنه يرسل إنذارًا للأطباء عبر رنين الهاتف المحمول والرسائل النصية القصيرة للتغلب على انقطاع الإنترنت. حيث تم تصميم النظام لتحقيق الدقة وصغر الحجم واستهلاك الطاقة المنخفض عبر استخدام ثلاثة أنواع من أجهزة الاستشعار في هذا العمل ، ECG، SPO2، وأجهزة استشعار درجة الحرارة. أيضًا ، تم استخدام وحدة sim800L GSM للاتصالات ، ووحدة التحكم الرئيسية في هذا العمل هي وحدة ESP32 .