International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. 10, No.2 (Mar-2021)

http://dx.doi.org/10.12785/ijcds/100135

Portable Heartbeat Rate Monitoring System by WSN Using LabVIEW

Fawaz Yaseen Abdullah[1], Mohammad Tariq Yaseen[1] and Yasir Mahmoud Hussien[1]

[1] Department of Electrical Engineering, College of Engineering, University of Mosul, Mosul, Iraq

Received 4 Jul. 2020, Revised 26 Nov. 2020, Accepted 30 Nov. 2020, Published 8 Feb. 2021

Abstract: In this paper, we present a prototype for heart rate monitoring. Heart rate monitoring technology can be achieved using the Wireless Sensor Network (WSN) and the LabVIEW platform. This proposed system deploys integrated devices to monitor individuals in periodic periods via wireless technology. As Biological factors are the only factors that can determine whether an individual is in normal health conditions. The first stage of the proposed system includes monitoring the heart rate, where the heart condition is the most vital sign, to determine the health status of individuals suffering from stress, and thus, converting abnormal states to fully verify the heart signal as the second stage signal. Then the collected signals are fed to LabVIEW setup for visualizing data, diagnosis and suggest treatment by medical specialists. As an experimental test, the proposed system was applied on football players in the field. As a result, medical specialists could be able to check the health of the players remotely during training sessions or real competitions. This system would save players' lives in an emergency situation. Therefore, this portable heartbeat monitoring system could play a vital role in many applications.

Keywords: Heartbeat Rate Monitoring, WSN, Health Status

1. Introduction

The death rate in the world has been increasing recently due to cardiovascular and other chronic diseases. Cardiovascular diseases are certain kind of disorders that damage the heart, veins, and arteries. Heart related cardiovascular diseases are like heart attack, stroke, and heart failure. On the other hand, blood vessels related cardiovascular diseases are like coronary artery disease, which are known as vascular diseases.

World Health Organization (WHO) showed that cardiovascular diseases are the most reason for death in the world [1]. In the United States, cardiovascular diseases remain the first reason for the death of patients [2]. Moreover, statistics in Europe, which are based on data from different health institutes such as the European Health Network, showed that in average 2 million deaths duo to cardiovascular disease yearly. Using Heart Rate Monitor is not only limited to healthcare monitors in the hospital or for the elderly. But, it can be used in sport fields as well. The Heart Rate Monitor will help monitor athletes during both performance and rest periods to maximize the training benefits [3].

The real-time monitoring of individuals suffering from heart problems, particularly patients with cardiovascular diseases, is a significant task [4]. Real-time monitoring of people can help reduce the necessity of direct monitoring by the human in the field and guarantee the monitoring of patients at urgent medical conditions without using substantial and expensive health management. Thus, the embedded monitoring system development is very vital. Also, it is promising to implement real-time monitoring system by incorporating the electrocardiogram (ECG) signal detection and its processing on the same board [5].

Direct heartbeat detection and real-time heart rate monitoring are the main concerns in modern medical care. Different studies have revealed that many of the cardiovascular diseases could be well recognized, managed, and avoided by real-time monitoring and analysis of electrocardiogram signals [6].

Therefore, the real-time monitoring of body signals like (ECG) signals would open a new general model for the evaluation of cardiovascular disease, which would help control and avoid the disease. Technology developments in different fields like communication networks, signals, and data processing could help improve

E-mail: fawaazyasen@uomosul.edu.iq

the performance of real-time monitoring which would provide a new smart, active medical care [7].

Different methods have been deployed recently to identify the QRS complex within the (ECG) collected signal. Various approaches in the used methods reveals the development in the field of signal and data processing. For instance, methods based on the discrete wavelet transform (WT), R-wave slope, support vector machines, and neural networks [8-11] have been proposed to identify the QRS complex. In addition to different other methods [12-15].

Nowadays, smart systems based on electronic devices have attracted people’s attention in many fields. Accordingly, designing a new smart system is not related to the used software only. it would be related to the hardware implementation as well to decrease the power consumption and the final system size. Hardware implementation using various new electronic devices has become the best tool for developing medical care systems. These developed systems can handle complex functions because of their certain purpose devices, cost effective, and flexibility [16].

The main objective of this work was to enable the usage of simple and low power compact sensor networks for real-time and fast patient monitoring, which could be very beneficial in many applications such as health care monitoring and sleep monitoring.

In this paper, we present a prototype for monitoring of heartbeat rate. This heartbeat rate monitoring technique can be realized by using a wireless sensor network (WSN) and LabVIEW application. This proposed system is using real-time heart pulse devices (HPDs) to monitor players during work and rest periods to maximize the training benefits via wireless technology. Biological factors are the only factors that can determine whether the players are in normal health conditions or not. HPDs have been utilized as a training aid equipment in the sport field. Moreover, the development of new HPDs has grown swiftly. Consequently, HPDs are mainly utilized to assess the training intensity during the training session. Heart rate signal is easy to collect and monitor. It also involves rich information of exercise intensity compared to the other indication.

This paper was arranged as follows. In the second section, the used setup of wireless heartrate monitoring system is described. Section three describes the experimental results and discussion of this work. Finally, we summarized all conclusions and future recommendations based on this proposed system.

2. Wireless Heart Rate Monitoring

In this section, the description of the proposed system via utilizing wireless sensor network is demonstrated. The flowchart and block diagram of the proposed heart rate monitoring system can be implement as shown in figure 1.

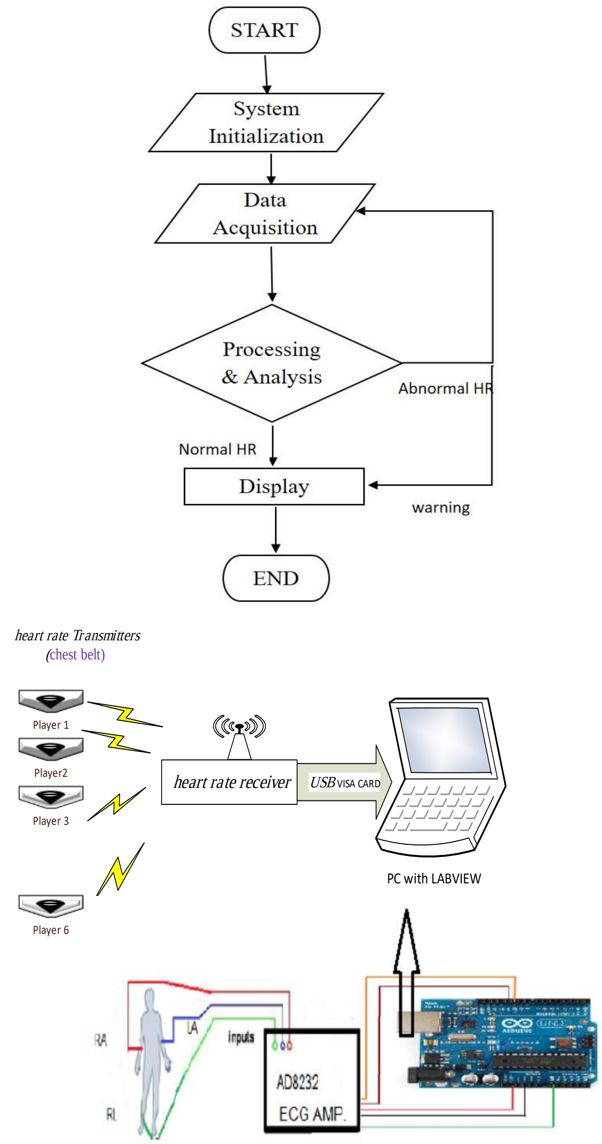


Figure 1. Flowchart and block diagram of the wireless heart rate monitoring

It can be split into two stages. The first stage is to monitor heart rate continuously, especially during stress. A KYTO2816C chest belt transmitter was used to interact with the 2.4GHz heart rate receiver and transfer data to the LabVIEW application for the patients' heartbeat. Then, it views the heart rate monitoring via the computer in real-time network settings. Several players, for instance, 3 to 6 players will put on a heart rate belt on their chests in different places. The heart rate data will be sent to the main processing unit wirelessly via a Wi-Fi wireless network. The received data from different players will be screened out by using LabVIEW before it will be shown as outcomes.

The heartbeat is received through the chest belt as mentioned previously and the data is sent to the computer through the identifier serial port monitor using the library VISA IN, which is necessary to define the belt due to the difference of the belt manufacturer from National Instrument company that manufactured LabVIEW platform. We also used the operator PL2303 to separate the received bits and then use the so-called graphical programming LabVIEW version 2018 to obtain useful information about the athletes' health condition through the pulse rate during the exercise of stress. In figure 2, the program interface for receiving a heartbeat from athletes by specifying the port number Com7 and the speed of data transmission between the two transmitters and receivers, baud rate, by 115200 bit/sec.

The second stage is using the ECG sensor technology to observe and measuring the electrical activity of the heart via deployment of Arduino microcontroller combined with the ECG Module (AD8232) in order to connect the ECG setup to the main processing unit to be able to analyze the received data by LabVIEW application.

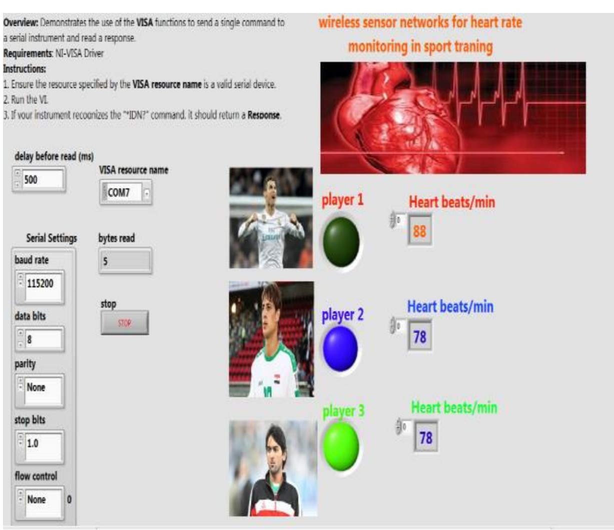


Figure 2. The interface program LabVIEW designed to receive heartbeat wirelessly to some players

The ECG signal describes the heart electrical activity as shown in figure 3. The ECG set is commonly used in the medical centers because of its non-invasive features. The ECG signal can be represented by a combination of three signals that are P, T, and the QRS, as shown in figures 4. These three signals involve the vital characteristic of the ECG signal. Every signal represents an electrical activity encompassed in the heart. The QRS complex represents ventricular depolarization [17]. The ECG signal is commonly collected through two steps. First by sensing weak electrical signal on the skin. After that, amplifying that weak electrical signal. This weak electrical signal is generated on the skin as a result of the heart electrical signal at every single heartbeat. The ECG setup props can sense this weak electrical signal as a voltage between the two sides of heart. For a practical implementation and validation of the QRS complex, it is suggested to use recorded data sets [10,18]. These recorded data sets were converted to digital at 360 Hz sampling rate and using band pass filter at 0.1 – 100 Hz.

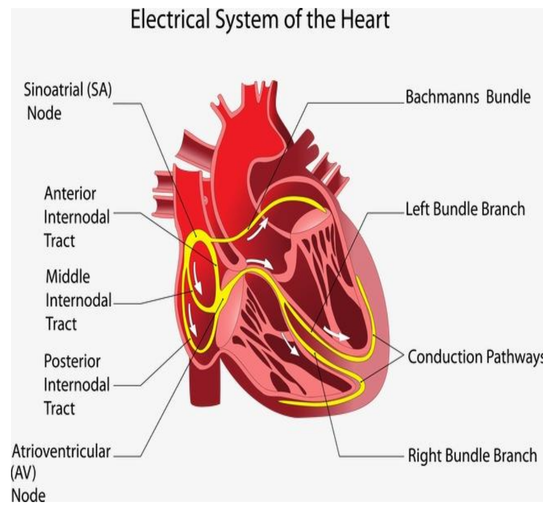


Figure 3. electrical System of a heart

The ECG signal is considered as a weak signal. An electrical signal of small amplitude (about 3mV) and low frequency where most frequency features of the signal is concentrated below 45Hz. This weak ECG signal is susceptible to interference from various sources like athletes breathing and movement, the setup electrodes movement, and the power line interference (~ 50Hz) [19].

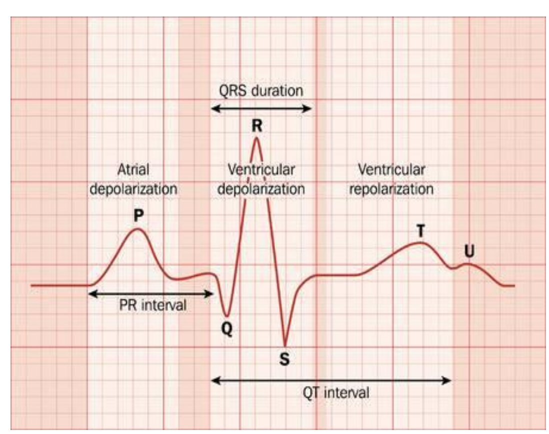


Figure 4. ECG of a heart in normal conditions.

3. Expermental Setup And Results

A. ECG Sensor and ECG Amplifier Circuit

As mentioned, collecting the ECG signal is a two-step procedure through monitoring the heart electrical activity over a certain period of time using props placed right over the skin. First, using props that are able to sense even weak electrical fluctuations on the skin that are originally generated because of the heart muscles movement at every single heartbeat. Then, the collected signal is amplified using an amplifier circuit based on an operational amplifier. AD8232 is the used operational amplifier as shown in figure 5. Later, the output amplified signal is sent directly to the Arduino microcontroller.

The industrial circuit AD8232 was used to receive the cardiac signal by connecting the circuit with Arduino microcontroller. Then, displaying the signal through the waveform or the personal computer and drawing the signal through the serial port.

In order to monitor the heart rate, we have used the integrated circuit AD8232 made by Analog Device, which is a noise removal circuit that is required especially in medical applications [20]. AD8232 is a signal conditioning integrated circuit used to pick up weak noisy signals, amplify, and filter them. To function properly, it requires a current of 170 mA, a voltage of 3.5 DCV, and gain equals to 100.

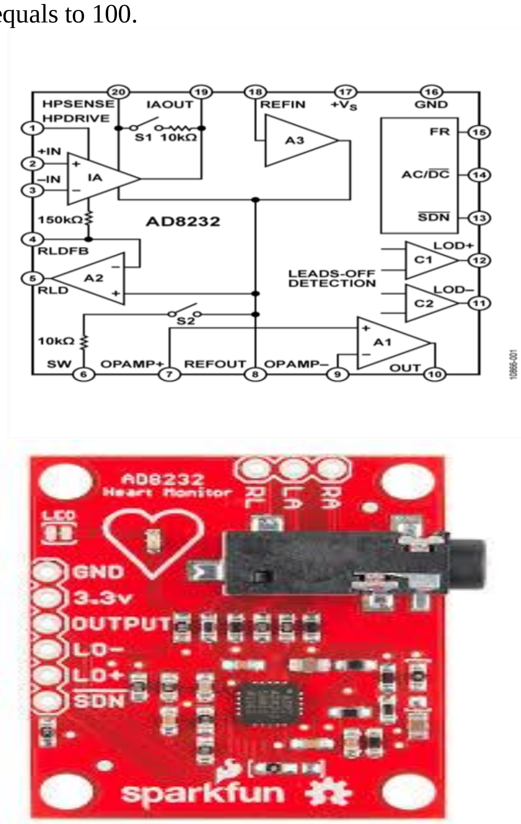


Figure 5. Integrated circuit AD8232

Arduino (At mega 328) controller of 14 input and output ports and a crystal oscillator of a frequency (16 MHZ) was used. Arduino is programmed by defining the variables, constants, then defining the entries and exits. After that, writing the main program code for collecting and displaying data [22,25], as shown in Fig. 6.

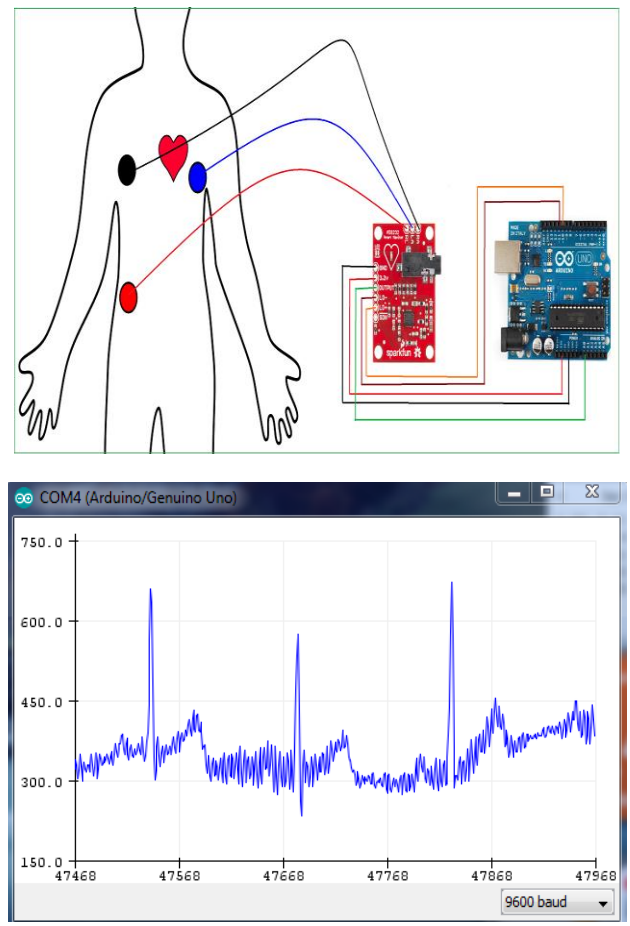


Figure 6. Collected ECG signal via Arduino controller

B. Signal Processing By LabVIEW Software

LabVIEW platform is known as virtual tools. It can be used for data acquisition including data storage, data sorting, data analysis and display. LabVIEW contains a comprehensive set of tools.

The LabVIEW platform is distinguished, as mentioned previously. It contains a large set of data receiving tools from the various input units of the computer. Even if there is no input tool in the LabVIEW, it is possible to define and build a special tool in the LabVIEW platform for data acquisition.

The interface is built on a block diagram, and the results will be displayed on the front panel using controls and indicators. Buttons, potentiometers, knobs and other input mechanisms are included in the controls. Indicators include charts and graphs from oscilloscopes and LEDs to represent on or off and other output screens, as shown in figure 7.

LabVIEW was used to collect data and display the analysis results of the heartbeat rate. Moreover, LabVIEW provides the ability to save the obtained results for future records. Heartbeat signal is frequently employed to distinguish heart and cardiac functions [23,24].

The implemented system using LabVIEW was used for data acquisition and data saving the input channel. One of the advantages of using this system is its ability to be extended by adding more athletes or channels at the same time. Moreover, it has the ability to read data during collecting signals which could be beneficial for real time applications and visualization [26,27].

The received analog signals were converted to digital data via the analog-to-digital convertor. After that, digital signal processing was deployed to produce high SNR to improve the system performance.

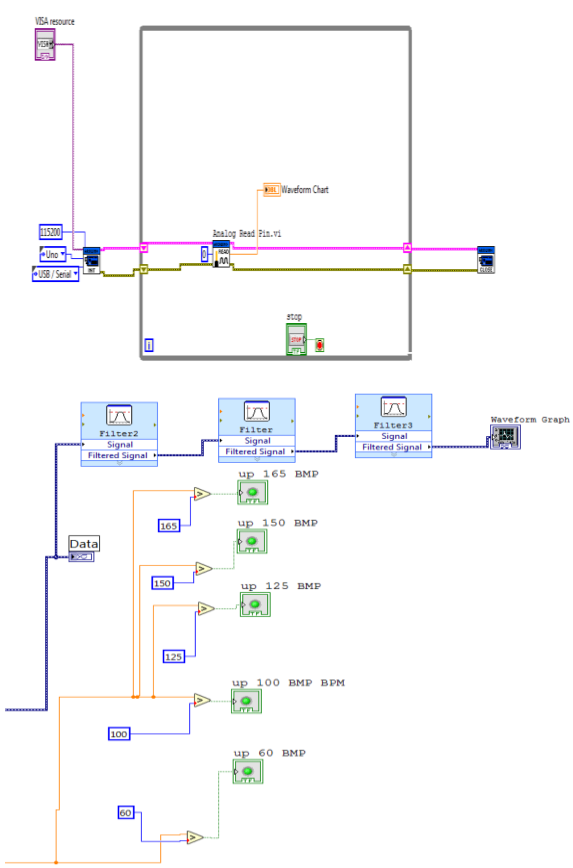


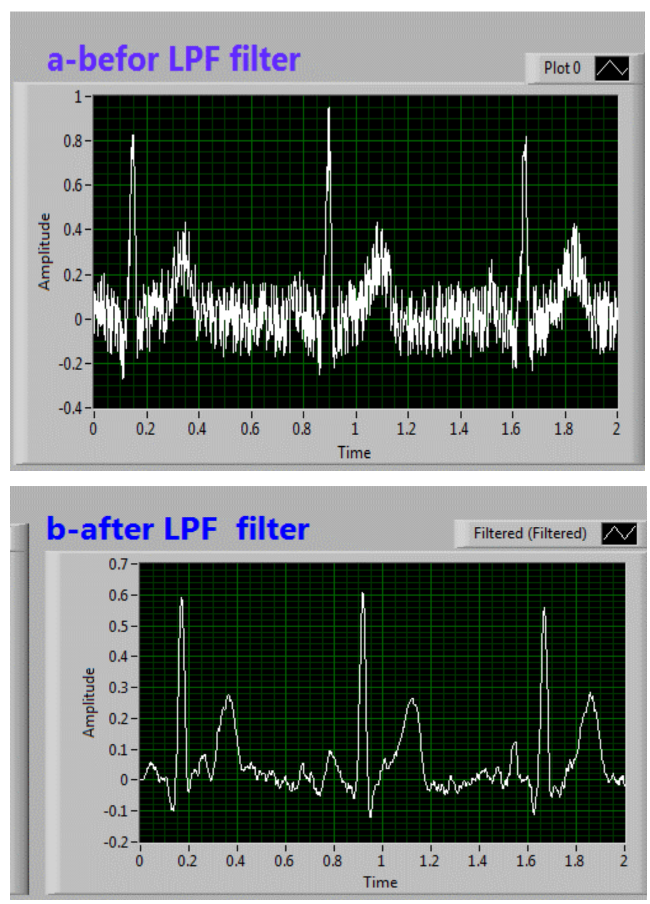
Figure 7. Implantation diagram using LabVIEW

LabVIEW was connected with Arduino microcontroller to acquire data from devices and process it in our software, to acquire data sequentially by serial port using NI-VISA driver for serial communication with Arduino and LabVIEW VI. The range of communication signal strength is up to 90 m for the following serial port setting (baud rate =115200 bit/sec, data bits =8 bit, stop bits=1 bit).

C. Digital Filter Design Using LabVIEW

The digital filter was employed in this system to remove the interference and unwanted signals. LabVIEW functions were used to implement this digital filter [28-30]. Previously, we talked about the heart signal being a small signal with a limited frequency range and. A signal with these characteristics is subject to many types of noise and interference that affect the signal and cause distortion. However, it is possible to get rid of this noise or reduce its impact by using filters.

The filter is a circuit that passes a signal with a limited range of frequencies and prevents the passage of other frequencies. There are different kinds of filters, for instance, low pass filter, band pass filter, and high pass filter [21], as shown in figure 8.



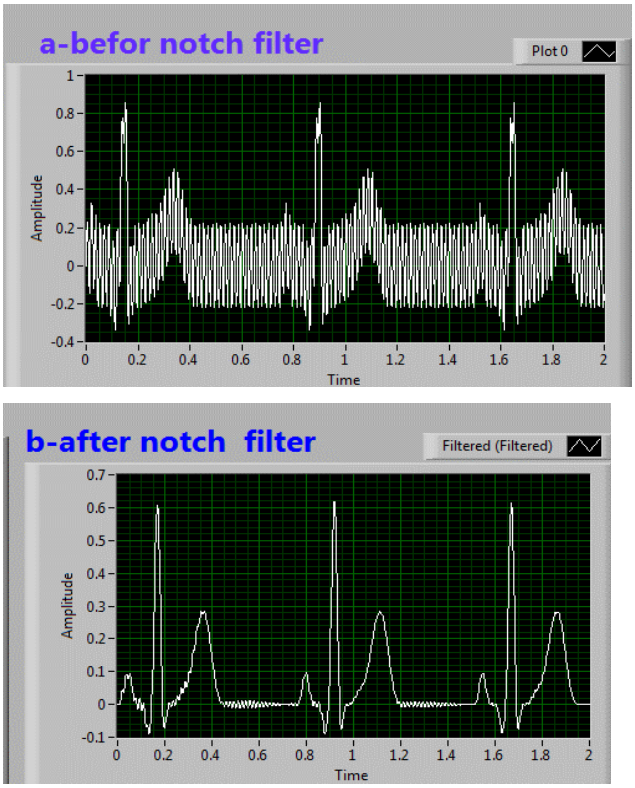


Figure 8. a low-pass filter to remove frequencies greater than (100 Hz) and notch filter to remove the the power source noise (50 Hz)

The ECG signal and heart rate were successfully obtained using the setup of this work, as shown in figure 9.

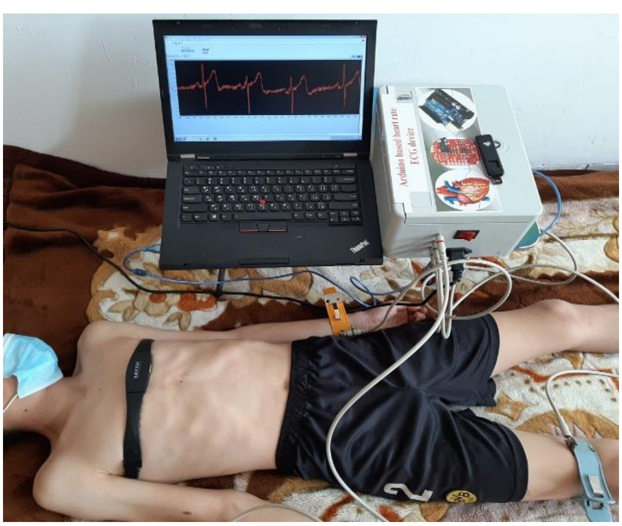


Figure 9. Portable heartbeat rate monitoring system setup

The heart rate signals from the sensor modules were measured in beats per minute (BPM) for six players as shown in Table 1.

TABLE 1. THE RESULTS OF SIX PLAYERS TESTING WITH DIFFERENT AGE.

Name	Age	Height	Weight	BPM
Ali	30	187cm	75kg	95-162
Ahmed	48	155cm	55kg	85-145
Yasser	35	184cm	80kg	88-157
Balsam	40	171cm	66kg	90-153
Laith	45	167cm	70kg	88-144
Mohammad	23	165cm	71kg	78-150

Authorized medical specialists can view the results continuously and get messages and alarms for an emergency situation so that they can take actions to help urgent cases immediately.

By using our portable heartbeat rate monitoring system that is shown in figure 9, normal ECG measurements were carried out. The obtained ECG measurements for three football players were viewed and visualized via a GUI window using LabVIEW, as shown in figure 10. The maximum distance between the players and the receiver designed to be up to 90 m. Also, remote medical specialists can keep monitoring players in field. The LabVIEW GUI windows were designed via LabVIEW 2018.

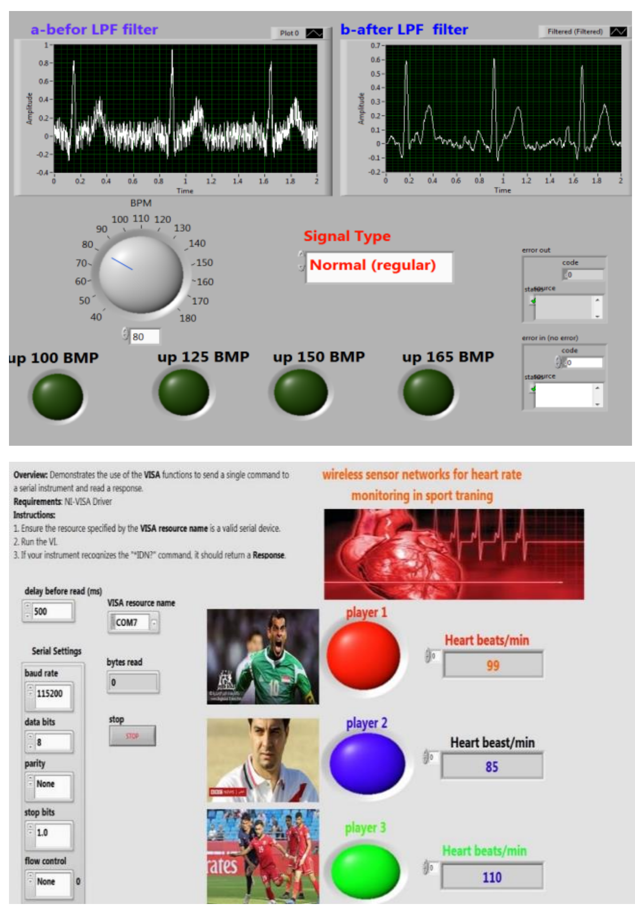


Figure 10. Normal ECG measurements for football players using portable heartbeat rate monitoring system and visulazied by LabVIEW patform.

The error data between the real heart rate and measured values of six athletes is shown in figure 11.

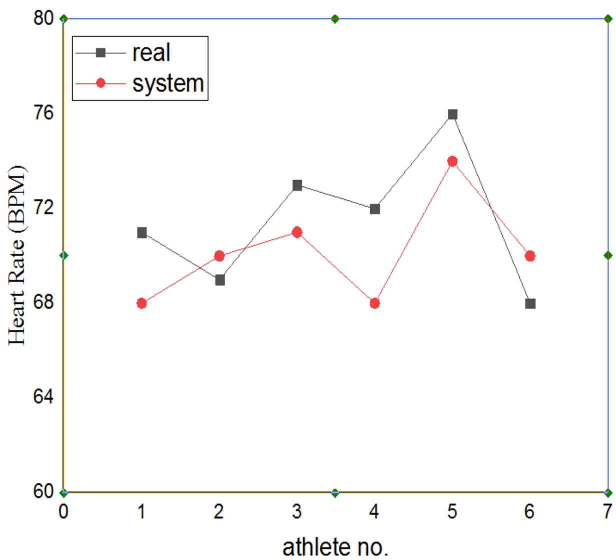


Figure 11. Error data between real and measured values

4. Conclusion

In this paper, a real-time wireless heart rate sensor network has been proposed and successfully implemented with the support of the LabVIEW environment and the wireless sensor network. The system allows many individuals to be monitored remotely and simultaneously. This proposed system can remotely monitor many athletes in the field during the training sessions and the real competitions in an efficient way at the same time. It consists of two stages. In the first stage, 2.4GHz heart rate transmitter by chest belt type KYTO2816C was used to interface with 2.4GHz heart rate receiver and transfer the data into the LabVIEW platform to collect heart rate signals for athletes in the field. Then, visualize the collected and analyzed signals through real-time wireless network conditions. The second stage is using ECG sensor technology to observe and measure the electrical activity of the heart by using Arduino microcontroller supported with ECG Module AD8232 to connect the ECG circuit to the PC and analyze the results by LabVIEW platform. The proposed portable heartbeat rate monitoring system is easy and effortless to use with simple working conditions and very small error percentage. In addition, this low-cost proposed system shows good performance in terms of high-speed response and high accuracy compared to the commercially available heart rate monitoring systems that could be useful in medical applications.

Acknowledgment

The authors are very grateful to the University of Mosul, College of Engineering for their provided facilities, which helped to improve the quality of this work.

References

[1] World Health Organization. Cardiovascular Diseases. Available online:www.who.int/health-topics/cardiovascular-diseases/#tab=tab_1. (accessed on 16 March 2020).

[2] Scutti, S. Nearly Half of US Adults Have Cardiovascular Disease, Study Says. CNN, Cable News Network. 31 January 2019. Available online: www.cnn.com/2019/01/31/health/heart-disease-statistics-report/index.html(accessed on 15 March 2020).

[3] European Cardiovascular Disease Statistics 2017; The European Heart Network (EHN): Brussels, Belgium, 2017; Available online: http://www.ehnheart.org/cvd-statistics.html (accessed on 15 March 2020).

[4] Pavlatos, C., Dimopoulos, A., Manis, G., et al.: ‘Hardware implementation of Pan and Tompkins QRS detection algorithm’. Proc. EMBEC05 Conf., Prague, Czech Republic, 2005.

[5] Kohler, B.-U., Hennig, C., Orglmeister, R.: ‘The principles of software QRS detection’, IEEE Eng. Med. Biol. Mag., 2002, 21, (1), pp. 42–57.

[6] Bsoul, M.; Minn, H.; Tamil, L. Apnea MedAssist: Real-time sleep apnea monitor using single-lead ECG. IEEE Trans. Inf. Technol. Biomed. 2011, 15, 416–427.

[7] Satija, U.; Ramkumar, B.; Manikandan, S.M. Real-time signal quality-aware ECG telemetry system for IoT-based health care monitoring. IEEE Intern. Things J. 2017, 4, 815–823.

[8] Arzeno, N.M., Deng, Z.-D., Poon, C.-S.: ‘Analysis of first-derivative based QRS detection algorithms’, IEEE Trans. Biomed. Eng., 2008, 55, (2), pp. 478–484

[9] Berwal, D., Kumar, A., Kumar, Y.: ‘Design of high performance QRS complex detector for wearable healthcare devices using biorthogonal spline wavelet transform’, ISA Trans., 2018, 81, pp. 222–230

[10] Karim Meddah, Malika Kedir Talha, MohammedBahoura, Hadjer Zairi. "FPGA-based system for heart rate monitoring", IET Circuits, Devices & Systems, 2019.

[11] Xiang, Y., Zhitao, L., Jianyi, M.: ‘Automatic QRS complex detection using two-level convolutional neural network’, Biomed. Eng. Online, 2018, 17, (1), pp. 1–13

[12] Raman, P., Ghosh, S.: ‘Classification of heart diseases based on ECG analysis using FCM and SVM methods’, Int. J. Eng. Sci., 2016, 6, pp. 6739–6744

[13] Diker, A., Avci, D., Avci, E., et al.: ‘A new technique for ECG signal classification genetic algorithm wavelet Kernel extreme learning machine’, Optik, 2019, 180, pp. 46–55

[14] Phukpattaranont, P.: ‘QRS detection algorithm based on the quadratic filter’, Expert Syst. Appl., 2015, 42, (11), pp. 4867–4877

[15] Kozia, C., Randa, H., David, L.: ‘ECG-derived respiration using a real-time QRS detector based on empirical mode decomposition’. 12th Int. Conf. Signal Processing and Communication Systems (ICSPCS), Cairns, Queensland, Australia, 2018, pp. 1–8.

[16] M. T. Yaseen, F. Y. Abdullah and M. H. Almallah, "Smart Green Farm," 2020 7th International Conference on Electrical and Electronics Engineering (ICEEE), Antalya, Turkey, 2020, pp. 299-302, doi: 10.1109/ICEEE49618.2020.9102495.

[17] Pal, S., Mitra, M.: 'Empirical mode decomposition based ECG enhancement and QRS detection', Comput. Biol. Med., 2012, 42, (1), pp. 83-92

[18] Sarkaleh, M.K., Shahbahrami, A.: 'Classification of ECG arrhythmias using discrete wavelet transform and neural networks', Int. J. Comput. Sci. Eng. Appl., 2012, 2, (1), pp. 1-13

[19] Goldberger, A.L., Amaral, L.A.N., Glass, L., et al.: 'Physiobank, PhysioToolkit, and PhysioNet: components of a new research resource for complex physiologic signals', Circulation, 2000, 101, (23), pp. e215-e220; Circulation Electronic Pages. Available at http://circ.ahajournals.org/content/101/23/e215.full, accessed on December 2018

[20] Thomas, M., Das, M.K., Ari, S.: 'Automatic ECG arrhythmia classification using dual tree complex wavelet based features', AEU-Int. J. Electron. Commun., 2015, 69, (4), pp. 715-721.

[21] Abba, S.; Garba, A.M. An IoT-Based Smart Framework for a Human Heartbeat Rate Monitoring and Control System. Proceedings 2020, 42, 36.

[22] Majumder, A.K.M.; ElSaadany, Y.A.; Young, R.; Ucci, D.R. An Energy Efficient Wearable Smart IoT System to Predict Cardiac Arrest. Adv. Hum.-Comput. Interact. 2019.

[23] Mohammad, S.I.; Mohammad, T.I.; Ali, F.A.; Gan, K.B.; Norbahiah, M.; Amin, N. Monitoring of the Human Body Signal through the Internet of Things (IoT) Based LoRa Wireless Network System. Appl. Sci. 2019, 9, 1884.

[24] Zompanti, A.; Sabatini, A.; Santonico, M.; Grasso, S.; Gianfelici, A.; Donatucci, B.; Di Castro, A.; Pennazza, G. A Sensor Platform for Athletes' Training Supervision: A Proof of Concept Study. Sensors 2019, 19, 3948

[25] https://arduino.cc/en/Main/ArduinoBoard

[26] https://www.ni.com/en-lb/shop/labview.html

[27] H. Sahool and K. Biswal, "Patient monitoring system for cardiovascular patient with body temperature using lab VIEW," International Journal of Engineering Research and Development, vol. 6, no. 8, pp. 27–30, 2013.

[28] Michaela Sidikova, Martina Ladrova, Radek Martinek, Matej Kahanek, Petr Bilik, Rene Jaros,Adaptive fetal ECG signal extraction based on LabVIEW and C# implementation,IFAC-PapersOnLine,Volume 52, Issue 27,2019,Pages 359-364,ISSN 2405-8963,https://doi.org/10.1016/j.ifacol.2019.12.687.

[29] A. A. M. Adam and M. B. M. Amin, "Design and implementation of portable PC-based ECG machine," International Journal of Sciences: Basic and Applied Research, vol. 15, no. 2, 2014

[30] N. Djermanova, M. Marinov, B. Ganev, S. Tabakov and G. Nikolov, "LabVIEW based ECG signal acquisition and analysis," *2016 XXV International Scientific Conference Electronics (ET)*, Sozopol, 2016, pp. 1-4, doi: 10.1109/ET.2016.7753471.

Fawaz Yaseen Abdallah received his B.Sc. degree in electrical engineering, electronic and communication from the University of Mosul, Iraq in 1990, and the M.Sc. degree in electronic and communication from the University of Mosul, Iraq in 1995. His research interests are in the field of computer networks and communication. He has published many scientific papers in Mobile Communication, LTE, and WSN fields. Since 2009, he joined the Electrical Engineering Department, University of Mosul as a lecturer. He has been teaching communication networks and computer interface systems courses.

Mohammad Tariq Yaseen received his B.Sc. degree in electrical engineering, electronics and communications, the M.Sc. degree in electronics, and his Ph.D. degree in Nanotechnology Engineering. His main research interests are in the field of Nanodevices, Nanoelectronics, and Smart Embedded Systems (SESs).

Yasir Mahmoud Hussien received his B.Sc. degree in electrical engineering, electronic and communication from the University of Mosul, Iraq in 2020. His research interests are in the field of wireless communication and computer networks.