Design and development of telemedicine based heartbeat and body temperature monitoring tools

by Liliek Sutjiatie

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To cite this article: I P C Gunawan et al 2020 IOP Conf. Ser.: Mater. Sci. Eng. **850** 012018

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I P C Gunawan*, D H Andayani, T Triwiyanto, E Yulianto, T Rahmawati, L Soetjiatie and S D Musvika

Department of Electromedical Engineering, Poltekkes Kemenkes, Surabaya, Jl. Pucang Jajar Timur No. 10, Surabaya, 60245, Indonesia

*ccahya.ggunawan@gmail.com

Abstract. Body temperature and heart rate monitoring based on telemedicine is an electromedical device served to determine the condition of the heart rate per minute (BPM) and the patient's body temperature in realtime remotely. The purpose of this study is to design the heart rate and body temperature monitor based on telemedicine uses the Internet of Things (IoT). The system allows unlimited distance monitoring by utilizing the internet as a medium for sending the data. The body temperature and heart rate monitoring system uses DS18B20, Arduino, and Raspberry Pi temperature sensors and finger sensors as data processing and transmission microprocessors, LCD Character displays the results of heart rate readings and body temperature per minute. The results of heart rate measurements and body temperature are sent to the database via microservice and displayed on a web page in the form of numerical data and responsive plot graphics on desktops and mobile phones. Based on the measurement and comparison to standard apparatus, the average error of BPM measurement is 0.72%, with a maximum permissible tolerance of ± 5%. While in the body temperature parameter the average difference is 0.3 ° C with a maximum permitted tolerance of ± 1 °C.

1. Introduction

Monitoring devices in the medical world can monitor a variety of vital signs of patients, including the electrical signals of the heart and body temperature. For heart parameters, it is usually displayed on ECG charts and beats per minute called beats per minute (BPM). Adults' normal heart rates range from 60 - 100 bpm. After exercise, the range is from 200 to 220 bpm [1,2]. For body temperature parameters are usually displayed in units of Celsius/Fahrenheit. Normal body temperature usually ranges from 37°C. Measurement of body temperature can be done on the tympanic membrane, rectal, oral, and axillary [3,4]. Monitoring for the parameters above is very important because if the symptoms occur as above, action must be taken so that the patient's condition does not deteriorate. The patient's condition can worsen anytime and anywhere [5]. For patients who are outpatient at home (home care) who do rehabilitation of heart disease, of course, not always accompanied by a nurse/personal doctor [6]. For that, we need a system that can inform the results of monitoring BPM records and temperature to the doctor so that an evaluation of the patient's development can be carried out and take action if the patient shows abnormal heart rate or body temperature [7-9].

Rizal et al. designed of monitoring body temperature parameters, PPG and ECG with the wireless monitoring method. These parameters are only focused on the local area network [10]. Pierleoni et al.

designed a heart rate monitoring system for elderly people and patients with heart disease with a cellular connection (phone/SMS) and internet connection to convey information to the doctor. The drawback of this research is that the display output is only limited to Android smartphones, which have limitations on the display screen resolution [11]. Kakria et al. designed the monitoring the heart rate on an Android smartphone and then sending information to doctors with an internet connection. The weakness of this study is still using smartphones as interface that are limited in display screen resolution [12]. Gunawan et al. designed the monitoring system of heart rate and body temperature with interfaces on android smartphones and telemedicine communication using the SMS gateway. The weakness in this study lies in the limited data transmission distance because it only utilizes a Bluetooth connection. Wardhana et al. designed a system of monitoring heart rate and body temperature with interfaces on the web through an intermediary PC (Personal Computer). In this study, the weakness of the data sent is not real data only image data that is not possible to edit.

Based on the results of the identification of the chronological problems above, the objective of this study is to design and development of telemedicine-based heartbeat and body temperature monitoring tools by using the internet and webpages as a medium for sending and displaying data to overcome the shortcomings of previous studies [13,14].

2. Methods

2.1. Experimental setup
This study was applied to normal human subjects aged over 17 years. Data retrieval is done in realtime with a measurement time of 1 minute for parameters of heart rate and body temperature. Sampling data is taken six times for each parameter.

2.2. Materials and tool
This study uses the Nellcor brand finger sensor on the parameters of heart rate and DS18B20 temperature sensor for body temperature parameters. The finger sensor is attached to the patient's finger, and the DS18B20 sensor is attached to the patient's axilla. The component used uses Arduino Nano as a Microcontroller for the acquisition of heart rate and body temperature data, the Raspberry Pi 3B is connected via the serial port to the Arduino module while functioning for the transmitter to display on the character LCD and web page interface.

2.3. Experiment
In this study, the researcher compiled a module conditioning the heartbeat signal from the finger sensor. The results of processing heart rate data and body temperature are displayed on LCD on apparatus display. Normally in 1 minute apparatus will send data to the server and displayed in the webpage interface. If one of the parameters has abnormal value, the apparatus will send data to the server automatically by interval 10 seconds. The researcher conducted several tests, including:

- Tests for processing heart rate data using an auto reference system against the results of Beat calculations per Minutes
- Test lost data delivery with a method of comparing the number of module shipment data with the amount of data displayed on the web display
- Delivery time testing with a method of calculating the process of sending data from the module until the data is displayed
- Comparison of the measurement results of the module with a comparison device for body temperature parameter using the thermometer, also for heart rate parameter using a pulse oximeter.
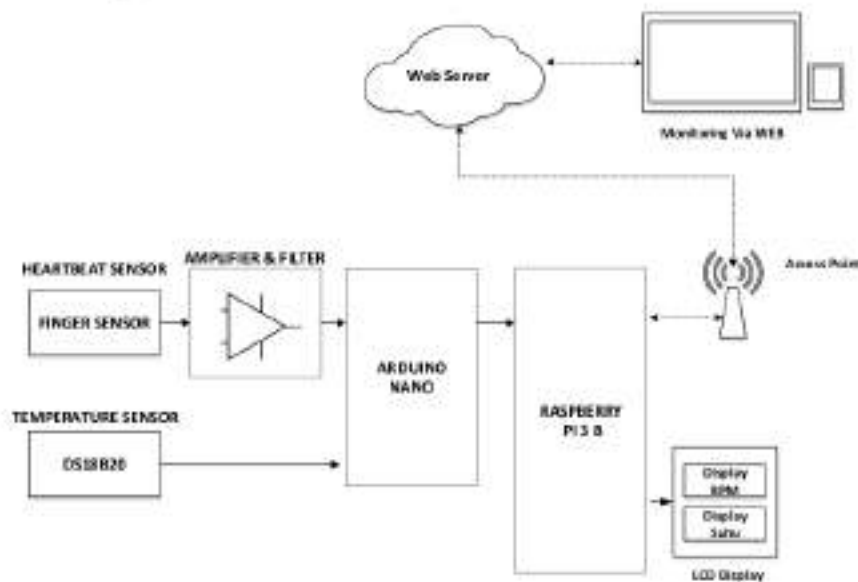
2.4. Telemedicine system

Figure 1. The diagram block of design and development of telemedicine based heartbeat and body temperature monitoring tools.

The circuit consists of a finger scanner to sensing the patient finger. Filter circuits and amplifiers function to filter unwanted signals and amplify the voltage divider resulting in the sensor circuit. Bandpass filter circuit with a cut-off frequency below 0.48 Hz and a cut-off frequency of 4.19 Hz and a gain of 101 times. The minimum system consists of two parts, namely the Arduino microcontroller as a device for processing data and the Raspberry Pi 3 B as a device for sending data to the database and arranging displays on 16 x 2-character LCDs. In this study, comparison of data results with predetermined comparison tools, measurement and analysis of delivery times, and calculation and analysis of lost shipping data were conducted.

As shown in Figure 1, the flow of reading the temperature value starts from reading the digital data generated by the DS18B20 sensor stored in a variable and sent to raspberry pi via serial communication. The flow of the heart rate reading starts with reading the ADC as a result of processing analogue signals on the finger sensor. The ADC signal is processed and calculated to get a heart rate per minute then sent via serial communication to the raspberry pi. The flow of data transmission starts from reading serial data; then, the results are displayed on the LCD. When the timer reaches 1 minute, the data is sent to the database via the data upload service. The flow of data appearance on the web page interface starts from retrieving data from the database with microscope access then displayed on plotting labels and graphics.

3. Results and discussion

3.1. Heartbeat calculation using auto reference result

The data processing program listing on Arduino starts from reading the ADC through pin A0 and converting ADC data to voltage. In the above program, listings use an auto reference system that uses the highest percentage of signal voltage to calculate heart rate.

Table 1. Result of auto reference testing.

Threshold setting	Apparatus	Average	Error
10%	Design	87.2	1%
	Standard	87.2	
20%	Design	92.2	1%
	Standard	91.7	
30%	Design	93.8	1%
	Standard	93.5	
40%	Design	71.3	25%
	Standard	94.5	
50%	Design	49.5	47%
	Standard	94.2	
60%	Design	42.0	55%
	Standard	92.7	
70%	Design	28.8	68%
	Standard	91.5	
80%	Design	0.0	100%
	Standard	89.8	
90%	Design	0.0	100%
	Standard	90.2	

From the results of testing that has been done with the retrieval of heart rate data carried out on a fixed subject and the auto reference value set with a range of 10%, the lowest error is obtained at 10%, and the highest error is at 90% as shown in Table 1.
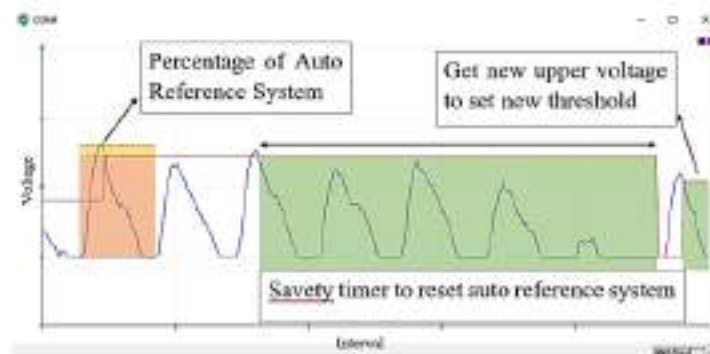
Figure 2. Auto reference system.

4

Analysis of the results of testing auto references that are applied to human heart rate calculations, as shown in Figure 2. Can be stated that the auto reference application works more effectively against a stable input pulse. At input pulse with a low level of stability, auto reference works effectively with settings below 30%.

3.2. Analysis and result lost data measurement

Table 2. Measurement lost data.

No	Time(s)	Amount of Transmitted Data	Amount of Received Data
1	100	10	10
2	200	20	20
3	300	30	30
4	400	40	40
5	500	50	50

The result data shown in lost data processing shows an error of 0%, which shows the amount of data sent is equal to the amount of data received at each measurement point 10, 20, 30, 40, and 50 sample data sent. Data testing is done by comparing the amount of data sent with the amount of data received as shown in Table 2.

3.3. Analysis and result interval of transmission data
Retrieval of data when sending data is done by taking the time when the data is sent via raspberry pi and retrieving data when the microservice program displays the data. The results between data are calculated as the time difference. In the above data retrieval carried out at internet download speeds of 36 Mb / s, the average shipping speed is 1 s per data transmission.

3.4. Results of the heartrate and temperature measurement
A comparison of data retrieval, as shown in Table 3, is made by comparing the module with a comparison device (Pulse Oximeter and Body Thermometer) carried out on five different subjects for temperature and bpm parameters. In the BPM parameter, the highest error calculated is 1.31%, and the highest temperature parameter error is 1.49%.

Table 3. Measurement error between module and comparison tools.

No	Subject	Error Heartrate (%)	Error Temperature (%)
1	P1	1.09	1.09
2	P2	1.23	0.68
3	P3	0.76	0.45
4	P4	1.31	1.40
5	P5	1.28	1.49

After comparing the results between the module and the measuring instrument, the average error in the parameters of the BPM is 1.14%, which is still within the tolerance range of the BPM value of 5%. For temperature parameters, the difference is 0.3 ° C, which is still within the tolerance range of the temperature value, which is ± 1 ° C.

The lost data test results with an error of 0%, which indicates that the shipment uses the IoT Telemedicine technique is safe for sending medical data because the data sent is in accordance with the original.

The results of testing the delivery time show the average delivery time per sample data of 1 second, and it can be concluded that the delivery of IoT Telemedicine can send a small sample of data at one sampling per second. The development of monitoring samples with the amount of data sampling of more than 1 / second cannot be applied to IoT technology that is still developing at this time, such as monitoring ECG signals.

4. Conclusion

This research shows that the Internet of Things (IoT) technology can be utilized in the health sector, especially in patients' vital sign monitoring that is done in a Realtime manner (Telemedicine). This technology allows the process of monitoring care without being accompanied by medical personnel directly more effectively. The design of this tool is expected to be able to handle cases of shortages of medical personnel in an area and maximize the monitoring process of outpatient conditions.

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