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Designing of Arrythmia Telemonitor Device Using Pulse Sensor Based on Web

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Abstract: This research aims to design a prototype medical device that is expected to be applied for independent monitoring of the remote by the patient as well as to record medical data of cardiac arrhythmias. This research was conducted by using experimental model research with laboratory test. The arrhythmia telemonitor device that has been constructed is composed of pulse sensor, keypad and press switch as input block. Process block consisting of Arduino Mega Kit module, Ethernet Shield, router and USB Modem. The output block is composed of a 16×2 alpha numeric LCD viewer module and a web display accessed using a computer or smartphone device. Based on test results on five respondents obtained level of accuracy is based on the calculation of procentstase error average of 0.25%. While the results of precision testing based on the calculation Standard deviation (Stdev) averaged 13.27.

Key words: Telemonitoring device, arrhythmia, web-based, pulse sensor, LCD, Ethernet Shield

INTRODUCTION

The heart is a human organ that has a vital function. Small abnormalities in heart organ can have a big effect on our body's performance. Based on data from the World Health Organization (WHO), heart disease has a 29% percentage of deaths in the world and 17 million people die each year from heart and blood vessel disease worldwide.

Detection of cardiac arrhythmias can be performed by a heart rhythmic recording device called Electrocardiography (ECG) (Tompkins and Webster, 1981).

In addition to EKG, medical devices that have been used by medical teams to detect heart rate and rhythm are Electrophysiology Study (EPS) (Babiker *et al*., 2011) and Insertable Loop Recorder (ILR) (Jones, 2015). The problems that arise in addition to the expensive cost of procuring these tools, also require special abilities in operation, so, it can not be used independently by the patient.

Kusuma *et al*. (2016) and Sukoco has succeeded in building Arduino-based heart arrhythmia detector with optical sensor. However, it has not been designed to monitor arrhythmias remotely and can not record the results and timing of the examination.

Kohler *et al*. (2002) have reviewed and compared algorithms to detect QRS-complex signals using software. One of the simplest algorithms for QRS detection is presented by Tompkins and Webster (1981) in his book biomedical digital signal processing. The book describes QRS detection using band pass filtering technique, so that, the patient's heart rate is calculated every minute by calculating the R-R interval. The research have been studying equipment to easily acquire cardiorespiratory information at home using piezoelectric sensors (Igasaki and Kobayashi, 2017). The other research by Zhang *et al*. (2014) have been studying from radar life parameter monitoring system for respiration and heartbeat signal separation, therefore, the characteristic parameters of respiration, heartbeat could be extracted to provide the basis for family care and disease prevention. But the two researches have not yet applied to a web-based monitoring process.

The development of information and communication technology enables data of examination result of heart rate can be sent to doctor through communication device like smartphone or laptop through internet network. This allows a doctor to monitor heart health from the patients he or she is handling.

Based on the above problems, this research will design and build devices that can monitor long distance (telemonitor) cardiac arrhythmia using web-based applications through internet communication channels.

MATERIALS AND METHODS

Arrythmia premonitory: This type of arrhythmia indicates a condition that harmful to the health of the patient including: Premature Ventricular Contraction (PVC) interpolated PVC, bigeminy, trigeminy, R-on-T beat, Atrial Premature Beats (APB), skipped beat. There are several methods to determine the presence of cardiac rhythm disorders, there are: using direct

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Table 1: Arrhythmia algorithm

Type of aritmia	Algorithm
PVC	$RR_{t-1}>0.9\ (AR_{t-2})$, $RR_{t-1}+RR_t = 2\ (AR_{t-2})$
R-on-T	$RR_{t-1}<0.33\ (AR_{t-2})$, $RR_{t-1}+RR_t = 2\ (AR_{t-2})$
Bigeminy	$RR_{t-3}<0.9\ (AR_{t-4})$, $RR_{t-1}<0.9\ (AR_{t-4})$, $RR_{t-3}+RR_{t-2} =$ $2\ (AR_{t-4})$, $RR_{t-1}+RR_t = 2\ (AR_{t-4})$
Trigeminy	$RR_{t-2}<0.9\ (AR_{t-3})$, $RR_{t-1}<0.9\ (AR_{t-3})$ $RR_{t-1}+RR_{t-1}+RR_t = 2\ (AR_{t-3})$
Interpolated PVC	RR_t-$<0.9\ (AR_{t-2})$, $RR_{t-1}+RR_t = 2\ (AR_{t-2})$
APB	$RR_{t-1}<RR_{t-1}+RR_t<(AR_{t-2})$

observation of study cardiogram. Arrhythmias can be diagnosed by the method of comparing the output signal with a variety of ECG arrhythmia signal images were then analyzed by using ANN (Artificial Neural Network). Using a mathematical model analysis of ECG signal output by the algorithm as shown in Table 1.

Table 1 shows a mathematical model that defines algorithms wide variety of arrhythmias were detected. There are two variables that are used are:

RR = One time interval R-R
AR = Average from interval R_1-R
AR_t = Average of eight time interval R_1-R_9
RR_t = Time interval R_8-R_9
RR_{t-1} = Time interval R_7-R_8
AR_{t-1} = Average of eight time interval R_1-R_8

Design of hardware : The design of this tool consists of several blocks of the series are arranged into a telemonitor device cardiac arrhythmia-based mobile communication as shown in Fig. 1.

Based on the block diagram shown in Fig. 1, the telemonitor arrangement of cardiac arrhythmias is suspended over the input blocks, process blocks and output blocks.

Input block: In the input block consists of 3 components of pulse sensor circuit, keyboard (keypad) 3×4 and push button (push button). Pulse sensor is a sensor that can detect heart rate based on blood flow. This sensor can be operated by attaching to the fingertips or ears. The schematic of the circuit and physical display is shown as Fig. 2.

Proses block: The process block is composed of 3 components of Arduino Kit module, Ethernet Shield Kit module and router device. The Arduino Mega 2560 module kit is used as a processing unit in the cardiac arrhythmia telemonitor device. Ethernet Shield W5100 module kit used for data communication function. Cardiac arrhythmia monitor results that have been processed by Arduino module, then the data is sent to the web server via. the internet using router device and USB Modem.

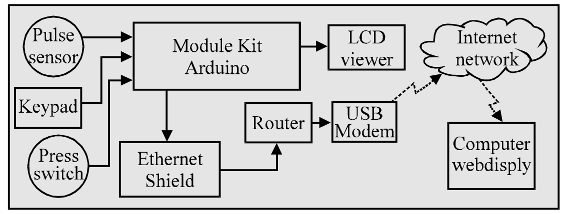


Fig. 1: Block diagram of telemonitor tool web-based heart Arrhythmias

Web views of monitoring results can be accessed using other devices such as notebooks or smartphones. Figure 3 show components needed in this device design.

Output block: The output blocks are composed of components consisting of LCD display kit module and web display as shown in Fig. 4-8.

Design of software: The design begins by defining the signal characteristics of the types of arrhythmias based on the Table 1 algorithm.

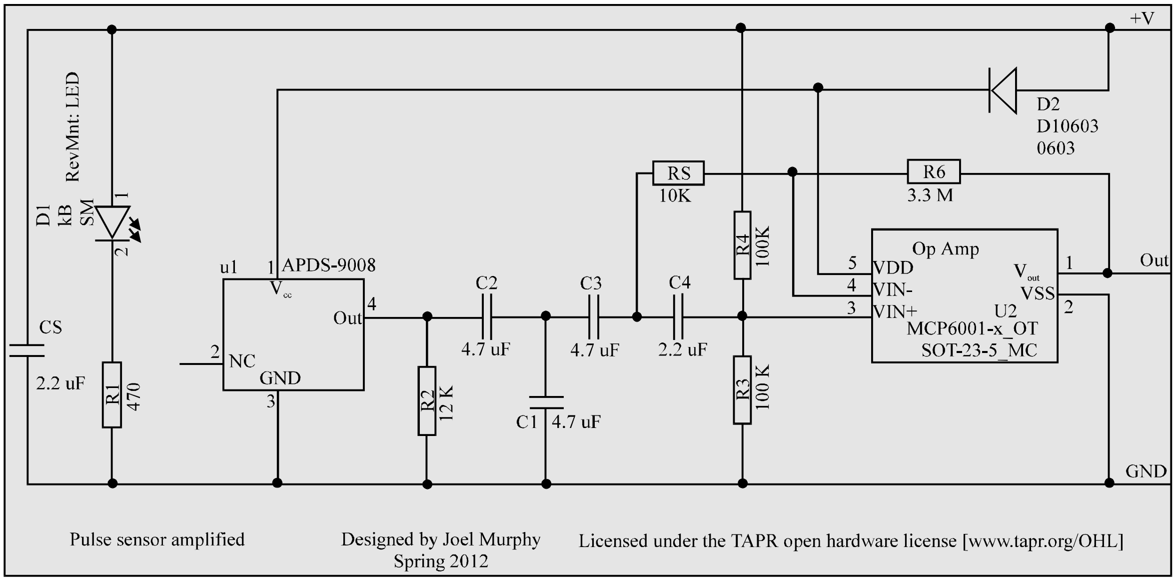
In this program, there are two RR and AR variables. RR is the R-to-R interval and the AR is the average range of the given time interval. The subscript value is used as a time-related sign. RR_t means the last interval. RR_{t-1} means an interval R-to-R interval of seven of the eight sample periods. AR_t is the average time R-to-R of the eight sample intervals. AR_{t-1} means that the mean time-to-R R seven intervals of eight intervals were sampled (Tompkins and Webster, 1981).

When the heartbeat peak signal is detected, the peak signal is marked as R, the subscript is the numbered sequence of detected heartbeats. To process the arithmetic algorithm formula it is necessary to know the interval between R-to-R and the period of each heartbeat. The value of T1 from R_1-R_2, the value of T2 from R_3-R_2 and continues through the period of eight.

Period is displayed before on the label program for RR. Subscript after RR stamped ordered period, RR_t is the period last period of last period of nine signals captured. RR_{t-1} is the period one before the last eight intervals are captured, continuing the first period RR_{t-7}.

The definition of AR is the average of each period based on the label on the subscript. AR_t is the average of eight captured intervals, the ART value is $RR_t+RR_{t-1}+RR_{t-2}+RR_{t-3}+RR_{t-4}+RR_{t-5}+RR_{t-6}+RR_{t-7}$ divided by eight. AR_{t-1} value is $RR_{t-1}+RR_{t-2}+RR_{t-3}+RR_{t-4}+RR_{t-5}+RR_{t-6}+$ RR_{t-7} divided by seven, continue to get RR_{t-7}. Figure 9 shows flow chart of the arrhythmia detection process.

(a)



(b)

Fig. 2: a, b) Schematic and physical display of pulse sensor circuit

(a)

(b)

(c)

Fig. 3: a-c) Physical display of Arduino Mega 2560 module kit, Arduino Ethernet Shield W5100 and portable router

(a)

(b)

Fig. 4: Output block devices: a) LCD viewer and b) Web display

Fig. 5: Physical display of arrythmia telemonitoring device

Fig. 6: R representation as the peak of the tick and T as the time period on the heartbeat signal

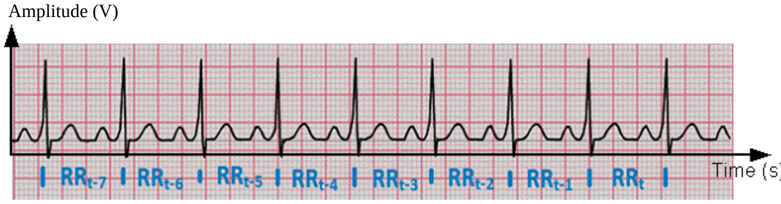


Fig. 7: Defining the time period of RR

Fig. 8: Defining AR as the average time period

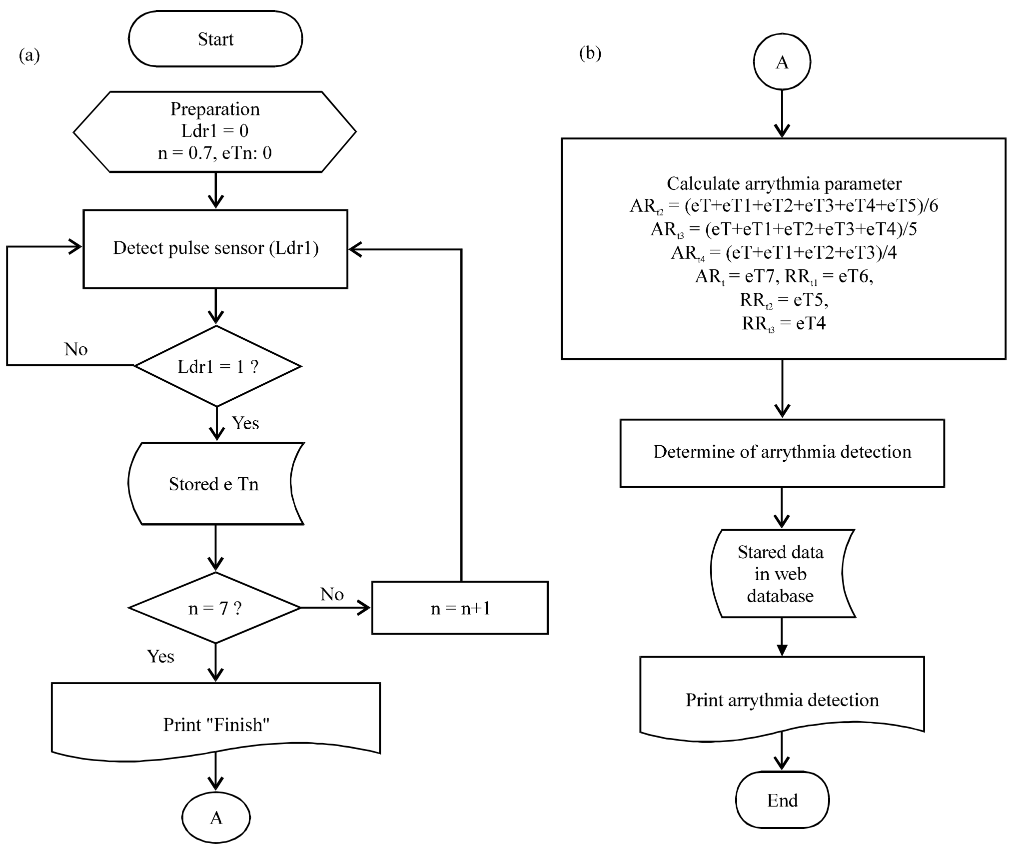


Fig. 9: a, b) Flow chart of the arrhythmia detection process

RESULTS AND DISCUSSION

Test of sensor block : Testing conducted to determine the success of the tool has been built. The test is performed on the output signal of the pulse sensor block. Figure 10 shows the signal display when the pulse sensor has not detected a heartbeat (stanby state). In this signal, shows the pulse sensor output, obtained the signal amplitude is around 10 mV with a period that cannot be determined, so, it is said to be a noise signal. Figure 11 shows the signal display when the pulse sensor has detected a heartbeat. In this signal shows the pulse sensor output, obtained an amplitude value of 8.4 V with a period value of 800 msec or frequency 1.25 Hz.

Table 2: Test result time interval R to R on the 1st respondent

	Attempt						
Period (msec)	1st (ND)	2nd (ND)	3rd (ND)	4th (ND)	5th (ND)	SD	Mean(msec)
T1	892	915	871	892	920	19.84	898.0
T2	907	880	889	903	887	11.37	893.2
T3	915	920	923	924	904	8.170	917.2
T4	923	890	901	895	924	15.92	906.6
T5	931	892	906	911	913	14.05	910.6
T6	905	896	898	903	907	4.660	901.8
T7	830	850	841	869	873	18.28	852.6
T8	796	821	786	807	792	13.83	800.4

Result aritmia; *ND = Disease not Detection

Table 3: Testing results of tool accuracy

		Period (msec)							
No. respondent	Tool	T1	T2	T3	T4	T5	T6	T7	T8
1st	ATD	892	907	915	923	931	905	830	796
	Osc	890	905	917	922	930	906	831	800
	% Er	0.22	0.22	0.22	0.11	0.11	0.11	0.12	0.50
2nd	ATD	915	880	920	890	892	896	850	821
	Osc	914	881	921	891	895	899	852	820
	% Er	0.11	0.11	0.11	0.11	0.34	0.33	0.23	0.12
3rd	ATD	871	889	923	901	906	898	841	786
	Osc	873	890	920	900	905	890	840	788
	% Er	0.23	0.11	0.33	0.11	0.11	0.90	0.12	0.25
4th	ATD	892	903	924	895	911	903	869	807
	Osc	890	900	920	900	910	900	870	805
	% Er	0.22	0.33	0.43	0.56	0.11	0.33	0.11	0.25
5th	ATD	920	887	904	924	913	907	873	792
	Osc	921	890	900	921	910	905	870	790
	% Er	0.11	0.34	0.44	0.33	0.33	0.22	0.34	0.25

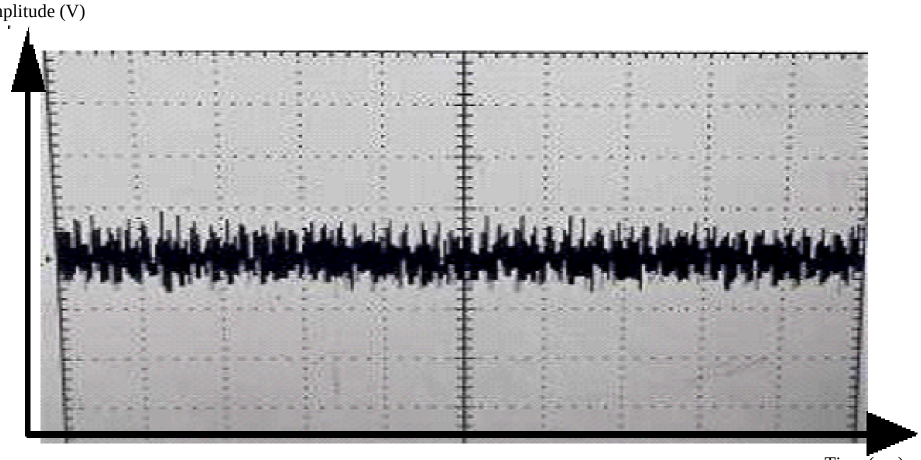


Fig. 10: The oscilloscope display of the pulse sensor output signal when it has not detected the heartbeat

Test of arrythmia monitoring device: The test of the arrhythmia module is done by detecting the output signal which calculated the interval time value (R-R) at 9 detected beats as shown in Fig. 6. Tests conducted on 5 respondents. Each respondent was detected as much as 5 times the measurement. Test results of respondent 1 are shown as Table 2.

Based on Table 2 shows the results of precision testing based on the calculation of Standard deviation (Stdev) averaging of 13.27. While the results of arrhythmia detection showed data ND (Not Detection) on the five tests.

Table 3 shows the results of the accuracy test based on the measurement of the Arrythmia Telemonitor Device (ATD) that was designed with the result of measurement of R-R signal using Oscilloscope (Osc). Based on the result of measurement to five respondents, the result of the calculation of percentage Error (%Er) is 0.25%.

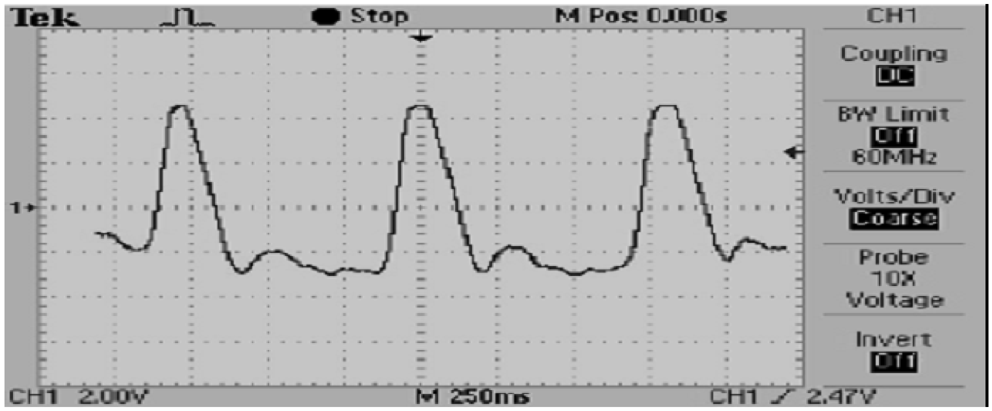


Fig. 11: Oscilloscope display of pulse sensor output signal when detecting heartbeat

CONCLUSION

This research has successfully designed a cardiac arrhythmia telemonitor device using internet communication whose results can be accessed on a web page with the address http://monitoraritmia.hol.es. The cardiac arrhythmia telemonitor device that has been constructed is composed of input blocks in the form of pulse sensors, keypads and press switches. Process block consisting of Arduino Mega Kit module, Ethernet Shield, router and USB Modem. While the output block consists of a 16×2 alphanumeric LCD viewer module and a web display accessed using a computer or smartphone device.

Based on test results on five respondents obtained level of accuracy is based on the calculation of procentstase error average of 0.25%. While the results of precision testing based on the calculation Standard deviation (Stdev) averaged 13.27.

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