A Microcontroller-Enabled System for Monitoring and Detecting Heart Rate Irregularities

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Abstract

The heart is an organ of the human body that plays an important role in blood circulation and is one of the bases for knowing the physical health of every human being. The heart rate monitoring system used by health institutions is quite good but it costs a lot of usages. In the design carried out by researchers produced a tool that can detect all ages, with a detection process for 60 seconds. The results after heart rate detection will provide condition information and BPM (Beat Per Minute) of the heart. The design of this tool uses a pulse sensor as a heart rate detector with a 3x4 keypad as input for age data and is displayed on a 16x2 LCD with the results of heart conditions and BPM. During testing the instrument, researchers tested approximately 20 respondents as counted tests to put their data in a comparison table. From the results of tests that have been done are classified into two systems testing. First using calculations manually or by the sense of touch and the second with a stethoscope. From the results of testing manually produces a percentage of relative error of 2.40%. While testing with comparison using stethoscope results in a percentage of relative error of 1.65%.

Keywords: *heart rate, finger, pulse sensor, BPM*

1. INTRODUCTION

The heart is a muscular organ cavity that works as a pump of blood through blood vessels by repetitive rhythmic contractions. The heart is a human organ in the blood circulation system. This organ is in the chest cavity, the size of a heart the size of a fist weighing approximately 300 grams.[1]

In 2012, World Health Organization (WHO) estimated that 17.5 million people in the world die from cardiovascular disease.[2]Cardiovascular disease (heart disease) is a condition in whichnarrow or blockage of blood vessels causing heart attack, chest pain or stroke.[3]WHO predicted that this occurred 31% of 56.5 million deaths around the world.

According to SRS (Sample Registration System) in 2014, CHD (Coronary Heart Disease) was the highest cause of death in all ages after stroke, with the number reaching 12.9 per-cent of the mortality rate.[2]Whilein 2013 according to the Ministry of Health in 2013,39 per-cents of heart patients in Indonesia were aged 44 years and under. In detail, 22 per-cent of them are aged 15-35 years, during which time is a productive period in human life.[4]

In the initial stages of a medical examination, medical check-ups will usually be carried out before a person's illness is diagnosed.[5]The medical check-up done at the hospital for the first time is to diagnose the patient's heartbeat. A method that is most commonly used in knowing body condition is based on the number of heart pulse. By knowing the amount of heartbeats, heart condition can be identified. That is because the heart is the main component in the blood circulation, which functions to pump blood to the body.

The most common method to find out a person's heart rate is to feel the blood pulse. Measuring the heart in this way is not accurate. In the medicine, *a stethoscope* is a tool to listen to the heart and breathing sounds. This tool is used to hearblood flow in the arteries and 'vein'.

Other alternatives for these tools will be designed by the researcher using microcontroller devices. The research that will be conducted is intended to monitor the heart rate. By knowing the heart rate, it be can determine the health condition of a certain person can be provided information about the state of a person's heart in the form of fast or slow cardiac impulse. The heart rate of children with adults is usually different, as well as between the heart rate of healthy and sick people. Heart rate is measured in Beat per Minute or BPM.

The heart rate monitoring system is designed by the researcher the users in detecting the number of heartbeats and can minimize costs. The results of the pulse sensor measurement can be viewed via an Arduino Uno R3 microcontroller and 16x2 LCD (Liquid Crystal Display). If the heart rate is normal, it will provide information on “Normal”.Whereas if the heart rate is below the average specifications available, then “Denyut Lambat”. Likewise, when the heart rate exceeds the average specification, it will show “Denyut Cepat”. With this tool, it is expected to be able to know the health conditions with the parameters above, at least in the initial stages of the examination.

2. LITERATURE REVIEW

2.1 Heart Anatomy

Inside the heart, there are four rooms divided into two ventricles and two atria. The left atria and left ventricle of the heart contain clean blood which is rich in oxygen, while the right atria and right ventricles contain dirty blood. Besides having four rooms, the heart also has four valves which are useful for keeping blood flowing properly.

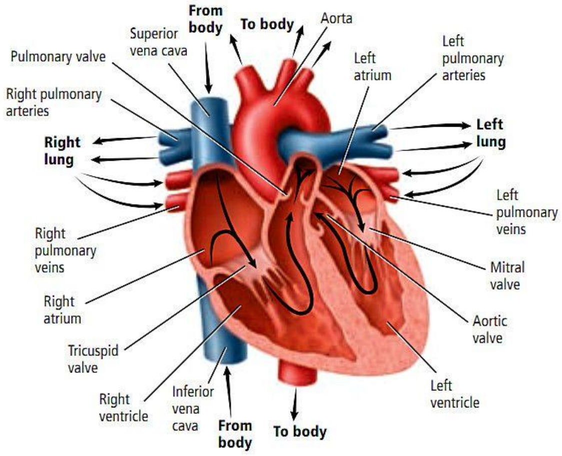

Figure 2.1 Human Heart Anatomy

Source: 'Yayasan Jantung Indonesia (YJI)' Team – 2015[6]

Heart pulse rate is measured with a Beat per Minute (BPM) unit, with the number of pulses can be varied and different each person. A low pulse usually occurs while resting, and increases when exercising. Things that affect the human heart rate are age, air temperature, body position, emotions, body size and side effects of the drug. Following are the specifications of the heart rate in **Table 2.1**.

Table 2.1 Pulse Specification at Various Ages at Rest

AGE GROUP	PULSE RATE (times / minutes)	AVERAGE PULSE (times / minutes)
0 months – 1 year	120 – 160	140
1 – 3 years	90 – 140	115
3 – 6 years	80 – 110	95
6 – 12 years	75 – 105	90
12 – 18 years	60 – 100	80
>18 years	60 – 100	80
>60 years	67 – 80	74
Athlete	40 – 60	50

Source: Nutrition Care Process (NCP)-2015[7]

2.2 Arduino Uno R3

Arduino is a microcontroller with a physical computing platform. Physical computing is to make a system or physical device using software and hardware that is intensive, that is to be able to receive stimuli from the environment and respond back or rather is a concept for understanding humane relations between the environment and its natural properties which are analogue with the digital world.[8]

Arduino UNO R3 is a microcontroller board based on Atmega 328 (datasheet). The Arduino UNO R3 has 14 digital input/output pins (6 of which can be used as PWM output), 6 analogue inputs, a 16 MHz Crystal oscillator, a USB connection, a power jack, an ICSP header and a reset button.Input/output (I / O) is also often referred to as GPIO (General Purpose Input Output Pins), which means that we can program pins as input or output as needed.[9]The Arduino UNO R3 is different from all previous Arduino boards, the Arduino UNO R3 does not use the USB-to-serial FTDI driver chip. Instead, the Atmega 16U2 features (Atmega 8U2 to R3) are programmed as a USB to serial converter.[10]

2.3 Pulse Sensor

A sensor is a device used to detect or measure something which is used to change mechanical, magnetic, heat, light and chemical variations into electrical voltages and currents. In a system of controller and robotics, sensors are a similarity that has eyes, hearing, nose, tongue which will then be processed by the controller as the brain.

The pulse sensor is a heart rate sensor designed for Arduino. This sensor can facilitate the incorporation of heart rate measurements with application data into its development and is an open source monitoring application.[11] In the pulse sensor used a green LED, because the light sensor used is APDS-9008 which has a peak sensitivity of up to 565 nm. In this case, green LED have wavelengths ranging from 495-570 nm, so that they fit the needs of the sensor.

2.4 16x2 LCD (Liquid Crystal Display)

Liquid Crystal Display (LCD) is one of the electronic components that functions as an appearance in a data in the form of characters, letters or graphics.The LCD has data pins, power supply control and display contrast control.[12]The following is an explanation of the pins of the 16x2 LCD in **Table 2.2**.

Table 2.2 Pin of 16x2 LCD

Pin Number	Name	Information
1	VCC	+5V
2	GND	0V
3	VEE	LCD contrast voltage
4	RS	Select Register
5	R/W	1 = Read, 0 = Write
6	E	Enable Clock LCD
7	D0	Data Bus 0
8	D1	Data Bus 1
9	D2	Data Bus 2
10	D3	Data Bus 3
11	D4	Data Bus 4
12	D5	Data Bus 5
13	D6	Data Bus 6
14	D7	Data Bus 7
15	Anode	Positive backlight voltage
16	Cathode	Negative backlight voltage

Source: Book of 'Panduan Praktis Arduino untuk Pemula' (2015)[13]

2.5 12 Converter

The 12C Converter Module is useful for making it easier for us to use the LCD where only 4 pins are used. 12C is asynchronously controlled LCD module with 12C / IIC (Inter-Integrated Circuit) or TWI (Two Wire Interface) protocols.[14]Normally, the LCD module is controlled in parallel both for the data path and its controls.

Arduino itself supports the 12C / IIC protocol, the Arduino Uno 12C port is located on the A4 pin for SDA (Serial Data) and A5 pin for SCL (Serial Clock) by connecting GND and VCC. This module uses the IC PCF8574 product chip from NXP as a controller with the IC used is an 8 bit I / O expander for the 12C bus that works like a shift register.

2.6 3x4 Keypad

The 3x4 keypad module is a keypad module with a size of 3 columns and 4 lines. This module serves to input data in applications such as digital security, attendance, motor speed controllers, robotics, and so forth.

The keypad is composed of several buttons with matrix techniques, namely the buttons arranged into a package with the technique of connecting one button with another button. The preparation of keypad buttons can be made from various components or materials, such as metal, carbon and resistive or capacitive (touch panel). The use of these materials is tailored to the needs for sensitivity, the action of emphasis and the need for a special button. Keypad with metal material is used for the needs of a keypad with a large current. Keypad with carbon material is used for the needs of a keypad with a small current, usually used in voltages of 0v to 5v. While the keypad of resistive or capacitive material is used as a touch panel on electronic devices, such as cellphones, smartphones, computers, and so forth. With this resistive material, a smaller resolution or button can be found in a smaller area.

3. RESEARCH METHODS

The method to be used in this study is to use the Waterfall model. Each process model represents from a certain perspective, thus only providing partial information about the process.In this waterfall model, taking activities in the form of basic process specifications, development, validation and evolution represent each of the separate phases, namely requirements analysis, design, implementation, system testing and maintenance.[15]

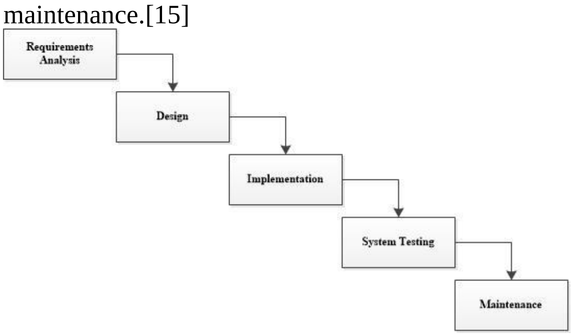

Figure 3.1 Waterfall Process Model

In **Figure 3.1** describes the basic steps in defining device development. The following researchers will explain the basic steps involved in the ongoing research process:

a. Requirements Analysis
In the requirements analysis, researchers will provide information about the usefulness of the device to be designed later. Explanations that will be carried out based on observation and documentation so that the design results can be used.

b. Design
The design system process will allocate requirements for designing devices in building the overall system in the form of architecture. In the design of this device, researchers will display hardware design, system diagram flow, Use Case Diagram, and system flowchart.

c. Implementation
In this process, the design of the device will begin with the use of Arduino IDE software to manage the system to be carried out. The researcher also assembled the design in the form of Arduino Uno R3, Pulse Sensor, 16x2 LCD, 3x4 Keypad and LED.

d. System Testing
After the implementation process is complete, the researcher will test the system in functionalist testing until the overall design test. In testing, the researchers explained the results of functionalist testing with several tables as a more detailed explanation, as well as overall design testing.

The last process in the waterfall process method is the maintenance process. In this stage, researchers do not use the maintenance process to detect errors. Because of the time limit that is on the researcher, the limitations of the research that took place and were less conducive to this study.

3.1 Hardware Design

In designing this research tool using a pulse sensor as a sensor that detects the heart rate and will be converted into analogue graph data. The 3x4 keypad is useful for entering age which will be a reference in the data processing. Data will be processed by Arduino Uno, as the task is to receive signals from pulse sensors, read data, calculate data and send data to the viewer. After the data is processed from Arduino Uno, the results will be displayed on the LCD and also on the LED. The following in **Figure 3.2** is hardware design.

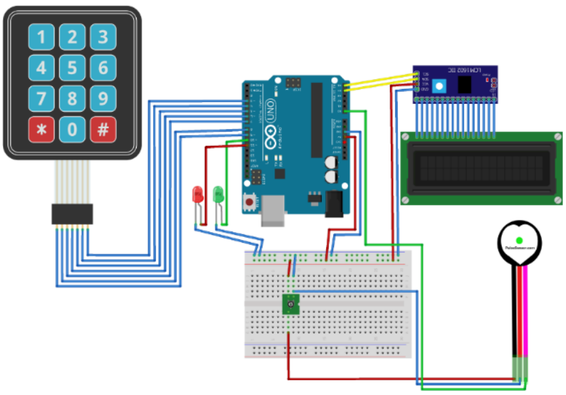

Figure 3.2 Hardware Design

4. IMPLEMENTATION, TESTING AND DISCUSSION

4.1 Implementation of Design System Results

The design of the tool from this study is to be able to read the heart rate for one minute by displaying the heart rate process (BPM) and heart condition after reading the sensor. The purpose of implementing the system is to implement a design that has been analyzed systematically so that the design is as expected.

Figure 4.1 Results of a Series of Heart Rate Detection Devices

4.2 Testing

The overall testing of the heart rate detector is done to prove that the tool can run properly as it functions without any obstacles. The process of testing the heart rate detector as a whole has several stages, these stages are as follows:

1. Turn on the button on the foot switch 2 first.
2. The user first pastes the index finger on the pulse sensor as a pulse sensor reading object.
3. The user enters age data when the age data input command has appeared.
4. The user reconfirms the system whether the age data entered is correct or not, by pressing the '*' (star) button if the age data is correct and the '# '(fence) button, if the age data entered, is incorrect. If the age data entered is incorrect, the system will return to the command to enter age data.
5. After confirmation of age, data is complete and correct, the reading process of the system will run. Users will wait for the process of reading the system for 60 seconds.
6. During the printing process, users can view timer data and BPM data on the 16x2 LCD.
7. Graph data of the heart rate reading process can be seen if the heart detector is connected to a laptop or PC that has Arduino IDE installed and opens the program code from the heart rate detection system. Then the user opens the serial plotter on the Arduino IDE before the system starts, the graph data will be visible

when the system is reading the heart rate process.

8. If it has been 60 seconds, the results will come out on the 16x2 LCD by providing condition and heart BPM information.
9. The program is complete.
10. If the user wants to read again, then the user presses the '*' button to immediately read the heart rate again with the index finger still attached to the pulse sensor and press the '#' button if the user will enter the age data again.

The following is the data from the testing results of a microcontroller-based heart rate detector with several people as users that will be presented in table form.

Table 4.1 Heart Rate Measurement Results

No	Username	Age (Year)	Manual Measured Heart Rate (BPM)	Measured Heart Rate Sensor (BPM)	An Absolute Error by Manual	Measured Heart Rate Stethoscope (BPM)	An Absolute Error by Stethoscope
1	Nizam	1	128	134	6	130	4
2	Dafa	2	125	130	5	128	2
3	Nabila	4	95	99	4	98	1
4	Fayyad	5	106	110	4	105	5
5	Lulu	6	96	99	3	98	1
6	Wawa	10	85	88	3	86	2
7	Lubna	12	90	94	4	90	4
8	Reva	14	90	90	0	90	0
9	Afiqah	14	97	98	1	96	2
10	Lazuardi	24	95	97	2	97	0
11	Fuad	24	96	97	1	95	2
12	Hasyim	23	74	74	0	72	2
13	Agung	23	76	77	1	77	0
14	Ahmad	30	86	86	0	86	0
15	Hasan	35	82	85	3	83	2
16	Imam	35	88	90	2	89	1
17	Bukhori	44	90	92	2	92	0
18	Patminingsih	54	98	98	0	98	0
19	Pak Kin	58	94	96	2	95	1
20	Mbah Kif	63	72	75	3	73	2
Total				**1909**	**46**	**1878**	**31**
Average Relatif Error				**95,45**	**2,3**	**93,9**	**1,55**
Average Relative Error Percentage				**2,40%**		**1.65%**	

Table 4.9 is the result of testing the tools that researchers have designed with a comparison of manual detection and detection using a stethoscope. The results of testing tools with manual testing get a percentage error value of 2.40%. While testing tools with a stethoscope get a percentage error value of 1.65%.

Based on experimental data, pulse sensors can detect and measure minute heart rate (BPM). Measurements are made in the age range found in **Table 2.1**, with users at rest. The data obtained then calculated absolute errors and relative error percentages. Calculation of absolute error percentage and relative error can be seen in the following formula:

$$\text{An absolute Error by Manual} = \text{Measured Heart Rate Sensor} - \text{Manual Measured Heart Rate}$$

$$\text{An absolute Error by Manual} = 134 - 128 = 6$$

$$\text{An absolute Error by Manual} = 130 - 125 = 5$$

$$\text{An absolute Error by Stethoscope} = \text{Measured Heart Rate Sensor} - \text{Measured Heart Rate Stethoscope}$$

$$\text{An absolute Error by Stethoscope} = 134 - 130 = 4$$

$$\text{An absolute Error by Stethoscope} = 130 - 128 = 2$$

To find out the average error in the above table calculation is:

$$\text{Average Relative Error} = \frac{\text{Total Measured Heart Rate Sensor}}{\text{Total Users}}$$

$$\text{Average Relative Error} = \frac{1909}{20} = 95{,}45$$

$$\text{Average Relative Error} = \frac{\text{Total Absolute Error by Manual}}{\text{Total Users}}$$

$$\text{Average Relative Error} = \frac{46}{20} = 2{,}3$$

$$\text{Average Relative Error} = \frac{\text{Total Measured Heart Rate Stethoscope}}{\text{Total Users}}$$

$$\text{Average Relative Error} = \frac{1878}{20} = 93{,}9$$

$$\text{Average Relative Error} = \frac{\text{Total Absolute Error by Stethoscope}}{\text{Total Users}}$$

$$\text{Average Relative Error} = \frac{31}{20} = 1{,}55$$

Here are the results of the average relative error in per cent form:

$$\text{Average Relative Error \%} = \frac{\text{Average Amount Absolute Error by Manual}}{\text{Average Amount Measured by Sensor}} \text{ x } 100\%$$

$$\text{Average Relative Error \%} = \frac{2{,}3}{95{,}45} \text{ x } 100\% = 2{,}40\%$$

$$\text{Average Relative Error \%} = \frac{\text{Average Amount Absolute Error by Stethoscope}}{\text{Average Amount Measured by Stethoscope}} \text{ x } 100\%$$

$$\text{Average Relative Error \%} = \frac{1{,}55}{93{,}9} \text{ x } 100\% = 1{,}65\%$$

The results of testing the tools that have been designed are divided into two parts, namely the results of testing tools with manual calculations and testing tools with a stethoscope. The first result by comparison with testing by manual calculation results in an average relative error of 2.40%. The second result compared with testing instruments with a stethoscope produces an average relative error of 1.65%.

5. CONCLUSION AND SUGGESTION

5.1 Conclusion

The conclusions that can be taken in designing a monitoring system for heart rate detection devices are:

1. Detection using a tool that has been designed by researchers can be used at all ages with a resting heart condition.
2. This detection system reads the heart rate at the fingertips for 60 seconds by entering the user's age first, after confirmation of a successful age, the pulse sensor will read the heart rate and the results will be displayed on a 16x2 LCD by displaying the heart condition and BPM.

5.2 Suggestion

After reviewing the conclusions that have been explained, the researchers hope to make this design better in the future. Following are the suggestions are given:

1. Can be integrated with the Android or desktop application in displaying the results of heart conditions, graphics and BPM.

2. For pulse sensors to use a better heart rate detection sensor because the pulse sensor performance in the sensitivity level and readings are a little slow.

3. Adding conditions for reading the heart rate detector, because the tool that has been designed now only reads the state of the human heart at rest.

4. Add database functions in data storage and print out results that have been read by a heart rate detection system.

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