Human Heart Rate Detection Application

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***Abstract*—Modern daily activities make some people have difficulty to care about his health. Urban air pollution, work pressure, and irregular diet increase the risk of such a person to become infected. In fact, some of the diseases would not cause any symptoms prior to severe ones. One of them is the coronary heart disease. According to a study conducted by the WHO (World Health Organization), in 2030 an estimated 23 million lives lost each year from cardiovascular disease. This value will continue to grow if no proper solution is found. Internet of Things (IoT) technology developments allow humans to control a variety of high-tech equipment in our daily lives. One of these is the ease of checking health using gadgets, either a phone, tablet or laptop. This paper describes the use of IoT technology for measuring the human heart rate that can be monitored using the gadget. As the result of this application, people can easily monitor their heart rate.**

***Keywords*—IoT; gadget; heart rate; measurement**

I. Introduction

Based on information taken from the site of the World Health Organization (WHO), it was estimated that in 2008 approximately 17.3 million people died from cardiovascular disease. Eighty percent mortality from the disease occurred in countries with low to medium incomes (low and middle-income countries). Estimated mortality rate was then calculated to obtain the data that by 2030 more than 23 million people will die each year from cardiovascular disease [1].

In 2005, an organization in the United States that is part of the ministry of health and community services, CDC (Centers for Disease Control and Prevention), conducted a survey in 2005. Ninety-two percent of respondents recognized chest pain as a symptom of a heart attack. However, only 27% of them were aware of all the symptoms and knew how to make an emergency call when someone was having a heart attack. Approximately 47% of sudden cardiac deaths occurred outside the hospital. It shows that many people with early symptoms of heart attack are not acting responsibly. The key to avoid death from a heart attack is just to recognize the early symptoms of a heart attack [2].

Based on the facts that there are many mobile phone users in Indonesia and there are problems regarding the indifference of many people about heart health, this paper presents a smartphone app that can measure heart rate for users. The application was created on Windows Phone 8.0 operating system. Fig. 1 shows block diagram of human heart rate detection system. The application connects to additional external devices with the communication media such as Bluetooth. External devices work to record the heartbeat of the fingers in any particular period by utilizing an infrared sensor [3]. The heart rate data are then processed by a microcontroller and then sent to the smartphone in question. The application's role is to infer the level of heart rate of the user [4]. In January 2014, there was 112% of the Indonesian population active mobile subscription. This indicates that almost the entire population of Indonesia already has a cell phone. Users interact with smartphones through applications that have a GUI (Graphical User Interface), entertainment apps, multimedia apps, productivity apps, news and weather apps.

II. Design

This system includes the involvement of hardware and software in the form of a mobile application. Hardware acts as the input system. That is, in this section there are sensors that can detect the environment. Meanwhile, the mobile application serves as the system output to the user. Both components are connected via the Bluetooth wireless communication.

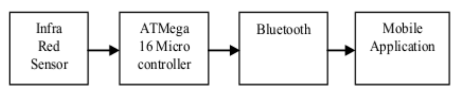

Figure 1. Block diagram of human heart rate detection system

On the hardware side, there are three main components, namely component processors, sensors, and a Bluetooth module. Microcontroller ATMega 16 works as a processor, which will execute any commands that exist in the hardware. The sensor embedded in the system is an infrared sensor that consists of an IR LED and photodiode. The sensor is useful for detecting the heartbeat of the user's finger. The raw data that have been received by the sensor are then processed by a microcontroller. The processed data are then sent wirelessly to the mobile application via a Bluetooth connection. The application will process and conclude the data for later display. The application works on smartphones running on Windows Phone 8.0 operating system [5].

A. External hardware Design

The design of the system hardware for detecting human heart rate based on Windows Phone 8.0 operating system using the infrared sensor includes:

978-1-4673-9899-2 /17 $31.00 © 2017 IEEE
DOI 10.1109/ICSIIT.2017.12

1. Design of the minimum system microcontroller AT Mega 16
2. Design of the infrared sensor
3. Design of the Bluetooth module

This system combines hardware power supply circuit and the three sub-systems that have been mentioned earlier. Sensor and Bluetooth modules incorporated in the minimum system form a larger system as shown in Fig. 2. The figure explains the schematic diagram of the hardware, but the hardware realization is printed in the form of PCB. Users simply press the switch to turn on or off the device. The setting and synchronization is done via Bluetooth windows phone. This hardware has dimensions of 11.6 cm × 9 cm × 10 cm making it possible to carry around (portable).

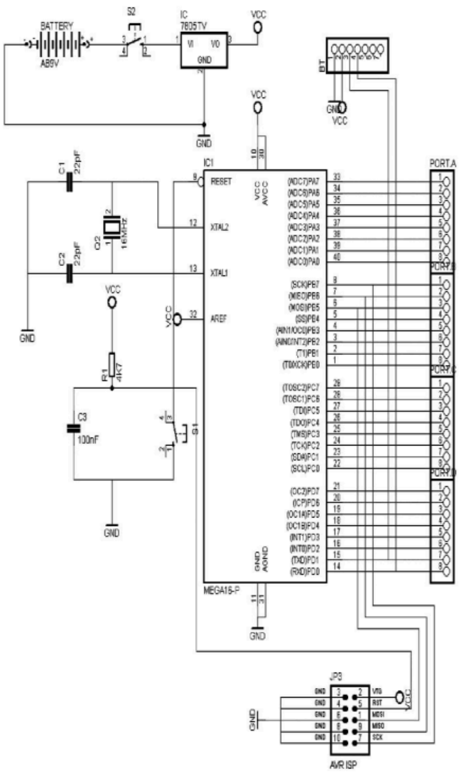

Figure 2. Schematic of hardware circuit diagrams

1) Design of the minimum system microcontroller AT Mega 16

The minimum system microcontroller ATmega16 is required in order to function properly. Therefore, the minimum system design is applied and become the primary circuit on additional hardware. A 16MHz crystal oscillator, two 22pF capacitors, a capacitor 10nF, a 4.7 KΩ resistor, and a push-button arranged in such a manner as shown in Fig. 2. Pins VCC, AVCC and AREF connected to the source voltage to the microcontroller are active as well as ADC features. ADC feature is enabled because it will be used by the microcontroller to process the analog data received from the sensors. GND and AGND pins are connected to ground [6].

2) Design of the infrared sensor

Infrared sensor consists of an IR LED and a photodiode arranged side by side. Infrared LED circuit is quite simple, by connecting the anode and the cathode to VCC and ground. A 330Ω resistor is included in it to prevent the reception of too large current to LEDs. Another thing with photodiode circuit is a little more complicated. Walking photodiode cathode is connected to VCC and anode to ground (photodiode reverse bias assembled using the relationship). Besides connected to VCC, cathode foot is also connected to the 40th pin (Pin A0) of AT Mega microcontroller 16. This pin serves as the microcontroller ADC channel used to receive data from the sensors. In the circuit there is also a 10 KΩ resistor providing the same functions as the resistor in the circuit of the IR LEDs. The series of infrared sensors on the detection system of human heart rate can be seen in Fig. 3.

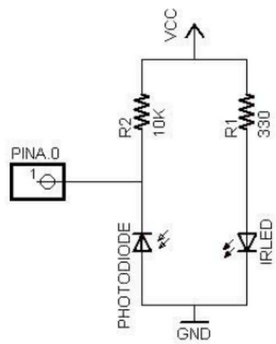

Figure 3. Infra-red sensor circuit

3) Design of the Bluetooth module

Communication between hardware with mobile applications is done wirelessly (wireless) using Bluetooth technology. Bluetooth module used in this system is the DFRobot V3 type. There are 7 feet owned by the Bluetooth module. However, only 4 feet are used by the system. The legs are VCC, GND, TX and RX. Walking VCC and GND are connected to the voltage sources to activate the Bluetooth module. Walking TX is connected to pin 14 (RXD) and RX leg connected to the pin 15 (TXD) of microcontroller. Both pins are responsible for delivering the data to be sent or received by the microcontroller via Bluetooth module. Bluetooth module circuit is shown in Fig. 4.

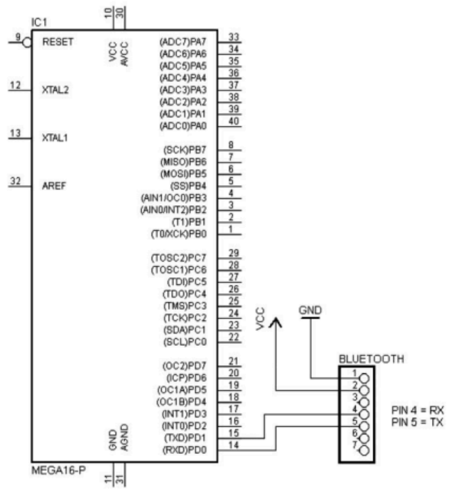

Figure 4. Bluetooth module circuit

There are several similar research like paper of Mallick and Patro (Heart Rate Monitoring System Using Finger Tip through Arduino Uno and Processing Software) [7] and Choi and Guiterrez-Ozune's paper (Using Heart Rate Monitors to Detect Mental Stress) [8].

Flow of the hardware program begins with the initialization of Analog-to-Digital Converter (ADC). Initialization is intended to enable ADC features provided by CodeVision AVR. In addition to ADC, another feature used is USART. Therefore, the initialization process is also made to the USART. In this stage, both USART transmitter and receiver are enabled, because the hardware is sending and receiving data from the application. The next stage is to initialize the port A as an input. Port A is set as an input for a sensor mounted on the port A. The sensors will provide data input to the microcontroller. A port initialization as the input is done via the command DDRA = 0x00. The rest of ports act as output because they will provide the data output of the microcontroller. For example, data to be sent by the Bluetooth module. The command to initialize the port as output is DDRi = 0xFF (i = Name of the port).

There are several variables that are made in the program's hardware. Variables with the names initVal, finalVal, and range, have an integer data type (int). While another variable with the name transmitChar has a character data type (char). These variables will be used to store certain values. FinalVal variable has an initial value of 0 (zero), while the other variables are set to have an initial value. Then, the program flow is followed by reading from the sensor port A pin-0. The data obtained from the sensor are analog data, so they need to be converted by the ADC into digital data, so they can be processed. Then, the digital value is saved in variable initVal. A formula is used to process the finalVal and initVal value, the formula is:

$$range = [finalVal - initVal] \qquad (1)$$

This formula has a function to get the difference's absolute value between finalVal and initVal. The result of the calculation is then set as the variable range's value. If the range's value ranges between 3 and 7, then invoke sub-routines SendData. If the requirements are not met, then proceed to the next command line. Commands from the sensor readings to call subroutines are in the loop forever. Accordingly, all such orders will continue to be repeated. Description of the program flow is summarized in the flow diagram in Fig. 5 [9].

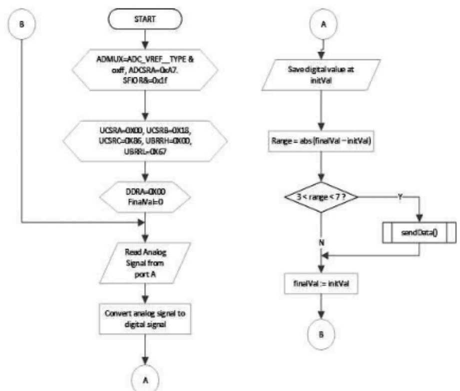

Figure 5. System flowchart

B. Mobile Application Design

Software system design for detecting human heart rate based on Windows Phone 8.0 operating system using the infrared sensor is divided into two parts. The first part is a program to run additional hardware. The second part is a mobile application that operates on a Windows phone. The program planted on a microcontroller is fabricated using C language programming, and the software used is CodeVision AVR. Another thing is that the mobile application is built using XAML and C#. XAML language is used to declare an application's user interface. Meanwhile, C# is used as the code behind. Programming software used to build the mobile applications is visual studio express for windows phone.

The program on the microcontroller is intended for reading the sensor data and sending data via bluetooth. The mobile application consists of 2 pages which display the input of user data and page output. The data entry page is called "MainPage.xaml". This page is tasked to retrieve the data for age, sex, and activity. Although, there are only two columns, i.e., first name and last name, we aim to develop further towards a database. The output page is called "HeartbeatPivot.xaml" which allows you to display data from the application process. Data shown are gender, age, activity, heart rate, maximum heart rate, and the concluded heartbeat condition. There is a timer, which indirectly instructs users to keep putting the finger on the sensor during run time. This application has several methods that are declared and called on both pages. In the manufacturing process, these applications directly simulated in the Windows Phone 8.0 operating system.

C. Mainpage Interface

The mainpage has 3 textblocks, 4 radio buttons, an application bar button, and some textblock as shown in Fig. 6. Elements of this interface serve for the user to enter data. Columns first name and last name will not affect the processing of the data by the application. The second column is intended for further development of the Heartbeat application.

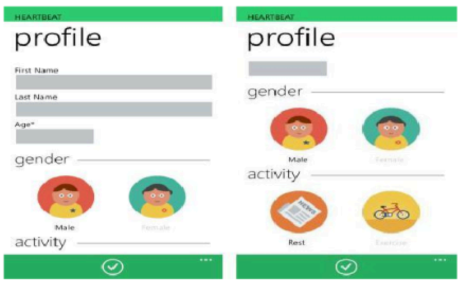

Figure 6. Main page interface

Users must enter data for age, sex, and activity being carried out via this page. For the age data, user gives input by touching the age column. Then the on-screen keyboard will appear and the user can type a number of age. As for the data gender and activity, user simply touches one choice of several options available. Male gender selection is symbolized by the image of a male and female gender by the image of a woman. For the activity choices, leisure activity is symbolized by the image of newspaper and strenuous activity by a bike's picture.

D. Heart rate Detection System

Fig. 7 shows the flowchart of main page, and a schematic diagram of the entire system is shown in Fig. 8. The system is divided into two parts, namely hardware and mobile applications. The hardware includes a microcontroller, sensors, power supply, Bluetooth modules, and other electronic components incorporated in an electrical circuit. The hardware will transmit heart rate data on the application to be processed. The mobile application will calculate the number of beeps and infer normality of the heart rate of the user.

The device is composed of a variety of electronic components and integrated circuits incorporated in a PCB (Printed Circuit Board). PCB is packaged in a beam, with the dimensions of 11.6 cm × 9 cm × 10 cm. The beam has two compartments: the battery space and PCB space. Hardware is powered by a 9V battery that is located at the bottom of the beam. A power button is located on the upper side, while the sensor is on the front left side. Sensors are placed in a cavity to minimize interference due to ambient light system. The device's appearance, beyond the hardware, is shown in Fig. 9.

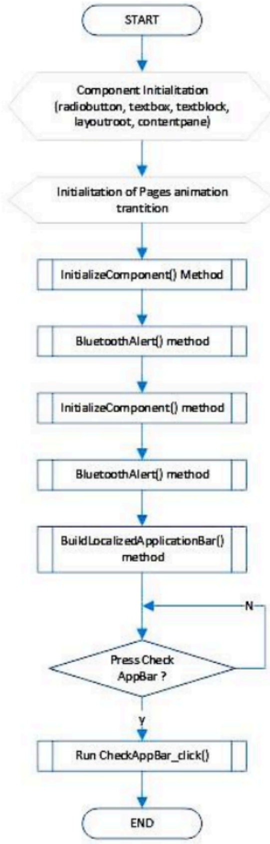

Figure 7. Main page flowchart

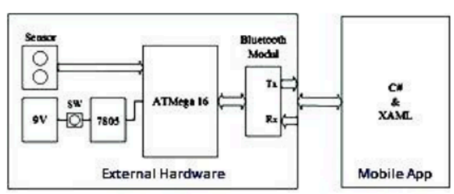

Figure 8. Heart rate detection system

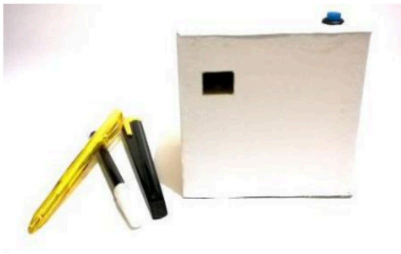

Figure 9. External hardware

Users should turn on additional hardware by pressing the blue button before the application is executed. Then, to start the recording process, place your index finger on the sensor. Then, Bluetooth will send data to the application to be processed. All activities are governed by the microcontroller ATMega 16 embedded in the PCB measuring 12.5 cm × 7.5 cm. Physical appearance of the PCB is shown in Fig. 10. The sensor has its own PCB (separated from the main PCB). This is because the sensor must be conditioned to clamp a user's finger. Thus, two other PCBs are created for IR LED and photodiode. The IR LED's PCB is placed at the bottom of the cavity (i.e., LED is attached to the finger), and the photodiode's PCB is on top of the finger (photodiode attached to the nail).

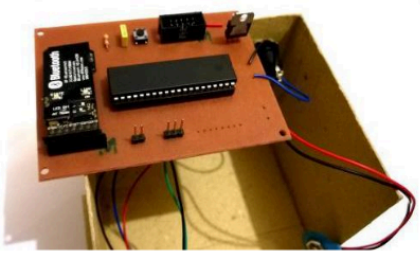

Figure 10. Main PCB

III. TESTING

TABLE I. USERS IDENTITY

Input Data			Output Data						
Age	Sex	Activity	HR	Max HR	Age	Sex	Activity	Status Bar	Animation
20	Man	Rest	×	200	20	Male	Rest	Device is ready	×
35	Man	Exercise	×	200	35	Male	Exercise	Device is ready	×
20	Woman	Rest	×	189	20	Female	Rest	Device is ready	×
35	Woman	Exercise	×	189	35	Female	Exercise	Device is ready	×

*HR = Heart Rate

TABLE II. USERS TESTS

Input Data			Output Data						
Age	Sex	Activity	HR	Max HR	Age	Sex	Activity	Status Bar	Animation
20	Man	Rest	×	200	20	Male	Rest	Recording Your Heartbeat	MyAnimatedEllipse, MyAnimatedLittleEllipse, txbRateOut
35	Man	Exercise	×	200	35	Male	Exercise	Recording Your Heartbeat	MyAnimatedEllipse, MyAnimatedLittleEllipse, txbRateOut
20	Woman	Rest	×	189	20	Female	Rest	Recording Your Heartbeat	MyAnimatedEllipse, MyAnimatedLittleEllipse, txbRateOut
35	Woman	Exercise	×	189	35	Female	Exercise	Recording Your Heartbeat	MyAnimatedEllipse, MyAnimatedLittleEllipse, txbRateOut

TABLE III. CALIBRATION TEST

Testing	Real Heart rate	App Heart rate	Different	Real Status	App Status	Conclusion	
						HR	Result
1	80	72	-8	Normal	Normal	False	True
2	72	69	-3	Normal	Normal	False	True
3	72	61	-11	Normal	Normal	False	True
4	76	80	+4	Normal	Normal	False	True
5	72	87	+15	Normal	Normal	False	True
6	80	94	+14	Normal	Normal	False	True
7	72	87	+15	Normal	Normal	False	True
8	76	65	-11	Normal	Normal	False	True
9	76	47	-29	Normal	Low	False	False
10	76	69	-7	Normal	Normal	False	True
11	72	83	+11	Normal	Normal	False	True
12	76	120	+44	Normal	High	False	False
13	84	98	+14	Normal	Normal	False	True
14	76	98	+22	Normal	Normal	False	True
15	76	87	+11	Normal	Normal	False	True
16	72	61	-11	Normal	Normal	False	True
17	72	91	+19	Normal	Normal	False	True
18	84	120	+36	Normal	High	False	False
19	76	50	-26	Normal	Low	False	False
20	72	72	0	Normal	Normal	True	True
21	76	69	-7	Normal	Normal	False	True
22	76	58	-18	Normal	Normal	False	True
23	76	65	-11	Normal	Normal	False	True
24	72	61	-11	Normal	Normal	False	True
25	72	65	-7	Normal	Normal	False	True
26	84	83	-1	Normal	Normal	False	True
27	72	80	-8	Normal	Normal	False	True
28	72	69	-3	Normal	Normal	False	True
29	72	72	0	Normal	Normal	True	True
30	76	83	7	Normal	Normal	False	True

Testing condition:

The value of the calibration used is 0.91. This value is used to minimize the difference between application pulse and normal pulse.

Percentage Error:

$$\sum difference = 384$$

$$\text{Difference Average} = \frac{\sum difference}{30} = 12.8$$

$$\text{Error} = \frac{4}{30} \times 100\% = 13.33\%$$

The pulse and decision facts are measured by calculating the heart rate manually by pressing a finger on the body to feel the pulse.

IV. CONCLUSION

Application for detecting human heart rate based on Windows Phone 8.0 operating system using the infrared sensor was successfully realized. The applications were built using XAML and C# languages with Visual Studio Express for Windows Phone.

Additional hardware was successfully realized in the form of Printed Circuit Board (PCB) and packaged in blocks. The hardware is programmed using C language on AVR CodeVision program. No problems were found relating to the percentage of errors on certain aspects. The error was most likely caused by a mismatch of sensors. However, this can be minimized by providing a calibration value.

Additional hardware with mobile applications can be connected with a Bluetooth connection. The hardware is able to send data, and the application is able to receive data from the hardware properly

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