Design and integration of portable health sensors

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Abstract. Body Area Network is a measurement concept using sensors with a pair directly attached to the body to monitor the condition directly. The benefits in the world of health are enormous plus remote monitoring capabilities. Currently the use of medical devices as a means of detecting heart conditions, blood pressure, and so forth is still considered less efficient, because in every health tool required several sensors and different platforms. Thus, the idea for integrating these sensors is to improve service quality and tool efficiency and time, to meet the Body Area Network concept, this research proposes a new approach to direct health monitoring. The purpose of this research is to integrate some medical devices such as Temperature, Electrocardiogram (ECG), Electromyogram (EMG), Galvanic Skin Response (GSR) and SPO2 Pulseoxymeter into one platform portable health sensor equipped with two delivery media for data storage that is by using Bluetooth and network Wi-Fi so that in a health check only use one tool. In the application of the results of the use of GSR, ECG and EMG sensors in the form of graphs that can be seen fluctuations based on measurements in the body, and on the use of temperature sensors and SPO2 Pulseoxymeter results from visualization on the sensor in accordance with the measuring value range in normal body.

1. Introduction
Health is an important aspect of human rights where everyone has the right to an adequate standard of living for health. Public awareness to carry out health checks is very influential in preventing early health problems. By carrying out regular checks, the community can also get information about health conditions at that time. The problem is that not all devices for detecting health are integrated into one platform. The majority of medical devices are separate and only owned by the hospital. Not all people have health devices in their homes that can be connected to hospitals.

With the development of Internet of Things (IoT) and Wireless Sensor Network (WSN) technologies that form a sensor network, each health device unit with a unique ID can collect health data. The medical device unit can be owned by everyone and can be taken anywhere. A person can see the development of his health condition and send the health condition status to the doctor at the hospital from his home[1].

The objectives of this research is to make portable Electronic Health (E-Health) device to monitor real time patient health condition with Integration of five sensors (Temperature, Electrocardiogram (ECG), Electromyogram (EMG), Galvanic Skin Response (GSR) and SPO2 Pulseoxymeter) in one platform supported by wireless networks used as data transmission medium for later medical analysis without requiring the patient to face to face with the doctor and facilitate the patient to conduct health checks anytime and anywhere independently[2].
Several studies have been conducted by several researchers relating to monitoring health conditions by utilizing sensors and wireless network. Sandeep et al. [3] developed an Internet of medical things (IoMT) framework for organizing, monitoring and managing health applications. The IoMT Framework consists of 3 layers, namely the data collection layer of the health device, the data transmission protocol layer, and the remote health monitoring layer with an efficient health device. To overcome the problem of limited energy availability, they proposed an energy efficient ON-OFF algorithm (EEOOA) method for sending health data from the source node to the destination node in the medical system. The experimental results show that the energy efficiency using the EEOOA method is better than the traditional method on IoMT. Soumya et al. [4] proposed an IoT system in the health field that provides information on the patient's current condition. The system will provide information on the location of the nearest hospital and information on the availability of health services in the hospital.

Pace et al. [5] proposed an IoT-based health monitoring service called INTER-Health. INTER-Health provides information about body weight, blood pressure, and physical activity carried out by the patient. The data is sent via sensors and analysed on cloud servers. Alpana et al. [6] propose the IoT framework model for health monitoring for hospitals. IoT in the field of health monitoring can be applied in several models: smart devices, digital health knowledge resources, remote health monitoring, remote weighting, electronic health data, elderly care, personal health applications, health information systems and hospitals. Udin et al. [7] developed a health device to detect fever symptoms in children to avoid the condition of febrile seizure. A temperature sensor is installed in the child's clothes which will sense the child's body temperature and send the sensor data to the cloud and his parents' mobile devices.

In this portable health research have differences with previous researches: There are 5 sensors used, namely SPO2 Pulse Oximeter, Galvanic Skin Response, Electrocardiogram, Electromyogram, and Temperature. The 5 sensors are integrated in one tool that can be used interchangeably. There is a direct display of the tools that have been made, so that the results of the inspection can be seen directly. There are several options available to see the results of the examination, namely through mobile phones by utilizing Bluetooth communication and through the web, where the examination data is stored in the cloud first, then the data will be processed so that the patient can see the results every examination on the web.

### 2. System Architecture

#### 2.1. Design System of Portable Health platform

This portable health implementation is a combination or integration of several health measuring instruments as shown in figure 1 the design system of portable health platform.

![Design system of portable health platform](image-url)

**Figure 1.** Design system of portable health platform.
The functions in the section above are:

1. On the left side there are 5 sensors that will be used for measuring or knowing the condition of the patient, the 5 sensors are Body Position, Electrocardiogram, Electromyogram, Galvanic Skin Response, SPO2 Pulseoximeter, Temperature and Blood Pressure.
2. Arduino Uno and E-health Platform, act as data readers and process measurement data that is carried out with 5 sensors which then the measurement data will be forwarded to Arduino Nano.
3. Arduino Nano is the main brain that functions how this tool runs, on Arduino Nano is connected with a button that can be used to choose which sensor to read, besides Arduino Nano can manage what is displayed and the data delivery media using Bluetooth or forwarded to NodeMCU to be sent to the cloud provided.
4. Bluetooth HC - 05 functions for communication lines between smart u - health with mobile phones wirelessly.
5. There is an LCD Nokia 5110 which functions as an interface with patients to see first-hand the data of the examination.
6. NodeMCU ESP8266 is a Wi-Fi module that functions as a sender of data to the cloud via the internet network.

Figure 2 shows the E-Health platform, Arduino Uno, NodeMCU, Arduino Nano, and Bluetooth have been combined into one. The device is used to read all sensors connected to Arduino Uno and E-Health platform.

![Figure 2](image_url)

**Figure 2.** (a) Sensing device, (b) Processing device.

Arduino Uno and the E-health platform are used to read the results of the measurement to the 5 sensors used. There is a connector that is used to receive commands obtained from the device, in addition there is a data path used for sending data from the measurement. Then, if the E-Health platform for measuring EMG and ECG has to move jumpers located at the top of the module, the switch has provided a switch that can be used without having to move the jumper to retrieve data.

On this device there are several modules installed at once such as Arduino Nano, Nodemcu, step-down and Bluetooth. Through this layout all devices can be connected, both from buttons, LCD, Arduino Uno and also MCU Nodes. This tool is working at a voltage of 5V so that a step-down module is needed to reduce the voltage so that it corresponds to the working voltage on this device.

There are 4 buttons provided to select the menu on this tool. Then provided 3 pairs of switches that can be used to select the sensor read EMG or ECG, also provided a switch to turn off and turn on Bluetooth, so that when unused Bluetooth can be turned off alone to save power of the battery.

Figure 3 is a box packaging design of smart E-Health prototype that will be made, in the design has been provided a place for LCD, button, power and place to connect the sensor that will be used for measurement. The prototype of smart E-Health has been assembled and connected all in this tool. The patient can perform a health check using the 5 sensors. There is a LCD with a resolution of 84x48 pixels provided to display the measurement data, 4 buttons used for menus, and also 6 switches.
Figure 3. Prototype of smart E-Health device.

Figure 4 is a source code that will be uploaded to Arduino Uno for reading of GSR, ECG, EMG, Temperature and SPO2 Pulseoxymeter sensors. Sensor readings on e-health occur on the line where there is source eHealth. Get Skin Resistance (), eHealth. getBPM(), eHealth. Get Oxygen Saturation(), and the other that serves to read sensor readings that are then stored into variables that have been provided. The program is embedded in Arduino Uno. The similar code is also done for Arduino Nano and NodeMCU.

Figure 4. Source code program software for reading sensors.

Figure 5 describes the sensor data transmission flow in Arduino Uno where Arduino Uno will read sensor data according to the command received from Arduino Nano which then the data is stored into
the corresponding variable with the sensor data respectively, then the data is sent to Arduino Uno via
the serial line. After the user chooses the sensor button, Arduino Uno will command the E-Health
sensor to send the sensor data. Once the data is received, the data will be from the 5 sensors has been
read. The data saved into the variable is proceed and displayed on the LCD that has been provided.

![Diagram](image.png)

**Figure 5.** Sensor data transmission flow.

### 2.2. Design of E-Health Cloud System

The E-Health system was also developed by adding cloud computing as a data processing and storage
centre as shown in figure 6.

![Diagram](image.png)

**Figure 6.** E-Health cloud system.

The system starts from patient biometric data collection. Then the health sensor data is sent to the
cloud after the Wi-Fi module gets an internet connection. The cloud section contains Firebase as a data
storage centre and cloud hosting subscription as a web server. Data from sensors in real time is stored
in Firebase database which has a structure like the JSON data format. Every single data from the
sensor that is successfully sent will be saved into one database tree.
The web server will forward data requests by the user to Firebase using REST. The web server used is cloud hosting subscription. It provides its own virtual network infrastructure that is isolated from each other. So if one of the servers goes down then the other web will have no effect. Network management is managed by more professional third parties.

The user interface is available through the E-Health web application. Users can find out the results of their health checks through a web browser connected to the internet by accessing the E-Health Cloud URL. The web page is created using PHP 7 and the Yii framework.

3. Result and Discussion

3.1. Testing Temperature Sensor

![Image of temperature sensor installation](image7)

Figure 7. Installation temperature sensor.

The first stage is the installation of a temperature sensor. The temperature sensor is placed on the fingers as shown in figure 7 to begin measuring. There are several menus on the device that have been made, so the user can choose the temperature sensor. A variable temperature with the float data type used to store sensor readings with an eHealth. Get Temperature function found in the eHealth.h library. After the data is stored then it is displayed on the serial monitor. In this experiment, data collection was taken every 200 ms. The results of measurements with temperature sensors are displayed on the serial monitor that has been provided by Arduino IDE with the condition of normal body temperature is in the range of 35 C - 37.5 C.

3.2. Testing SPO2 Pulseoxymeter Sensor

![Image of SPO2 sensor installation](image8)

Figure 8. Installation SPO2 sensor.
The SPO2 sensor is attached to the finger as shown in figure 8 to start measuring. In the Pulseoxymeter SPO2 reading, there are two stored values, pulse rate bits per minute (bpm) and oxygen in the blood (SPO2) which is the value of reading the percentage of hemoglobin molecules in the arterial blood. The results above show that the measurement of SPO2 in the blood is 98% where the value is still in the normal range measurements using SPO2, the normal hemoglobin level in blood is between 95% - 100%.

The data retrieval of Pulseoxymeter SPO2 use digital pin 6 to set the interrupt of sensor reading so that when interrupt send interrupt on digital pin 6 function of read Pulseoxymeter will be executed which then will update data stored on private variable in program. The eHealth.getOxygenSaturation() and eHealth.getBPM() functions are started on the program i, to retrieve the heart rate data per minute and hemoglobin level in the blood. In this experiment the data retrieval is taken every 500 ms then displayed to see the conformity of the measurement data on a device with processed data displayed on the monitor serial.

3.3. Testing Galvanic Skin Response (GSR) Sensor

The installation of GSR sensor is mounted on both fingers as shown in figure 9. The patient must be in a state of relaxation in this examination, because the sensor is sensitive to sweat. If the patient is emotional or in a condition that is not relaxed will make the sweat glands secrete more sweat so that will affect the results of the measurement. The function in GRS sensor is used to read the conductance, resistance, and voltage of the conductance resulting from the reading done. The measurement results are stored in the variable conductance, resistance, conductance Vol in the float data type, then adds the Serial.print() command to retrieve the results of the measurement. The results of the measurements can be seen in the monitor serial feature provided by the Arduino IDE.

After the trial shows the sensor data to serial monitor successfully then the author tries to develop to take the value on serial monitor and process it into a desktop application with C# language as shown in figure 10.
This application has several features such as that can store the results data examination of numbers and graphs as follow.

1. Connect button: This button serves to start taking data and display data in the form of graphics and numbers from the E-Health smart prototype.
2. Disconnect button: The button functions to Disconnect from application with tool.
3. Save Data button: This button is used to store data from the measurement results in the form of numbers.
4. Save Graph Button: This button is used to store data from the measurement result of the graph.
5. Combo box baud rate: function to determine the baud rate on the port to be read. This baud rate must be the same as the one set in the Arduino.
6. Combo box Port Com: function to determine which device will be done serial reading.
7. Reset Button: Works to restore applications at initial values where the graphs and existing data are emptied.
8. Radio Button: On the radio button there is a choice of 5 sensors that will be read, namely Temperature, SPO2 Pulseoxymeter, GSR, Electrocardiogram (ECG), and EMG (Electromyogram).

3.4. Implementation of Web Applications

Sending data to the database can be done by setting Wi-Fi delivery on the device. The MCU node on the E-Health platform can send data to Firebase as long as the device is connected to the internet. To connect to the internet, you need to initiate an SSID and access point password that is used. If the connection status is successful, the IP address will be displayed. After that the connection request to the Firebase account is done. This is done with the help of FirebaseArduino and ArduinoJSON libraries.

Before sending data, the patient's name must be inputted first on the E-Health Cloud web page. After that, the patient begins to do data checking and parsing. Patient name, date of examination, and patient status data will be asked for NodeMCU for the location of the data tree to be sent. The parsed data is made into JSON format and then sent using the Firebase.push() method.

Figure 11 shows the results of inspection data using a pulseoximeter sensor. There is a pulse rate bit per minute (prbpm) value that shows the number of pulses, the SPO2 value for oxygen saturation in the blood, and the data category that is normal.
Figure 12. GSR sensor graph in the web.

Figure 12 shows the results of the inspection data using the GSR sensor. There is a conductance value from the user's sweat. Data graphs are taken from measurements in two conditions. On the graph, the first condition is to the left of the red line. The graph line looks smoother which shows the psychological condition of the user tends to be good. Changes occur in the line to the right of the line from the measurement results in the second condition. Visible lines experienced sharp fluctuations. In this condition the psychological user is feeling not good.

4. Conclusion
This research designed and implemented a portable Health to detect Temperature, Electrocardiogram (ECG), Electromyogram (EMG), Galvanic Skin Response (GSR) and SPO2 Pulseoxymeter sensors into one device. The data sensors will send to the cloud by using Bluetooth and network Wi-Fi. The experimental results show that Desktop applications for monitoring are used successfully. The measurement results display using the SPO2 Pulseoximeter sensor from the visualization of the sensor with the data displayed after processing accordingly. Measurement with temperature sensors in normal body conditions according to the temperature range contained in the sensor description. With the implementation of this research, the data of each sensor can be collected and monitored. The results of collected biometric data that can be monitored in the form of fluctuations in graph movements obtained from the measurement results. The web application for monitoring is successfully used. In future research, this device can be added with other several vital sign monitoring sensors.

5. References
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Acknowledgments

This research was supported in part by Ministry of Research, Technology and Higher Education of Indonesia, under scheme ‘Penelitian Terapan Unggulan Perguruan Tinggi (PTUPT)’ 2020.