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Vital Sign Monitoring in ICU Patients Based on MEWS (Modified Early Warning Score) with IOT (Internet of Things)

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Abstract

Vital signs are signs that show important functions of the human body, from these signs can be known whether a person is relatively healthy, has a serious illness, or suffers from a life-threatening disorder. Vital signs are the value of physiological functions consisting of blood pressure, temperature, oxygen saturation, pulse and respiratory rate. Vital sign monitoring tools researchers used four parameters, namely blood preasure, heart rate, oxygen saturation, and body temperature. The tool uses the IoT (Internet of Things) system, where this tool uses sensors used, namely the DS18B20 temperature sensor, the Heart Rate sensor and the SPO2 MAX 30100 sensor, the OMRON HME-7130 sensor, the ESP 32 microcontroller as a data processor and Wi-Fi connection. The patient's vital condition data will be displayed on the android smartphone and on the mydevices.com WEB page. This tool is rule-based with a Modified Early Warning Score (MEWS) system to determine the status of patients and assist medical personnel in monitoring the vital parameters of patient signs in real time at each location and responding quickly and precisely so as to improve the quality of life of patients. Comparison using patient monitor tools, body temperature measurements produce the highest and lowest percentage of error that is 0.19% and 0.08% with an average temperature of 36.06ºC and 35.96ºC, then heart rate measurements obtained the highest and lowest percentage of errors of 0.08% and 0.3% with an average heart rate of 74 bpm and 87.3. Then the measurement of SpO2 obtained the highest and lowest percentage of error of 1% and 0% with an average SpO2 of 97% and 97.3%, then the NIBP measurement obtained the highest and lowest percentage of error systole / diastole of 7.4% / 7.2% with NIBP with an average systole / diastole of 109.6 / 64 mmHg and the lowest error percentage is 0.3% / 1.1% with an average NIBP of 125 / 62.3 mmHg. Data transmission to the internet using the cayene application on Android smartphones and WEB is greatly influenced by the quality of the connection from the internet network.

Keywords: *Vital Signs, Modified Early Warning Score (MEWS), DS18B20, MAX 30100, ESP32 Microcontroller, IoT.*

1. Introduction

The hospital as one of the public service institutions, requires the existence of an information system that is accurate and reliable, and is sufficient to improve services to patients and other related environments. Information intensive plays a vital role in decision making [1]. Patients in intensive care units (ICU) are patients who are in severe and life-threatening conditions that need continuous monitoring of the condition of the vital sign and all body functions, namely: blood pressure (blood pressure), average heart rate (heart rate), oxygen saturation (SPO2), and body temperature with the most advanced equipment available.

Vital sign parameters consisting of blood pressure (blood pressure), average heart rate (heart rate), oxygen saturation (SPO2) and body temperature monitored based on Modified Early Warning Score (MEWS) and connected with IoT can be used to identify the state of the patient at risk early based on the value of the parameters of the vital sign. Vital parameters of the patient's sign in real time at each location and respond to it quickly and precisely so as to improve the quality of life of the patient.

Cayenne is one of the IoT (Internet of Things) platforms as well as a server capable of storing projects that are being created. Cayenne supports various types of microcontrollers such as Raspberry, Arduino, and others. Cayenne has a user-friendly interface and has various types of connections in connecting between the microcontroller and the internet platform. In addition to these advantages, there are still features that make Cayenne more user-friendly, namely the existence of smartphone-based applications with Android OS, IOS, and Windows Phone so that it makes it easier to make various electronic devices with remote control via the internet.

Vital signs are signs that show important functions of the human body. From these signs can be known whether a person is relatively healthy, has a serious illness, or suffers from a life-threatening disorder. Vital signs are the value of physiological functions consisting of blood pressure, temperature, oxygen saturation, pulse and respiratory rate [3]. Blood pressure is the amount of blood energy pressed against the walls of arteries (arteries) when the heart pumps blood throughout the body. There are two human blood pressure readings, systole and diastole. Systole is a phase in the cardiac cycle when contraction of the ventricles to pump blood into the arteries, normal systolic pressure is around 120 mmHg and ranges from 95-120 mm Hg. Diastole is the relaxed phase of the cardiac cycle for further contraction or when blood from veins flows to the heart, normal diastolic pressure is 80 mm Hg and ranges from 60-80 mm Hg. Heart rate (HR) is the number of heartbeats in one minute and is represented in beat-per-minute (bpm) units. According to the ECG heartbeat chart is the number of complex QRS, which is the amount of ventricular depolarization in a long minute period. Heart rate is not always the same as pulse. The heart rate is a measure of electrical activity, while the pulse ensures blood perfusion to the target tissue. Heartbeat is a function of time. There are several methods for measuring the heart rate of an ECG. The simplest, most common and accurate method involves multiplying the number of QRS complexes found more than six seconds by a factor of 10 to get a number of complex QRS in one minute [4].

Oxygen saturation, often considered the fifth vital sign, is used to set the initial initial Spo2 value. This is an excellent monitor to assess patient responses to respiratory care interventions. In adults, normal Spo2 values range from 95% to 99%. SpO2 values from 91% to 94% indicate mild hypoxemia. Mild hypoxemia guarantees additional evaluation by respiratory practitioners but usually does not require additional oxygen. Spo2 readings from 86% to 90% indicate moderate hypoxemia. These patients often need additional oxygen, SpO2 values of 85% or lower indicate severe hypoxemia and require immediate medical intervention, including oxygen administration, ventilatory support, or both [5]. Normal body temperature can range from 97.8 ° F or equivalent to 36.5 ° C to 99 ° F or 37.5 ° C. Someone said normal temperature, if the body temperature is at 36 ° C - 37.5 ° C. A person is said to be low temperature (hypothermia) if his body temperature is <36 ° C, said to be high temperature or hot if it ranges between 37.5 ° C - 38 ° C, Febris 38 ° C - 39 ° C and Hyperthermia if the temperature is > 40 ° C.

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Table 1. The Modified Early Warning Score [5].

Input	*Low*-3	*Low*-2	*Low*-1	*Normal*-0	*High*-1	*High*-2	*High*-3
SBP	<75	70-80	80-100	95-199	-	-	>185
HR	-	<50	45-60	53-100	95-110	105-130	>125
SPO2	<85	83-90	87-95	>93	-	-	-
TEMP	-	<36.5	-	36-38.5	-	>38	-
BS	<66	63-72	-	70-110	-	106-150	>140
AVPU/GC	< 9	9-13	14	A/15	V/Confuse	P	U

2. Methodolgy

System Architecture Model

ESP32 Microcontroller Score is a single 2.4 GHz Wi-Fi-and-Bluetooth combo chip designed with 40 nm TSMC ultra-low-power technology. It is designed to achieve the best power and RF performance, demonstrating durability, versatility and reliability in a variety of applications and power scenarios. The ESP32 chip series include ESP32-D0WDQ6, ESP32-D0WD, ESP32-D2WD, and ESP32-S0WD [6].

Features of ESP-WROOM-32 include:

- 80-240 MHz Tensilica DUAL-CORE.
- IEEE 802.11 b / g / n WiFi (802.11n up to 150 Mbps)
- Bluetooth v4.2, Bluetooth Low Energy (BLE),
- CVSD and SBC audio codec
- Interface: SD card, UART, SPI, SDIO, I2C, PWM LED, PWM Motor, I2S, IR
- GPIO, capacitive touch sensor, ADC, DAC
- On-chip Hall sensor, temperature sensor
- 4 MB SPI external flash memory to store data

DS18B20 Temperature Sensor is a temperature sensor whose output is digital, produced by dallas semiconductor. In DS18B20 having 12 bit resolution, DS18B20 communicates via 1 cable with only 1 data needed for communication [7].

The MAX30100 sensor is an pulse oximeter integrated with a heart rate monitor module. In this module combines two LEDs (IR and Red Led) a photo detectors, optical elements, and low-noise electronics, optimally used as signal processing to detect oximetry and heart rate monitors [8]. Benefits and Features:

- Simple design contains a heart rate monitor sensor and a Pulse Oximeter Sensor
- Small 14-Pin Optical Module 5.6mm x 2.8mm x 1.2mm 14-Pin
- Integrated Cover Glass, Sturdy Performance
- Ultra-Low Power Operations for Cellular Devices
- Low Power Heart Rate Monitor (<1mW)
- Ultra-Low Shutdown Current (0.7µA, typ)
- Fast Data Output Capability, High Sample Rate
- Strong Resistance Artifact Motion, High SNR
- Operating Temperature Range of -40 ° C to + 85 ° C

The OMRON HME-7130 Blood Pressure Sensor is a series consisting of several parts including a DC motor drive circuit, selenoid valve control, regulating the work of the selenoid valve and reading the output of the MPX 5050DB pressure sensor. This blood pressure sensor is a sensor kit from OMRON, the working principle of this sensor is that when the pump fills air on the cuff, the sensor reads the air pressure in the cuff, while also detecting the pulse of blood flow, this pulse will later be read as a systole and diastole.

Connectivity between electronic equipment and the Internet network requires an interface or platform to connect properly. Cayenne is one of the IoT platforms as well as a server that is capable of storing and supporting various types of microcontrollers such as Raspberry, Arduino, and others. Cayenne has an easy to use interface and has various types of widgets connecting microcontroller devices. In addition to these advantages, there are still features of the Cayenne that are easier to use. There are smartphone-based applications with

Android, iOS, and Windows Phone OS. So this makes it easy to make various kinds of visualization of results from electronic devices with remote control via the Internet, or IoT.

Cayenne also supports the drag-and-drop system of Arduino sensor features that are used to display sensor readings. Users can use various kinds of shields to be used as an IoT platform with quite easy settings, including Wifi, BLE, IR, NFC, and so on [9]. In designing the prototype system of Vital Sign Monitoring on ICU Patients Based on Modified Early Warning System (MEWS) with IoT (Internet of Things) is inseparable from the research design. Figure 1 shows the prototype monitoring design of vital sign.

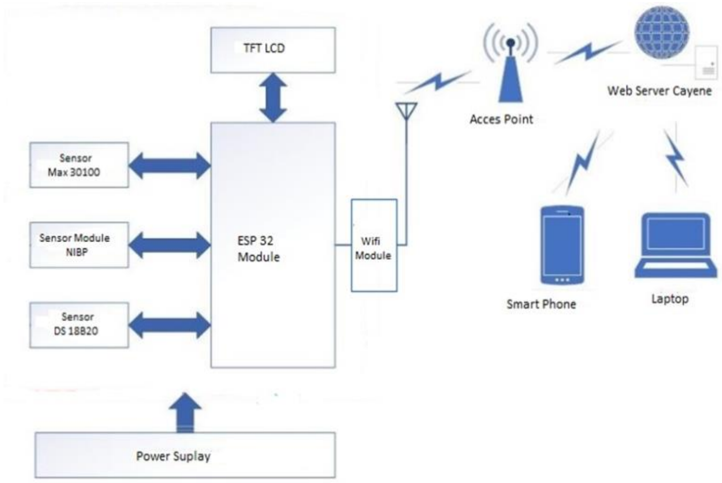

Figure 1 Design of Vital Sign Monitoring in ICU Patients Based on Modified Early Warning System (MEWS) with IoT (Internet of Things)

The system consists of several sensors that are useful for tapping vital signs from the body, including blood pressure, heart rate, oxygen saturation, and temperature, then the signal or data from the sensor will be converted to digital data that will be processed by an ESP 32 microcontroller. , then displayed on the LCD screen and connected to the web server using a wi-fi network and transfer data with an internet connection via wifi so that the display or results can be viewed via a smart phone (android) or Web.

In making monitoring of Vital Signs in ICU Patients Based on Modified Early Warning System (MEWS) with IoT (Internet of Things) using the MAX 30100 sensor which is useful for detecting oxygen levels in the blood and heart rate, DS18B20 sensor is used to measure body temperature and sensor modules OMRON HME 7130 pressure to detect blood pressure. Figure 2 is a schematic of a system.

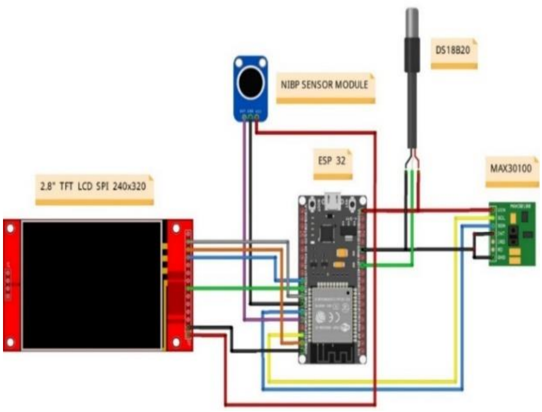

Figure 2 System Schematic Diagram

3. RESULTS AND ANALYSIS

The measurement results are data about the measurements of each section which find out whether the results of the series are in accordance with the planning results, for the first measurement time interval with subsequent measurements of 5 minutes, while analyzing the data from which aims to compare the theory with the results of the measurement points by knowing the percentage Data errors are detected using the following formula:

$$\%\,Error = \frac{Measuring\ results - Theory\ results}{Theory\ results}\ X\ 100\ \% \ldots\ldots\ldots(4-1)$$

As for the measurement results of the tapping from the researcher's instrument, it uses a comparison with the original instrument, where the percentage of errors does not use a formula but the difference in reading. The power supply circuit is designed according to Figure 3, testing of the power supply circuit is carried out to determine the output voltage of the circuit. Expected voltage is 7.2 volts for input power supply and 6 Volts for output. Tests carried out using a digital multimeter and compare it with theory. Table 2 Is the result of testing the input power supply

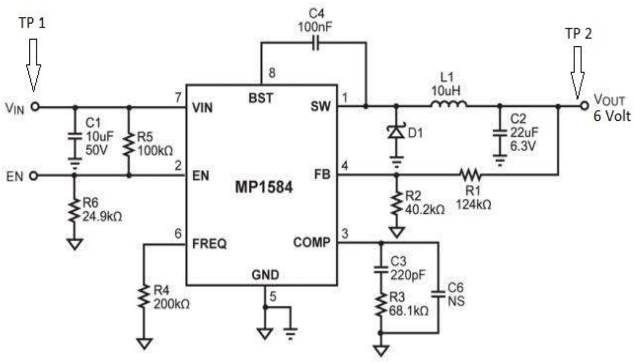

Figure 3 Power supply circuit

Table 2. Testing the power supply input circuit

Measurement	Datasheet	Input Supply	Difference (V)	Difference (%)
1	7,2 V	7,30	0,1	1,3
2	7,2 V	7,30	0,1	1,3
3	7,2 V	7,29	0,09	1,25
4	7,2 V	7,27	0.07	0,97
5	7,2 V	7,27	0.07	0,97
Average		7,286	0,085	1,158

The output from the battery in theory produces 7.2 Volts, following the percentage error.

$$\%\,Error = \frac{Measuring\ results - Theory\ results}{Theory\ results}\ X\ 100\ \% \ldots\ldots\ldots(4-1)$$

$= \left|\left(\frac{7{,}286 - 7{,}2}{7{,}2}\right)\right| \times 100\%$

= 0,085 x 100%

= 1,158 %

Data analysis results of measurement of TP 1 error percentage on average of five times the measurement of 1.158%, the TP1 error percentage does not have much effect because the amount of voltage on the battery will be stabilized by the IC regulator.

Table 3. Testing of DS18B20 Temperature Sensors with Mercury Temometers

Measurement	Mercury Thermometer Temperature Measurement (°C)	DS18B20 Temperature Sensor Measurement (°C)	Error	Error (%)
1	29	29,6	0,6	2,07
2	34,7	35,0	0,3	0,86
3	35,2	35,5	0,3	0,85
4	35,0	35,75	0,75	2,14
5	35,7	35,94	0,24	0,67
6	35,9	36,0	0,1	0,28
7	36,0	36,06	0,06	0,17
8	36,1	36,12	0,02	0,06
9	36,2	36,31	0,11	0,30
10	36,3	36,38	0,08	0,22
Error rate			0,256	0,76

The test results on the temperature sensor DS18B20 obtained an average level of error of 0.256 ° C, which means the accuracy of the sensor measurement when compared with the mercury thermometer is not too far away. The DS18B20 temperature sensor has good accuracy. Figure 4 Graph of Temperature Test Results Using a DS18B20 Sensor with a Mercury Thermometer.

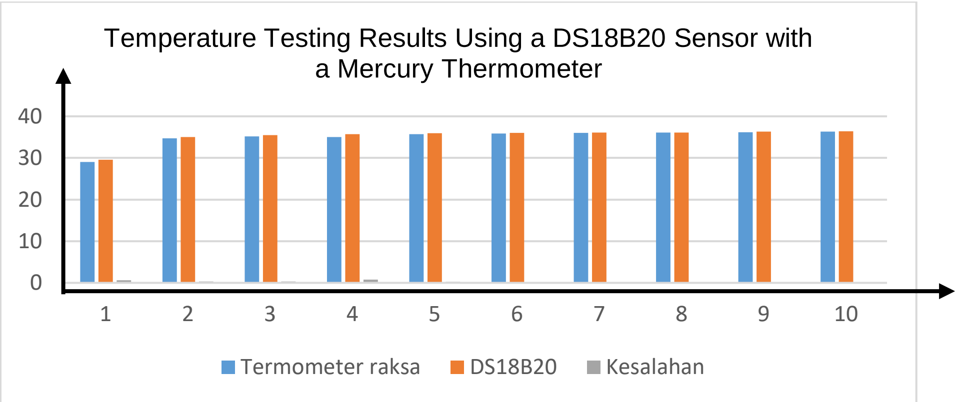

Figure 4 Graph of Temperature Test Results Using a DS18B20 Sensor with a Mercury Thermometer

Test results and data comparisons were sent on the cayene page using patient monitors using 3 respondents with 3 measurements in each respondent. Comparison of readings of sensor output (body temperature) sent on cayene with sensor readings of body temperature using patient monitors using 3 respondents with 3 times the measurement of each respondent. The results of the comparison can be seen in Table 5.

Table 5 Comparison of Temperature of Researchers with Patient Monitors

No	Sample	Research Tools		Cayene	Patient Monitor		Error %
		Body temperature	Average	Body temperature	Body temperature	Average	
1	Adi	36,2 ºC 36 ºC 36,1 ºC	36,1 ºC	36 ºC 36 ºC 36 ºC	36,1 ºC 36 ºC 36,1 ºC	36,03 ºC	0,11%

2	Aji	36 ºC 35,8 ºC 36,1 ºC	35,96 ºC	36 ºC 36 ºC 36 ºC	35,9 ºC 35,9 ºC 36 ºC	35,93 ºC	0,08%
3	Ridwan	36,2 ºC 36 ºC 36 ºC	36,06 ºC	36 ºC 36 ºC 36 ºC	36,1 ºC 36,1 ºC 36,2 ºC	36,13 ºC	0,19%

In the comparison of temperature samples between the researcher and Patient Monitor, the largest percentage of errors is 0.19% and the smallest percentage is 0.08%, where the largest percentage of errors is in sample 3 with an average temperature of 36.06ºC and the percentage of errors the lowest is in sample 1 with an average temperature of 36.1ºC, where changes in human body temperature can be affected by room temperature, body temperature conditions can change at any time, then in sending temperature data to the WEB application mydevices.com takes less than 1 minute depends on the internet network connection.

Comparison of the reading of the Heart rate output sent on cayene with the Heart rate reading sensor using a patient monitor using 3 respondents with 3 measurements at each respondent. The results of the comparison can be seen in table 6.

Table 6 Comparison of Researchers Heart Rate with Patient Monitors

No	Sample	Alat Peneliti		Cayene	Pasien Monitor		Kesalahan %
		Heart Rate (BPM)	Rata – Rata	Heart Rate (BPM)	Heart Rate (BPM)	Rata – Rata	
1	Adi	85 88 89	87,3	85 88 91	85 86 90	87	0,3%
2	Aji	74 74 74	74	74 74 74	75 76 73	74,6	0,8%
3	Ridwan	71 69 69	69,6	71 69 69	70 67 70	69	0,8%

In the comparison of the Heart Rate sample between the researcher and Patient Monitor, the biggest percentage of error is 0.8% and the smallest percentage is 0.3%, where the largest percentage of errors are in samples 2 and 3 with an average heart rate of 74 BPM and 69.9 BPM and the lowest percentage error is in sample 1 with an average temperature of 87.3 BPM, where changes in the heart rate of the human body can be affected by hand movements, body temperature conditions can change at any time, then in sending heart rate data to the cayene application takes less than 1 minute depending on the internet network connection.

Comparison of SPO2 output readings sent on cayene with SPO2 sensor reading using a patient monitor using 3 respondents with 3 measurements at each respondent. The results of the comparison can be seen in table 7.

Table 7 Comparison of Researchers SPO2 with Patient Monitors

No	Sample	Alat Peneliti		Cayene	Pasien Monitor		Kesalahan %
		SPO2 (%)	Rata-Rata	SPO2 (%)	SPO2 (%)	Rata–Rata	
1	Adi	98 97	97,3	97 97	97 97	97,3	0%

		97		97	98		
2	Aji	97 97 97	97	97 97 97	98 98 98	98	1%
3	Ridwan	97 97 97	97	97 97 97	97 98 98	97,6	0,6%

In the comparison of the SpO2 sample between the researcher and Patient Monitor, the biggest percentage of error results is 1% and the smallest percentage is 0%, where the largest percentage of errors is in sample 2 with 97% average and the lowest percentage error is in sample 1 with The average SpO2 of 97.3ºC, where changes in human SpO2 can be influenced by hand movements, the condition of the body SpO2 can change at any time, then in sending SpO2 data to the cayene application takes less than 1 minute depending on the internet network connection.

Comparison of reading of blood pressure output (BP) on cystolic pressure sent to cayene with BP reading using patient monitors using 3 respondents with 3 measurements at each respondent. The results of the systolic pressure comparison can be seen in Table 8.

Table 8 Comparison of NIBP in Systole and Diastole Research Equipment with Patient Monitors

No	Sample	Alat Peneliti		Cayene	Pasien Monitor		Kesalahan %
		Sistole	Rata – Rata	Sistole	Sistole	Rata – Rata	
1	Adi	118 133 124	125	118 133 124	123 125 126	124,6	0,3%
2	Aji	112 111 106	109,6	112 111 106	110 97 99	102	7.4%
3	Ridwan	124 120 118	120,6	124 120 118	109 115 116	113,3	6,4%

In the comparison of NIBP samples on cystole pressure between the researcher and Patient Monitor, the smallest percentage with a percentage of 0.3% was obtained, whereas the percentage of the smallest errors was in sample 1 with an average of 125 mmHg and 7.7%, the largest percentage of errors, in sample 2. with an average of 109.6 mmHg. The results of the diastole pressure comparison can be seen in table 9.

Table 9 Comparison of NIBP on Diastole Research Equipment with Patient Monitors

No	Sample	Alat Peneliti		Cayene	Pasien Monitor		Kesalahan %
		Diastole	Rata – Rata	Diastole	NIBP	Rata – Rata	
1	Adi	75 72 67	71,3	75 72 67	78 74 75	75,6	5,6%
2	Aji	62 64 61	62,3	62 64 61	62 62 64	63	1,1%
3	Ridwan	65 60 68	64	65 60 68	73 71 66	69	7,2%

In the comparison of NIBP samples on the diastole pressure between the researcher and Patient Monitor, the smallest percentage with a percentage of 1.1% was obtained, where the largest percentage of errors was in sample 3 with an average of 64 mmHg and the lowest percentage of errors was in sample 2 with an average 62.3 mmHg.

4. Conclusion

After making a prototype tool for monitoring patient's vital sign (blood pressure, heart rate, oxygen concentration and body temperature) based on MEWS with the IoT system, from literature studies, planning, experiments to data collection and data analysis, this esearch conclude that comparison using patient monitor equipment, body temperature measurements produce the highest and lowest percentage of errors, namely 0.19% and 0.08% with an average temperature of 36.06ºC and 35.96ºC, then the measurement of heart rate obtained the highest percentage of error and the lowest of 0.08% and 0.3% with an average heart rate of 74 bpm and 87.3. Then the measurement of SpO2 obtained the highest and lowest percentage of error of 1% and 0% with an average SpO2 of 97% and 97.3%, then the NIBP measurement obtained the highest and lowest percentage of error systole / diastole of 7.4% / 7.2% with NIBP with an average systole / diastole of 109.6 / 64 mmHg and the lowest error percentage is 0.3% / 1.1% with an average NIBP of 125 / 62.3 mmHg. Data transmission to the internet using the cayene application on Android smartphones and WEB is greatly influenced by the quality of the connection from the internet network. Adding Vital Vital parameters other than (blood pressure, heart rate, oxygen concentration and body temperature) such as respiration rate, IBP and electrocardiograph.

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