The prototype of infant incubator monitoring system based on the internet of things using NodeMCU ESP8266

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Abstract. Growth parameters that parents often pay attention and monitoring for their infants are weight and temperature to determine the health condition of the infant. Parents don’t realize that the size of the head circumference reflects the brain volume. The head circumference is an important thing that should always be monitored to see whether the infant's brain grow and develop normally or not. Generally, doctors or midwives use a separate measuring instrument. The use of separate measuring instruments requires considerable time and digital measuring instrument. This study aims to make a tool in one system that consists of three measurement parameters including weight, temperature, and head circumference. The tool can record the parameters automatically. The parameters automatically measure the infant's weight, temperature, and head circumference to determine the condition of the infant. The tool is operated through IoT (internet of things) which can facilitate paramedic to monitor the infant's situation wherever and whenever through internet network that can be accessed via web or Android. The three parameters are controlled directly with the NodeMCU ESP8266 module using two ultrasonic sensors to determine the circumference of the infant's head, the weight sensor using load cell, and the temperature sensor using an SHT31 temperature sensor. It is expected that this tool can help the paramedic work to act quickly because it can monitor the state of the infant online.

1. Introduction
In developed and developing countries, many infants die in the first week of birth. Problems that are often encountered include hyperthermia, asphyxia and also infants born prematurely. WHO records the classification for hyperthermia which (1) cold stress or mild hypothermia: 36.0 to 36.4°C (96.8 to 97.5°F); (2) moderate hypothermia: 32.0 to 35.9°C (89.6 to 96.6°F); and (3) severe hypothermia: below 32°C (<89.6°F). So here the incubator plays a big role where the incubator temperature must be set to maintain the infant's temperature between 95°F and 98°F or 99°F. The infant can live well with temperatures that are slightly below normal [1-2].
Infants born prematurely have a high risk of controlling the exchange of heat between the surface of the skin with the conditions of the surrounding environment, even the heat dissipation that occurs can exceed the heat production of the infant's own metabolism. So, infants born prematurely are more likely to suffer from illness or death than infants born normal. One of the procedures to make premature infants still alive is put them into the incubator, the period premature infants in the incubator according to soundness, durability, and system of organs of them. The incubator is one of the tools to help premature infants to adjust with the outside world because the condition in the womb is very different with the outside world, especially condition of temperature. The temperature in the womb is approximately 36-37°C but in the outside world is approximately 27°C–28°C [3-4].

The incubator discovered in 1880 triggered dramatic, popular and professional excitement about the prospect of reducing premature infant mortality. But, technology in the incubator develops slowly, which illustrates that the history of technology involves more than discovery. The invention of the incubator itself is less significant than the development of a system to support the devices that are in it. In this way, a new type of infant incubator must be studied that can independently adapt the environment based on a series of sensors and monitor in real time vital signs for the infant [5-7].

Advances in technology today following increases in the use of electromagnetic waves in everyday life. One example is the infant incubator. Monitoring the infant incubator is essential to keep the infant has a temperature corresponding to the environment at the newly born.

Not many parents realize that the size of the head circumference that also reflects the brain volume is also an important thing that should always be monitored growth to see whether the infant's brain grow and develop normally or not. Generally, doctors or midwives use a separate measuring instrument. The use of separate measuring instruments requires considerable time and a partially manual and part digital measuring instrument.

This research aims to make a tool in one system that there are three measurement parameters including weight, temperature and head circumference that can record automatically. Facilitate the performance of paramedics to automatically measure the infant's weight, temperature, and head circumference to determine the condition of the infant. The tool is operated through IOT (internet of things) which can facilitate paramedic to monitor the infant's situation wherever and whenever using internet network that can be accessed via web or Android. The three parameters are controlled directly with the NodeMCU ESP8266 module using two ultrasonic sensors to determine the circumference of the infant's head, the weight sensor using load cell, while the temperature sensor uses an SHT31 temperature sensor.

Head circumference measurements use two ultrasonic sensors. The data will be processed directly with NodeMCU module ESP8266 displayed through web and Android with internet network. So that the instrument will get three measurements automatically in one system. Making this instrumentation through three stages including, making hardware, software manufacture, and testing instrumentation system. Test results infant incubator is a tool used to monitor the circumference of the infant's head circumference, the infant's weight and the temperature in the infant.

2. Basic theory
2.1. Incubator
Infant incubator shown in Figure 1 is one of the medical support devices used to maintain the temperature conditions of new-borns, both born normally and prematurely. Temperature is one of the most important factors to be taken care of for new-borns, because of the condition of new-borns who are unstable and cannot yet do their own heat production to warm their bodies and produce heat to maintain their body stability [8].
The important thing to pay attention in addition to the temperature needed by the infant at birth is as follows: Normal-born infants have a body weight of around 2.9 kg to 3.6 kg, height of about 48 cm to 51.8 cm and head circumference around 33.2 cm to 35.7 cm.

2.2. IOT (Internet of Things)
Atzori et. Al. identified that the Internet of Things can be realized in three paradigms - internet-oriented (middleware), sensors and knowledge or experience [9]. Although delineation of this type is needed because of the interdisciplinary nature of the subject.

According to Forrester [11]
- Use information and communication technology to make better components and services from city administration, education, health, public, real estate, transportation, and utilities, more aware, interactive and efficient.

In a European research project that discusses the Internet of Things, clusters argue [10]
- 'Things' is an active role in business, information and social processes where they are used to communicate and communicate with each other in the environment such as exchanging data and information.

IoT can be used to monitor data in real time, which parameters can be monitored through a website and can be monitored using Android by accessing the internet [12].

2.3. SHT Sensor
SHT sensor represented in Figure 2 is a single chip that can measure temperature and relative humidity. This sensor produces excellent output with very fast response time. This SHT humidity carefully is calibrated using a hygrometer as a reference. Just as DHT, these sensors have OTP memory useful for programming calibration coefficient used to calibrate the output of the sensor during the measurement process [13].

2.4. Ultrasonic HC-SR 04
Sensor HC-SR04 represented in Figure 3 is a distance measuring sensor based on ultrasonic waves. The working principle of this sensor looks like ultrasonic radar. Ultrasonic waves are radiated then received back by the ultrasonic receiver. The distance between the transmitter and receiver time is a
representation of the object distance. These sensors are suitable for electronics applications that require detection distance including for sensors on the robot.

![SHT Sensor](image)

**Figure 3. SHT Sensor**

2.5. Load Cell

A load cell represented in Figure 4 is a transducer that used to create an electrical signal whose magnitude is directly proportional to the force being measured. The various load cell types include pneumatic, strain gauge, and hydraulic. A load cell usually consists of four strain gauges in a configuration of Wheatstone bridge. Load cell of one strain gauge (Quarter Bridge) or two strain gauges (half bridge) are also available. The electrical signal output is typically in the order of a few millivolts (mV) and requires amplification by an instrumentation amplifier before it can be used[14].

![Load Cell](image)

**Figure 4. Load Cell**

2.6. NodeMCU ESP8266

ESP 8266 is a Wi-Fi module that lately more and more popular among hardware developers. In addition, because the price is very affordable. Versatile Wi-Fi module already is SOC (System on Chip), so we can do the programming directly to ESP8266 without requiring an additional microcontroller. Another plus, this ESP8266 can run ad hoc role as access points and clients as well. ESP8266 series products now showed in Figure 5 still in the development stage. ESP8266 itself is equipped GPIO (General Purpose Input / Output), with this we can do a GPIO input or output function like a microcontroller. For example, in the series, ESP8266-01 features 2 GPIO, while the series ESP8266-12E have a read analog pin as well as some digital pin.

![ESP8266](image)

**Figure 5. ESP8266**

Another advantage is the ESP8266 have the deep sleep mode, so that power usage will be relatively much more efficient than the Wi-Fi module. Important note that should be underlined is that ESP8266 operated at a voltage of 3.3V. Figure 6 is pin configuration of module NodeMCU ESP 8266.
Figure 6. Pin Configuration of ESP8266

ESP8266 NodeMCU v0.9 having 4MB Flash, 11 GPIO pins where 10 of them can be used for PWM, ADC pin 1, 2 pairs of UART, Wi-Fi 2.4GHz and supports WPA / WPA2. NodeMCU than can be programmed using LUA language can also be programmed using C language using Arduino IDE.

3. System Design
In system design, there are three sensors, a Wi-Fi module and screen for monitoring data from the sensors. Figure 7 shows the system design of IoT implementation for infant incubator monitoring. Figure 6 is the system design of IoT implementation for infant incubator.

Figure 7. System Design

3.1. Design of Transmitter
Transmitter design used in this study is the nodeMCU ESP8266 module connected with the sensors namely ultrasonic sensors, SHT 31, and the load cell. Figure 8 shows the system design of IoT implementation at the transmitter side.
3.2. Design of Receiver
Receiver design of this research applies a web browser which will display the results of the measurements from the sensors. Figure 9 shows the system design of IoT implementation at the receiver side.

4. Experimental Data Analysis
The first step to collect data is to connect the sensors with nodeMCU module and put the sensors in the incubator system. Figure 10 is Physical model of the infant incubator system.

The result obtained from experiment of each sensor is in Table 1.
Table 1. The Result of Measurement

| Head Circumference | Temperature | Humidity | Weight  |
|--------------------|-------------|----------|---------|
| 9 cm               | 30 °C       | 72%      | 2782g   |
| 25 cm              | 29 °C       | 59%      | 2500g   |
| 30 cm              | 28 °C       | 62%      | 2620g   |
| 18 cm              | 33 °C       | 55%      | 2573g   |
| 22 cm              | 26 °C       | 80%      | 2893g   |

The second step is comparing between data from system design with measurement instrument. Table 2 is data comparison obtained from the measurement instrument.

Table 2. Data Comparison

| Ruler | Temperature | Humidity | Weight  |
|-------|-------------|----------|---------|
| 10 cm | 30 °C       | 72%      | 2700g   |
| 25 cm | 29 °C       | 59%      | 2500g   |
| 29 cm | 28 °C       | 62%      | 2600g   |
| 19 cm | 33 °C       | 55%      | 2500g   |
| 22 cm | 26 °C       | 80%      | 2800g   |

The last step is to display the data. The result of the data obtained during the test will be sent and displayed on the website. Here, system use Thinger.io and the result is displayed on the same monitor. Figure 11, 12, 13 respectively is display data of distance from head circumference, temperature/humidity and infant weight.

![Figure 11. Display of distance from head circumference in the web](image-url)
5. Conclusion
The result obtained from research data is concluded that in this system each sensor are working properly in accordance with the calibration tool namely ruler, thermometer and multitester. Based on sensor data obtained at the time of testing, monitoring the Internet-based system is to run well. Based on the experimental results of monitoring, the results of sensor data displayed is the same on the display thinger.io website and look at the monitor serial Arduino software. The device (infant incubator) is to...
put the ultrasonic sensor on all sides of the box incubator, to measure the head circumference infant and then SHT sensors and Loadcell sensor to monitoring the weight of infant.

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