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Monitoring Baby Incubator Central through Internet of Things (IoT) based on Raspberry Pi Zero W with Personal Computer View

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ABSTRACT kids born before 37 weeks of pregnancy or weighing less than 2500 grams are considered premature, whereas kids born between 38 and 40 weeks of pregnancy and between 2500 to 4000 grams are considered full-term. Given that their organ systems are still developing within the womb, premature infants find it difficult to adjust to life outside the womb. As a result, special consideration must be made. They include modifying the environment's temperature, humidity, and oxygen needs to reflect those of the mother's womb. These conditions might be replaced with a baby incubator. This tool's creation is intended to make it easier for midwives and other healthcare professionals to keep an eye on many baby incubators. The Internet of Things (IoT) system is used by this instrument to transfer data. Using three ESP32 modules that have been put together to create modules that can collect data and have that data analyzed by a server (central monitoring) Raspberry Pi Zero W. Data will be sent via Internet of Things (IoT) technology, and the website will display the data. Two tests were conducted at 32 degrees Celsius, one at 34 degrees Celsius, and one at 36 degrees Celsius for a total of five tests. This technique was developed using a form of pre-experimental, after-only study. In this configuration, researchers may only see the module reading results; incubator analyzer data are not shown. Error value 3 in monitoring at 32 degrees Celsius has a maximum error of -0.04 percent. The largest error value occurs when the temperature is set to 34 degrees Celsius, when the monitoring error value is -0.016%. Monitoring inaccuracy is at its highest, 0.01%, when the temperature is 36 degrees Celsius. The monitoring 3 error value is most at 32 degrees Celsius (-0.025 percent), followed by 34 degrees Celsius (0.031 percent), and finally 36 degrees Celsius (0.049 percent), as shown by data on noise measurements. The findings demonstrate that each measurement performed by the module still contains mistakes. Medical staff should find it easier to concurrently monitor many infant incubators thanks to this discovery.

INDEX TERMS Baby incubators, IoT, ESP32, Raspberry Pi Zero W, Humidity

I. INTRODUCTION

A baby incubator is a device that keeps newborn newborns warm and is often used with preterm babies. Baby incubators are also used to keep newborns' bodies warm and humid, as well as to avoid respiratory infections in babies and to keep them isolated, particularly if they were delivered prematurely. Premature birth is defined as birth before 37 weeks of pregnancy or birth weight of less than 2500 grams. Babies delivered between 38 and 40 weeks are considered full term. Premature infants have an increased risk of visual and auditory impairments. These risks become apparent only when a preterm birth occurs. The leading global cause of infant mortality is preterm birth. About 15 million babies are preterm each year [1][2][3] Different nations have different preterm infant death causes. The increased PB prevalence in underdeveloped nations is often linked to hunger and illness (malaria, HIV).[4]. Compared to babies born at term, preterm newborns have a greater chance of dying. This is because their organ systems are still developing, which makes it difficult for them to adjust to life outside the womb. [1] . As a result, particular consideration must be taken. A temperature, humidity, and oxygen demand adjustment is one of them based on the environment in the mother's womb. [5][6][7]. In this case, a baby incubator might be used instead. The primary purpose of an incubator is to prevent hypothermia by maintaining the infant's body temperature.[8][9]. One of the reasons of baby mortality before its time is hypothermia. A fall in body temperature known as hypothermia happens when the body loses more heat than it can hold. Retinued babies quickly lose body heat. Hypothermia brought on by a slow metabolism, a poorly functioning central thermoregulatory system, and a relatively large body surface. This is referred to as a focal body temperature below 35.0°C in people. Exposure to a chilly environment has the potential to induce hypothermia. Because they have less fatty tissue on their skin, have a higher body surface area to weight ratio, and have less fat deposits, premature newborns are more likely to experience hypothermia.[10][11]. In order to prevent hypothermia or low body temperature in neonates, the temperature of the incubator must be maintained at around 35°C to 36°C. This is because babies have less fat tissue than adults do. [12][13][14][15][16]. Neonatal incubators in the room need to be closely monitored by medical staff for humidity and temperature. Too high of a temperature in the incubator may cause the baby's skin to burn, while too low of a temperature can cause hypothermia. Loss of body heat (hypothermia) is a leading cause of illness and death in infants. [2][17]. For now, incubator monitoring is still done manually[18][19]. Therefore, the nurse needs a direct line of sight into the incubator to ensure the temperature inside is maintained at the desired level at all times. Each infant in the incubator receives particular attention and is watched over

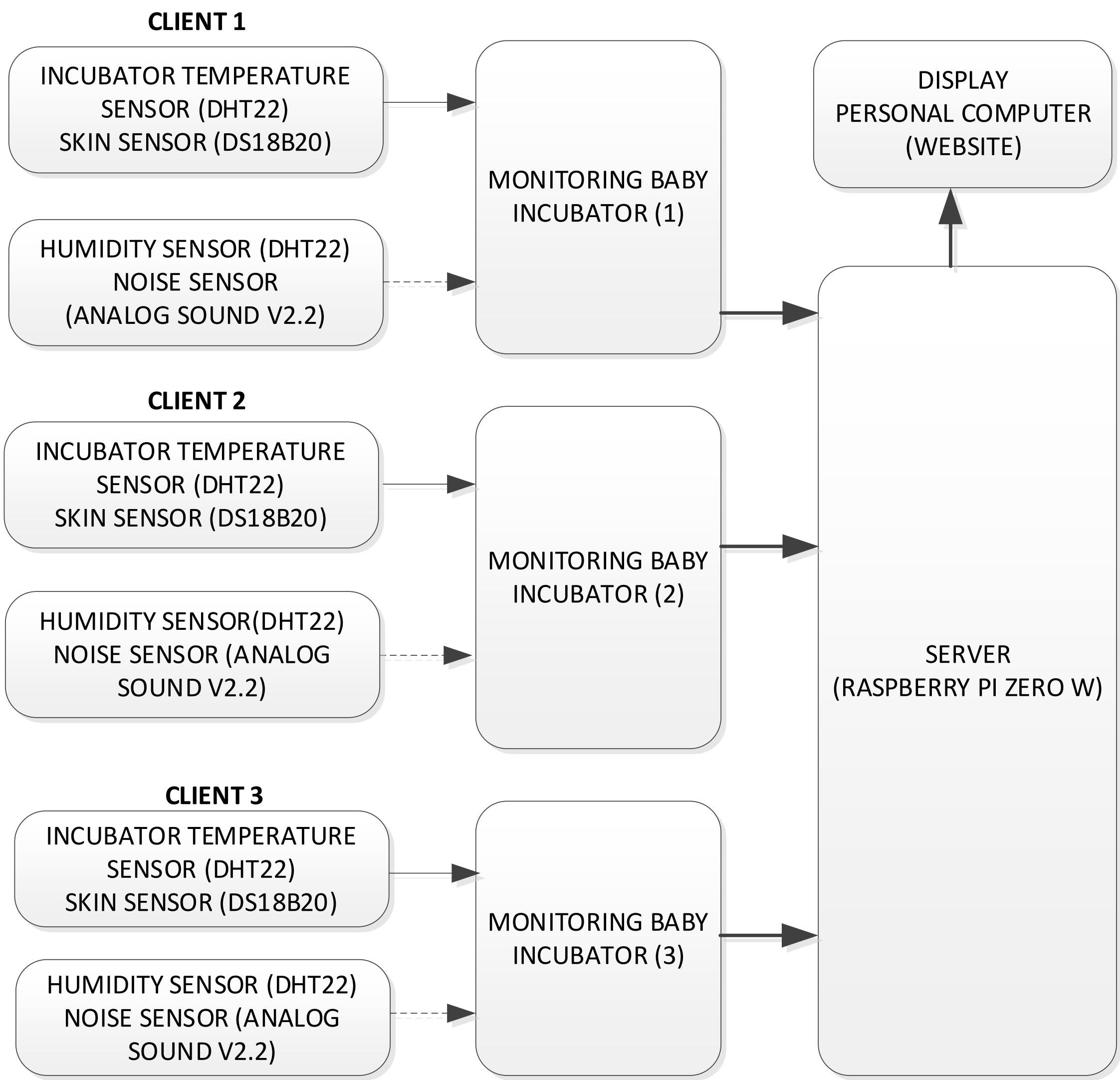

FIGURE 1. System Block Diagram of Baby Incubator Monitoring

at certain intervals. However, neglect in monitoring infants in incubators is often seen. [20].

Although Rizky Handayani Rayu and La Ode Saafi published a study titled Monitoring Temperature and Humidity in Atmega 328 Microcontroller-Based Incubators, Bluetoot is still used throughout delivery. A baby incubator monitoring tool was also created by Qory Hidayati, Nur Yanti, and Nurwahidah Jamal in 2019 with the working title Monitoring Baby Incubator. Then, in 2020, Deny Alfredo Tampubolon and Nuristadarro created a project called Baby Incubator Monitoring Center through Wifi. While the instrument now integrates environmental variables including temperature, skin temperature, humidity, and noise, the nextion display is still used to examine the observed results [3]. The Baby Incubator Monitoring Center for Temperature and Humidity Using WiFi Network was developed by Furi Kristya Palupi, Sari Luthfiyah, I Dewa Gede Hari Wisana, and Mohseena Thaseen (2021). Only temperature and humidity parameters are tracked in this tool.[1]. Furthermore, the most recent research by Raulina Naura Salsabila and Lutfia Nur Fadila (2021), Monitoring Baby Incubator Through ESP32-Based WiFi Network, continues to use WiFi, where data transmission is still hampered by distance, and includes elements like chamber temperature, body heat, moisture level, and ambient sound level.

In order to create a central baby incubator monitoring tool based on IoT with Humidity , Noise parameters and a display on a Personal Computer, further research is needed, as is currently the case according to the existing literature. which would make it simpler to monitor the parameters of multiple baby incubators in the PICU-NICU room. The DHT22 sensor, which has a larger temperature range and greater resolution than the DHT11 sensor, was employed by the authors of this research as a humidity sensor. [21][22][23]. and using a noise sensor that is an analog sound V2.2 sensor. Noise in infant incubators may be measured using V2.2 sensors. [24] The main part of this sound sensor is a condenser microphone, which is also used to amplify the signal from the condenser mic. This microphone is a receiver of the electrical power that will be generated and has a relatively high level of sensitivity to sound response. The goal of the Internet of Things (IoT) is to enable diverse uses for collected data by connecting devices and making this data accessible via always-on internet services. Uses ESP32 to process data and transfer data[25], and using an access point server made by Raspberry Pi Zero W

The purpose of creating this technology is to make it easier for midwives and other healthcare professionals to monitor many infants in the baby incubator in the PICU-NICU room at once. The midwife's and other medical staff's responsibilities are made easier by the monitoring data being shown on a computer screen through a website, improving the rate at which measurements of skin temperature, humidity, noise, and incubator temperature may be taken. so that it may lessen the possibility of patient-related accidents.

In FIGURE 1 the block of the diagram. In order to read each sensor on each client, the system will operate. The ESP32, which has served as a monitoring device, will read and send the data immediately. The Raspberry Pi Zero W, which has been configured to operate as an access point server, will then receive the data. The information gathered by the Raspberry Pi Zero W access point will then be analyzed, with the outcomes being shown on the computer's monitor.

II. METHOD

This study was carried out in Surabaya, Indonesia at the Health Polytechnic Department of Electromedical Engineering and Integrated Laboratory. In order to gather data for this research, three identical-brand baby incubators were used. After the design was finished in this research, testing was done to see how the humidity sensor and noise sensor would react in detecting the humidity and noise levels in the baby incubator. For the purpose of comparing the module to the Incu analyzer standard, the baby incubator is adjusted at 32, 34, and 36 degrees Celsius.

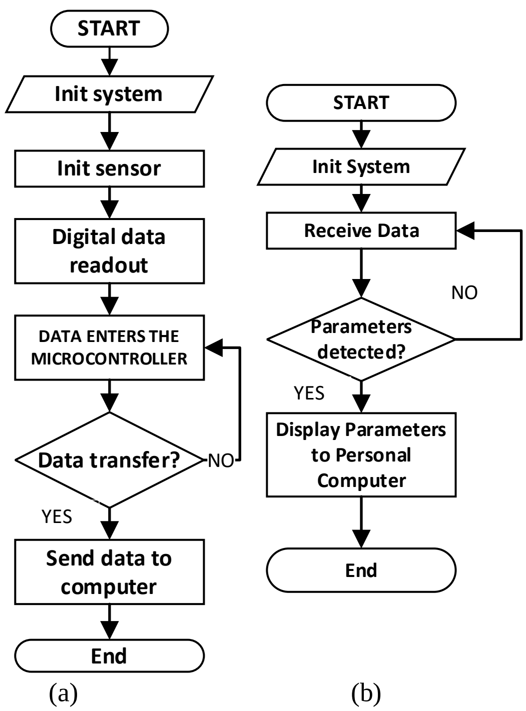

FIGURE 2. **Flowchart (a) monitoring, (b) server communication**

The ESP32, which has been paired with a DHT 22 sensor, a DS18B20 sensor, a V.22 analog sound sensor, and a DHT 22 sensor that measures noise and ambient temperature, serves as the only monitoring circuit in this study. W as a server for an access point. Five times of data collection are carried out once the temperature has stabilized. The standard Incu analyzer will detect the humidity and noise values as a reference and comparison to the monitoring module's humidity and noise values, as well as the monitoring module's humidity and noise graph, which will be presented in real time on the PC. The average value, error, and other metrics will be used to assess the data acquired from the monitoring module.

In FIGURE 2 (a) is a diagram for the monitor's flow.When the On button is pushed, the device begins to operate. Additionally, each client's sensors will work to measure the noise level, humidity, skin temperature, and incubator temperature. Following that, ESP 32 monitoring will receive and analyse the data. The ESP 32, acting as a monitoring device, will connect to the Raspberry Pi Zero W, acting as a server, after processing the data. The sensor reading data will be transferred from the monitoring to the server if the device is connected, and if it is not will reconnect until monitoring and server are connected.

In FIGURE 2 (b) is a flowchart for a server. Initialization will start as soon as the On button is hit. The sensor will then function to measure noise, humidity, and room and skin temperatures. The ESP 32, which is set up as a monitoring device, will then receive the gathered data and transmit it to the Raspberry Pi Zero W, which is setup as an access point server, using the microcontroller. The data will subsequently be processed by the Raspberry Pi Zero W access point server. The display will indicate if the received parameter data meets the specified set point.

A. DATA ANALYSIS

On each module, measurements were made at every parameter. The data was collected in a newborn incubator at three distinct temperatures (32 degrees Celsius, 34 degrees Celsius, and 36 degrees Celsius). After the temperature had stabilized, measurements were made five times to assure precision, and these results would be compared to those from the incu analyzer. Equation (1) is used to compute the mean or average in order to calculate the average value of measurements. The average is calculated by dividing the total quantity of data collected or measurements made by the total number of measures intended to assess the applicability of the instrument.

$$\overline{x} = \frac{x1+x2...+xn}{n} \quad (1)$$

The %error number reflects the variance between each data point and the mean. A low percentage of error means there isn't much variation in the mean values for each data point. In equation (2), the error formula can be seen:

$$\%\mathrm{ERROR} = \frac{(x_n - x)}{x_n} \times 100\% \quad (2)$$

The calibrator machine's measured value is denoted by xn, while the evaluated module's value is denoted by x.

III. RESULT

An incu analyzer will be used to compare module testing in this investigation. FIGURE 3 consists of a collection of monitoring module designs using an ESP32 and three separate sensors: a DHT 22 for measuring ambient temperature and humidity, a DS18B20 for measuring skin temperature, and a V.22 for measuring ambient noise levels through analog signal processing. This module has a battery circuit and relies on a lithium battery for power. of assistance given to newborns who need it.

FIGURE 3. Design of monitoring module

TABLE 1
Average Overall Humidity Measurement

Average Overall Humidity Measurement (oC)									
Set.	Incu I	Incu II	Incu III	M1	M2	M3	Error 1	Error 2	Error 3
32°C	59.8	52.3	47.5	59.8	51.5	49.8	-0.0006%	0.015%	0.04%
34°C	52.3	45.4	47.4	52.2	44.8	48.2	0.0003%	0.014%	-0.16%
36°C	48.7	43.1	50	48.9	42.6	49.9	-0.004%	0.01%	0.003 %

The TABLE 1 displays the average humidity measurement findings derived from the device's measurement data. Data gathering starts after the temperature has reached a stable level. The average humidity is calculated using data collected from three different newborn incubators maintained at 32 degrees Celsius, 34 degrees Celsius, and 36 degrees Celsius. calculation of the mean humidity readings from all three sensors.

The values in the table above are the average of five individual measurements conducted at each temperature setting and compared in real time using the incu analyzer comparison tool. The average result for the incu analyzer at 32 ° C is shown in the table above; at that temperature, Module 1 registers 59.8% RH, Module 2 registers 51.2% RH, and Module 3 registers 49.8% RH. Module 1: 52.2%, Module 2: 44.8%, and Module 3: 48.2% are all set at 34 degrees Celsius and Relative Humidity, respectively. Setting 36°C with Module 1 value of 48.9%RH, Module 2 value of 42.6%RH, and Module 3 value of 49.1%RH. The biggest difference between the data incu analyzer and module occurs in module 3 at 32 °C. Module 2 has the highest difference at 36 ° C while module 3 has the largest difference at 34 ° C. For a 32 ° C setting, the error value is calculated as follows and is included in the measurement data: monitoring 1: -

0.0006%; monitoring 2: 0.015%; 0.04% for tier 3 monitoring. At 34 degrees Celsius, Monitoring 1 hits the error value with a value of 0.0003%, Monitoring 2 reaches a value of 0.014%, and Monitoring 3 reaches a value of -0.016%. At a temperature of 36 ° C, the errors in Monitorings 1 and 3 are -0.004% and 0.01%, respectively. According to the aforementioned measurements, the monitoring 3 error value drops to -0.04% when the temperature is set to 32 ° C, drops to -0.016% when the temperature is set to 34 ° C, and drops to 0.01% when the temperature is set to 36 ° C. The measurements show that while the findings are still within the threshold, they nonetheless differ significantly from the measurement results of the incu analyzer, which are used as a reference.

TABLE 2
Overall Average Results of Noise Measurements

Overall Average of Noise Measurements (dB)									
Set	Incu I	Incu II	Incu III	M1	M2	M3	Error 1	Error 2	Error 3
32°C	48.9	48.2	47.9	49.5	48.6	49.1	-0.011%	-0.007%	-0.025%
34°C	49.1	48.9	47.7	48.8	47.7	46.2	0.006%	0.023%	0.031%
36°C	49.9	48.6	47.7	48	49.8	45.4	0.037%	-0.025%	0.049%

The TABLE 2 displays the average noise measurement findings derived from the device's measurement data. Data gathering starts after the temperature has reached a stable level. Three newborn incubators with temperatures of 32 degrees Celsius, 34 degrees Celsius, and 36 degrees Celsius were used to compile data for an average noise level calculation.

For each temperature setting, we gathered data five times and compared it in real time using the incu analyzer comparison tool to get an average noise measurement result. as indicated in the table above. The following table displays the average value of the incu analyzer at 32 °C, where module 1 has a value of 49.5 dB, module 2 is 48.6 dB, and module 3 is 49.1 dB. With a module 1 value of 48.8 dB, a module 2 value of 47.7 dB, and a module 3 value of 46.2 dB at setting 34 ° C. Additionally, at Setting 36 ° C, Modules 1 through 3 had values of 48 dB, 49.8 dB, and 45.4 dB respectively. Conclusion: Module 3 exhibits the highest difference between the data from the incu analyzer and the module at a temperature setting of 32 °C. Module 3 also has the greatest difference between its temperature settings of 34 and 36 degrees Celsius. The error value is also included in the 32 ° C temperature setting measurement data and is calculated as follows: All three of the monitors showed negative values: -0.011 percent, -0.007 percent, and -0.025 percent. Monitor 2 gives a value of 0.031% while the temperature is 34 degrees Celsius, whereas monitor 1 gives a value of 0.023%. At a temperature of 36 ° C, errors were found during checks 1, 2, and 3 with values of 0.037%, -0.025%, and 0.049%, respectively. The data above shows that when the temperature is set to 32 degrees Celsius, the monitoring 3 error value is -0.025%, when it is set to 34 degrees Celsius, it is 0.031%, and when it is set to 36 degrees Celsius, it is 0.049%. The obtained measurement data shows that the reference measurement results from the incu analyser are somewhat off, but still well within tolerance.

IV. DISCUSSION

The results of this data collection and analysis are shown in tables 1 and 2 above. Module 3 has the highest difference between incu analyzer data and the module when the temperature is set to 32 °C; module 2 has the largest difference when the temperature is set to 36 °C; and module 3 has the largest difference when the temperature is set to 34 °C. Due to the volume of data sent, the module sends data alternately with other parameter measurement data, which causes a buildup of data received by the server. This is because the baby incubator that we use is not very accurate during the process of taking the data, resulting in high differences between the incu readings.

Research from the past has led to the creation of Monitoring Baby Incubator Through WiFi Network. Based on ESP32, the tool is still utilizing WiFi and features temperature, humidity, noise, and skin temperature sensors. Data transmission is still hampered by distance and has a high error rate. The authors will create a study named "monitoring baby incubator central through IoT based on raspberry pi zero w with PC view" that intends to simplify the monitoring of various baby incubator parameters based on the issues and research that has been done. The incubator monitoring system employs the website as a visual application, which is advantageous for this study. The monitoring data will then be shown on a computer screen so that medical staff may more quickly learn the baby's condition.

IV. CONCLUSION

It is envisaged that the creation of a central monitoring tool for infant incubators based on the Raspberry Pi Zero W would make it simpler for medical professionals to keep an eye on incubator settings so they stay stable and lessen neglect and mishaps while using the instrument. Based on the collected data, the monitoring error value 3 at 32 °C has the greatest error value (-0.04%), followed by the monitoring error value 3 at 34 °C and the monitoring error value 2 at 36 °C. Noise measurements show that the biggest inaccuracy values occur at 32 degrees Celsius (-0.025 percent), 34 degrees Celsius (0.031 percent), and 36 degrees Celsius (0.049 percent). We anticipate that our findings will help healthcare professionals monitor infant incubators more effectively. We advise employing more precise sensors for future study that can also incorporate internal storage and airflow characteristics.

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