INFANT INCUBATOR MONITORING AND EMERGENCY ALARM SYSTEM USING THE INTERNET OF THINGS

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Abstract- Giving birth to a child is one of the most precious moments in life. Every second a new life is brought into the world and not many children are lucky enough to be healthy. Monitoring the health conditions of a baby in an incubator is considered a critical medical issue. Baby incubators play a vital role in the life-saving of premature babies since premature newborn babies cannot regulate their body temperatures on their own like normal newborn babies. Hence, there is a need for health caregiver interactions due to certain conditions. So a novel-based solution is provided in this paper for the above-mentioned problem by using the Internet of Things (IoT) in incubators to alert the neonatal nurses so that preventive measures can be taken. It prevents the theft from being held in the incubator rooms of the baby. The parameters such as heartbeat, temperature, wetness, etc., of the baby are monitored, measured, and saved in the cloud for every 10 minutes. The power failure is also intimated within a short span.

***Index Terms*— Incubators, Internet of Things, Alerting, Neonatal, Parameters, Heartbeat, Temperature, Wetness, Cloud, Power Failure**

I. INTRODUCTION

A. General:

According to a study, the major reasons for the 370,000 neonatal deaths in India in 2015 were low birth weight and premature birth. It is also found that the neonatal deaths due to the above-mentioned reasons were around 12.3/1000 births in 2000 to 14.3/1000 births in 2015. The rise in the deaths of premature babies and low weight at birth is uniform across India. It means that the death rate is high in rural areas and less in urban areas. Furthermore, these babies needed more investments in incubators and Intensive Care Units (ICU) to get proper neonatal care.

Even though incubators play a vital role in the lives of premature babies, they require instrument-health caregiver interactions due to their environmental and working conditions. For the sustainment of premature babies, oxygen and nutrition are a must. There should be an appropriate thermal environment in incubators in addition to this. The thermal environment impacts the intrauterine conditions of premature infants. The rectal temperature should be targeted to 37 to 37.5°C and a comfort temperature is suggested.

In Intensive Care Units (ICU), the use of a central monitoring system is essential and more convenient. This helps the caretakers to monitor the patients in real time. But this system is missing in the infant's ICU. The caretakers should go around each incubator to check it. This made way for the development of a web-based monitoring system after some decades. A recent study shows that over 20 million newborn babies are premature babies or babies with low birth weight every year. And among them around 450 are estimated as deceased for each hour. The death of these premature or low birth weight babies can be prevented by using the neonatal incubator. Neonatal incubators are life-saving devices for many of these babies by providing them with appropriate environmental and thermal conditions so that the baby can get normal weight and adequate nourishment by taking the available resources from the incubators.

In 2015, it was proved that more than ¼ of the population worldwide is using smart phones. The mobile applications are for social media, sports, games, news, business, healthcare and even shopping. The growth of bio-medical sensors, the need for patients, and the expense of healthcare induces the developers to create an m-health application. Some of those applications are based on the staff level like sophisticated monitoring, database handling, clinical advice, diagnostic data, etc. and some applications are based on patient monitoring for vital signals, fitness, online medical advice, and drug prescriptions.

The information technology (IT) field is developing more in the instance of sensors, nano-technology, and bio-industries. The e-healthcare system is very useful in hospitals

for gaining information from the patients. But these are a wired process based on the network protocol and database. Nowadays wireless communication is going on increasing in the healthcare field due to the advanced and new technologies built in smart devices with the help of wireless sensor nodes. A wearable sensor should have the characteristic of a long battery life. So, the development of self-powered sensors based on body heat is proposed. The wireless remote healthcare system and monitoring are usually achieved by using wearable sensors. These devices can collect the required programmed data from the patients anywhere and these collected data are then transferred to the central storage with the help of advanced technologies like GSM or SMS to the target mobile or computing systems of the doctor nurse or caretaker. The use of the incubator is to maintain an adequate environment for premature newborn babies. This is because premature infants have limited immunity and limited thermoregulation. They are more sensitive to the environmental conditions. Even a small change in the surroundings can cause adverse effects on them. Hence, there is a need for some artificial devices to make those infants sustainable in the world.

Around 1.8 million infants die every year due to improper maintenance of the temperature in their bodies. The World Health Organization (WHO) reported that globally more than 1 in 10 pregnancies results in preterm birth, which means a birth that, happens after the pregnancy but not more than 37 weeks, as the normal pregnancy should be of 40 weeks. The preterm birth can be classified into 3 stages based on their gestational age. They are: (1) Late Pre-term i.e., 32-37 weeks, (2) Very Pre-term i.e., 28-32 weeks and (3) extremely Pre-term i.e., < 28 weeks. The pre-term birth is the major reason for the death of children below 5 years and their mortality rates increase every year in underdeveloped environments. The preterm birth can be prevented by providing steroid injections or antibiotics and essential care for the newborns.

B. Literature Survey:

Suswetha Parisineti and Eswaran. P in (2011) design and implementation of real-time monitoring of an infant incubator, based on a sensor fault tolerant control system, using a PIC microcontroller, the purpose of a first trimester combined screening (FTCS) scheme is to detect sensor fault automatically and to isolate faulty sensor which leads to system failure.[1] N.S. Salahuddin. et al (2014), designed a system that would stabilize the temperature and relative humidity when the value is not in accordance with the predetermined value and immediately send a warning message to the destination mobile number.[2]

Kalaiyarasi M. et al. (2021) included the addition of a sound sensor and alarm to the block, which will notify the nurse in the event of an emergency in a typical incubator.[3] Suthagar S et al. (2022) help to detect the baby's temperature, heartbeat, weight, and baby's sound inside the incubator. If there are any changes in the above-said parameters beyond the threshold level, intimation will be sent to the concerned doctor through the GSM. The system will keep sending the alert message to the doctor every minute until the doctor acknowledges the baby's condition. [4]

C. Problem Statement:

Temperature and humidity are two of the most important aspects that need to be monitored to provide a healthy environment for infants, for instance, hyperthermia in neonates can lead to an increase in oxygen requirements, dehydration, and apnea. According to that, the temperature and humidity should be monitored continuously in the infants' incubator to provide a suitable environment and to maintain a stable core temperature of the baby at 37 ºC. Premature infants are usually born less than normal weight (often less than 2.5 kg), and sometimes severe weight loss (less than 1 kg) may cause the baby to die, so it is necessary to follow the changes in the child's weight by measuring his weight between the period and another. Also, the skin temperature often results in huge fluctuations in the air temperature inside the incubator and the air temperature causes fluctuations in the skin temperature. So, it is a big question mark whether the air temperature and the skin temperature can be controlled simultaneously.

D. Scope of the Study:

An IoT-based infant incubator approach is introduced to continuously monitor heart rate, jaundice level, humidity, temperature, skin temperature and thermoregulation of the neonatal and share all the data in real-time over the IoT application and it can be monitored in any device connected to the internet. A color sensor is used to detect the jaundice level in the incubator.

E. Aims and Objectives:

The main aim of this thesis is to design an infant incubator, to measure the weight, heart rate, temperature and humidity of the baby internally for that it proposed an automated system for monitoring and controlling this environment (temperature) and designed a monitoring system by using an application.

F. Internet of Things in Health Monitoring:

The Internet of Things (IoT) and Smart Grid are of great importance in promoting and guiding the development of information technology and economics. At Present, the application of the IoT develops rapidly, but due to the special requirements of some applications, the existing technology cannot meet them very well. Much research work is being done to build IoT. Wi-Fi-based Wireless Sensor Network (WSN) has the features of high bandwidth and rate, non-line-transmission ability, large-scale data collection, and high cost-effectiveness, and it has the capability of video monitoring, which cannot be realized with Zig Bee.

The research on Wi-Fi-based WSN and its application has high practical significance to the development of the Internet of Things and Smart Grid. Based on the current research work on applications in the Internet of Things and the characteristics of Wi-Fi-based WSN, this paper discusses the application of Wi-Fi-based WSN in the Internet of Things, which includes Smart Grid, Smart Agriculture, and Intelligent environment protection. Sensors are used for measurements and acquisition of data but they require an effective data transfer mechanism to enable full-fledged applications that utilize the data they collect Embedded systems are one of the most important, yet overlooked subjects in the electronics world. When you think technology, mobile phones, tablets, and laptops come to mind, but the devices that help us in our daily lives are not talked too much about. They're often confused with larger or more general-purpose computers, and it's sometimes difficult to discern between one and the other.

II. PROPOSED SYSTEM

A. Overview:

The methodology has been divided into three main parts, The Simulation part is to examine the circuit that had been depended on in the design and be sure it can provide us with the demands of monitoring and controlling. The second part is related to the hardware and design of the circuit and to test it experimentally. Finally, the third part contains the Application side and connects it with the design and records the temperature, humidity, sound, and weight values in the database. Heartbeats values are displayed as a graph in the application.

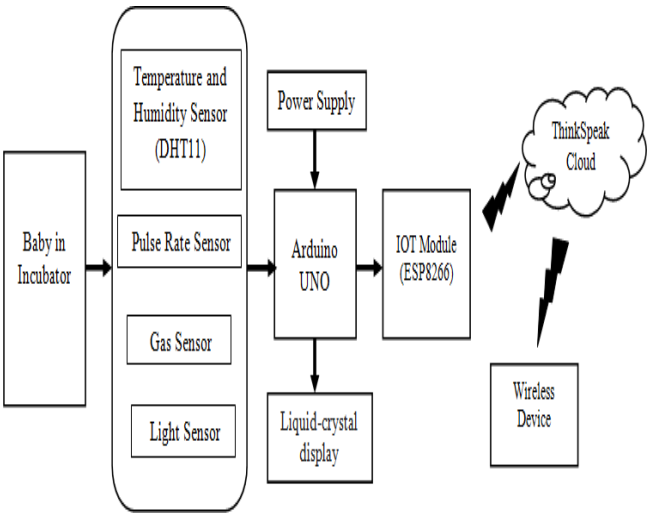

Fig.1- Block diagram of the Infant Incubator Monitoring

Whenever the sensors are combined with IoT technology, it can be an illustration of a cyber-physical system, smart home, smart grid, smart city, intelligent transportation, and virtual power plants. Therefore, the IoT can help in controlling the objects remotely being sensed by the sensors so that the physical systems can be easily integrated by the computing systems. This advantage not only improves the accuracy and efficiency of a machine but also minimizes the human intervention needed for monitoring a machine or a device 24/7. The use of the Think Speak platform makes it easy to access the data stored in it using IoT-Data Analytics. Moreover, the used sensors in the proposed models are of low cost and easily affordable so the cost of periodic maintenance is also easier.

B. Circuit Diagram:

The proposed system consists of an Arduino UNO microcontroller, which is to be connected directly to the incubator and several sensors are used to sense the biological signals inside the incubator and in the body of the premature infant. The various sensors used in the proposed model of neonatal incubator for real-time monitoring and control include

the Temperature and Humidity sensor (DHT11) for sensing the temperature and the humidity in the surroundings of the neonate, the Pulse rate sensor to record the heart rate of the infant, the Gas Sensor to sense the additional gas leakage and the Light sensor to capture the extra light penetration.

Additionally, the IoT Module (ESP8266) is used for transmitting the recorded or sensed data wirelessly which are to be uploaded to the Think Speak platform, which is an open-source IoT and Application Programming Interface that is used to store and retrieve the data from sensors which are then transferred to the receiver's device and an LCD is also connected to the microcontroller to display the recorded signals near the incubator for monitoring.

The proposed neonatal incubator design consists of 3 sections namely, the terminal device, the network protocols, and the monitoring and control of the neonates. The various sensors connected are used for monitoring and controlling the incubator via IoT. The Arduino microcontroller is programmed in such a way as to get the output of these sensors and display it on the LCD for monitoring purposes. The values of the sensors are then uploaded in the Think Speak cloud to display on the wireless device on the receiver side, which is then used for enabling the control of the incubator environment.

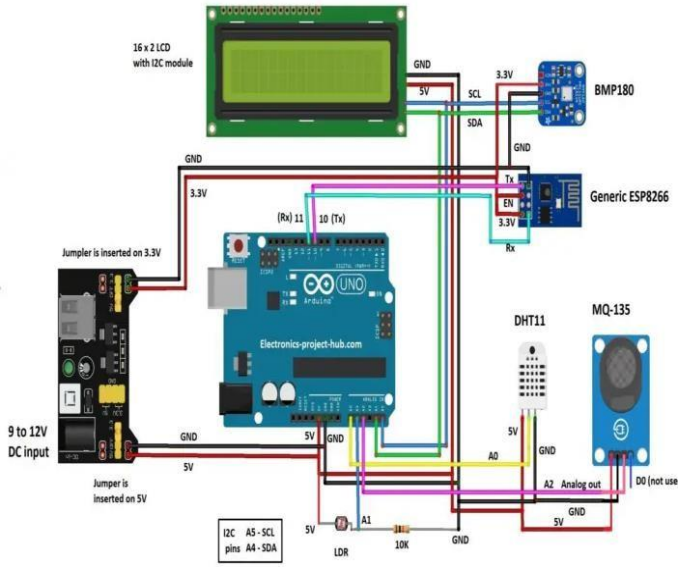

Fig.2- Circuit diagram of the Infant Incubator Monitoring

The circuit connection of the system is as follows: Arduino Uno: Connect the 5V pin of the Arduino Uno to the positive terminal of the power source (e.g., USB or an external power supply). Connect the GND pin of the Arduino Uno to the negative terminal of the power source. Heart Pulse Sensor (Heart Rate Monitor): Connect the VCC pin of the heart pulse sensor to the 3.3V or 5V pin of the Arduino Uno, depending on the sensor's voltage requirements. Connect the GND pin of the heart pulse sensor to the GND pin of the Arduino Uno. Connect the OUT pin of the heart pulse sensor to one of the analog input pins (e.g., A0) of the Arduino Uno. Moisture Sensor: Connect the VCC pin of the moisture sensor to the 5V pin of the Arduino Uno. Connect the GND pin of the moisture sensor to the GND pin of the Arduino Uno. Connect the A0 pin of the moisture sensor to one of the analog input pins (e.g., A1) of the Arduino Uno. Temperature Sensor (e.g., DHT11 or DHT22): Connect the VCC pin of the temperature sensor to the 5V pin of the Arduino Uno. Connect the GND pin of the temperature sensor to the GND pin of the Arduino Uno. Connect the data pin of the temperature sensor to one of the digital pins (e.g., D2) of the Arduino Uno. Fan: Connect the VCC or Vin pin of the fan to a digital pin (e.g., D3) of the Arduino Uno. Connect the GND pin of the fan to the GND pin of the Arduino Uno. IoT Connectivity (ESP8266 or ESP32): Connect the VCC pin of the Wi-Fi module to the 3.3V or 5V pin of the Arduino Uno. Connect the GND pin of the Wi-Fi module to the GND pin of the Arduino Uno. Connect the TX pin of the Wi-Fi module to the RX pin (pin 0) of the Arduino Uno. Connect the RX pin of the Wi-Fi module to the TX pin (pin 1) of the Arduino Uno.

Communication between Arduino Uno and IoT module: Connect the Arduino Uno's Reset (RST) pin to the Reset (RST) pin of the IoT module. This connection allows the Arduino Uno to reset the IoT module programmatically. Control Logic: The Arduino code will implement the control logic based on the sensor readings. For example: If the temperature is too low, the Arduino will activate the fan to increase the temperature inside the incubator. If the heart pulse sensor detects abnormal heart rate, the Arduino can trigger alerts or notifications. If the moisture sensor detects low humidity, the Arduino can activate a humidifier or notify the user. Power Source: Connect the positive terminal of the power source (e.g., battery or power adapter) to the VCC and Vin pins of the Arduino Uno and other components as required. Connect the negative terminal of the power source to the GND pins of the Arduino Uno and other components. Remember to check the voltage and current requirements of each component to ensure that they are compatible with the power source and the Arduino Uno. Additionally, consider using proper voltage level shifters or level converters if needed

to match the voltage levels between components that operate at different voltages.

C. Flow Chart:

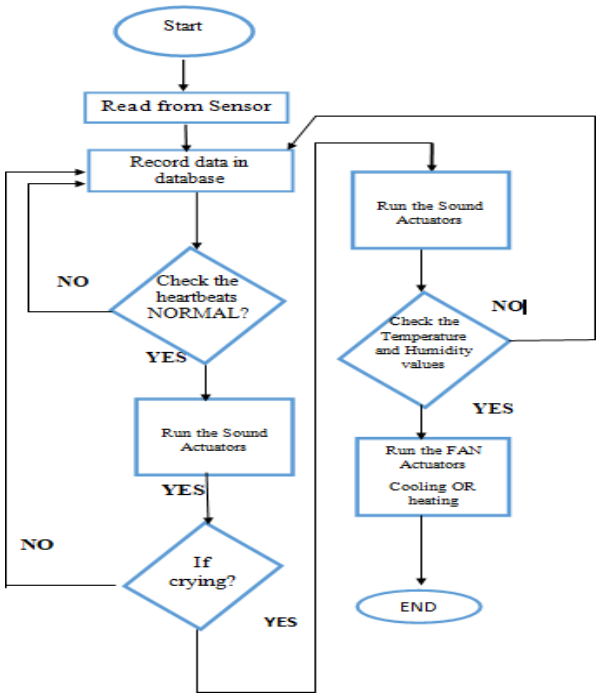

Fig.3- System Operation Flowchart

The system is clarified using the flowchart; it illustrates comparing the set values with the acquiring values as shown in Fig.1. First get the values of the incubator storage parameters from the sensor and upload these values into the database unit to compare with acquiring values. If the temperature is greater than the acquired temperature the Arduino sends a signal to run the fan. If the baby cries then the Arduino sends a signal to run the stepper motor to swing the incubator. If the infant's heart pulse is normal the Arduino sends a signal to run the buzzer.

III. RESULTS AND DISCUSSION

A. Results:

The working of the IoT-based baby incubator with Arduino Uno, heart pulse sensor, moisture sensor, temperature sensor, and fan involves creating a controlled environment for a baby by monitoring vital parameters, maintaining the right conditions, and enabling remote monitoring through IoT connectivity. Here's a step-by-step explanation of its working: The heart pulse sensor continuously measures the baby's heart rate and sends the analog signal to the Arduino Uno through the A0 analog input pin. The moisture sensor measures the humidity level inside the incubator and sends an analog signal to the Arduino Uno through the A1 analog input pin. The temperature sensor measures the ambient temperature inside the incubator and sends digital data to the Arduino Uno through the D2 digital input/output pin.

The Arduino Uno continuously reads the sensor data from the heart pulse, moisture, and temperature sensors. Based on the sensor readings, the Arduino Uno implements the control logic to maintain the desired environment for the baby. For example, if the temperature is too low, the Arduino activates the fan to increase the temperature. If the temperature is too high, the fan can be turned off, or a cooling mechanism can be activated. If the heart pulse sensor detects an abnormal heart rate, the Arduino can trigger an alarm or send notifications to caregivers or medical professionals through IoT connectivity. The fan is used for temperature regulation inside the incubator. The Arduino controls the fan based on the temperature readings. The fan may be turned on or off as needed to maintain the desired temperature. The Arduino Uno is equipped with an ESP8266 or ESP32 Wi-Fi module for IoT connectivity. The Arduino sends the sensor data (temperature, heart rate, and humidity) and other relevant information (such as system status) to a cloud-based IoT platform via Wi-Fi. The cloud-based IoT platform receives the data sent by the Arduino Uno. The received data is processed and stored on the IoT platform's servers, allowing remote access and monitoring.

Caregivers, medical professionals, or parents can access the IoT platform remotely through a web interface or mobile app. They can monitor real-time sensor data, including the baby's heart rate, temperature, and humidity levels. The IoT platform can be configured to send alerts or notifications in case of abnormal sensor readings or critical conditions inside the incubator, ensuring timely response and appropriate action. The Arduino Uno and sensors are powered by a stable power source, such as a battery or an external power adapter. Power management strategies, like sleep modes, can be implemented to conserve energy when the system is idle or when sensor readings are not required frequently.

Overall, the IoT-based baby incubator with Arduino Uno and various sensors provides a safe and controlled environment for the baby while enabling remote monitoring and alerts for caregivers and medical professionals. The

system's ability to monitor vital parameters and maintain ideal conditions can be critical in ensuring the baby's well-being during their time in the incubator. The designed infant incubator is shown in figure 4

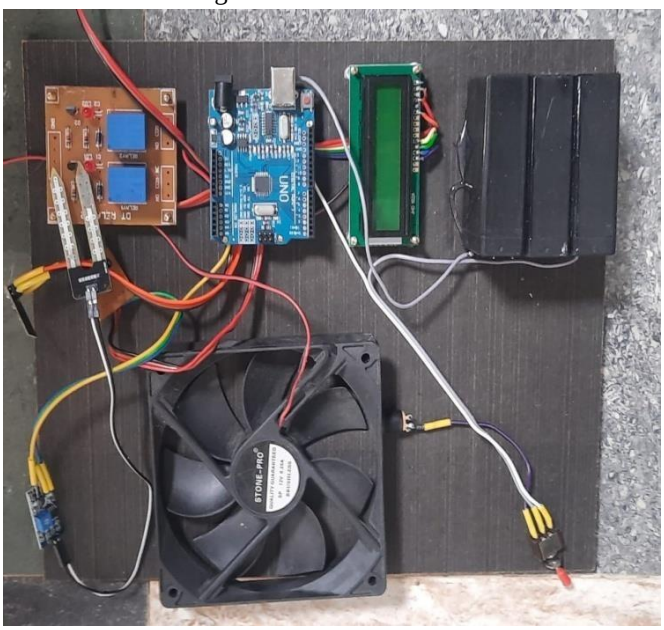

Fig.4- Designed Infant Incubator

B. Advantages:

Enhanced Baby Care: The IoT-based baby incubator provides continuous monitoring of vital parameters like heart rate, temperature, and humidity, ensuring a safe and stable environment for the baby. Real-time Remote Monitoring: Caregivers, parents, or medical professionals can remotely monitor the baby's condition through the IoT platform, receiving real-time updates and alerts, leading to timely interventions if necessary. Automatic Environment Control: The incubator's control logic, based on sensor readings, allows for automatic adjustments of temperature and humidity levels, reducing the need for manual interventions.

Early Detection of Abnormalities: The heart pulse sensor helps detect abnormal heart rates, enabling early identification of potential health issues, such as arrhythmias or distress. Consistent Humidity Control: The moisture sensor ensures that the incubator maintains an optimal humidity level, which is crucial for premature babies' delicate skin and respiratory systems. Improved Safety: With temperature and humidity regulation, the incubator reduces the risk of hypothermia, hyperthermia, or dehydration, enhancing the baby's safety. Data Logging and Analysis: The IoT platform can store historical data, allowing medical professionals to analyze trends, identify patterns, and make informed decisions for improved care.

Reduced Human Errors: The automation provided by the IoT-based incubator reduces the chances of human errors in maintaining the baby's environment. Scalability and Connectivity: The IoT platform enables multiple incubators to be connected, making it suitable for larger healthcare facilities or remote monitoring networks. Cost-effectiveness: Compared to traditional, manual incubators, the IoT-based system offers a cost-effective solution with enhanced functionalities.

C. Applications:

Neonatal Intensive Care Units (NICUs): In hospitals, the IoT-based baby incubator is ideal for premature infants or newborns with medical conditions requiring specialized care. Home Care: The incubator can be used for babies requiring post-hospitalization care at home, with remote monitoring capabilities providing peace of mind to parents and caregivers. Mobile Health Units: IoT-based incubators can be deployed in mobile health units or rural healthcare centers to provide advanced care for newborns in underserved areas.

Telemedicine: The IoT platform facilitates telemedicine consultations, allowing medical experts to remotely monitor and advise on baby care in real time. Disaster Relief: In emergencies or natural disasters, when medical facilities are limited, IoT-based incubators can serve as temporary solutions for infant care. Preventive Healthcare: The incubator's early detection capabilities aid in preventive healthcare by identifying health issues in newborns at an early stage. Healthcare Facilities in Remote Areas: In regions with limited access to healthcare facilities, IoT-based incubators can bridge the gap and provide specialized care.

IV. CONCLUSION AND FUTURE WORK

A. Conclusion:

This paper proposed a system that monitors the heartbeat of the infant and the temperature and humidity of the surroundings. Temperature monitoring is done to keep the environment suitable for the neonate. Temperature monitoring of the infant's body will help to detect many other internal diseases like infections, the common cold, and pneumonia have a common symptom of fever as the body temperature

goes high. Humidity measure values also help in detecting of having internal problems like cold, and dehydration. Continuous heartbeat monitoring helps to detect any kind of cardiovascular disorder in the infant. It also helps to detect arrhythmia or irregular heartbeats. But if the temperature inside the incubator is loose due to the atmosphere or any other problems, the heating pad will turn on automatically.

The IoT-based baby incubator with Arduino Uno, heart pulse sensor, moisture sensor, temperature sensor, and fan represents a significant advancement in neonatal care. It combines smart sensing, automatic control, and IoT connectivity to create a safe and monitored environment for newborns, especially premature or medically fragile infants. The system's ability to continuously monitor vital parameters, maintain optimal conditions, and provide remote access to caregivers and medical professionals enhances the quality of care and improves the chances of positive outcomes for newborns.

The integration of the heart pulse sensor allows for early detection of potential health issues, providing timely interventions. The moisture and temperature sensors ensure a consistent and comfortable environment, while the fan enables precise temperature regulation. The IoT connectivity enables remote monitoring, real-time data analysis, and the potential for scalability in larger healthcare settings.

B. Future Work:

The IoT-based infant incubator has a promising future with the potential for further advancements and applications:

AI and Machine Learning Integration: Incorporating artificial intelligence and machine learning algorithms can enable more advanced anomaly detection, predictive analytics, and personalized care for individual babies based on their specific needs. Mobile Application: Developing a user-friendly mobile application for caregivers and parents to access real-time data and receive alerts directly on their smartphones would enhance convenience and accessibility. Remote Diagnostics and Consultations: Integrating video conferencing or telemedicine capabilities into the IoT platform would allow medical professionals to remotely assess babies' conditions and provide guidance to caregivers. Integrated Medical Devices: Collaborating with medical device manufacturers to integrate additional medical sensors, such as blood oxygen level monitors or respiratory rate sensors, can offer a more comprehensive view of the baby's health. Smart Alarms and Notifications: Implementing smart alarm systems that use gentle sounds or vibrations to alert caregivers of any changes or critical situations, reducing noise disturbances for newborns. Wireless Sensor Networks: Expanding the system to support wireless sensor networks can reduce the need for physical wiring, enabling greater flexibility in incubator design and placement.

Energy Efficiency: Implementing energy-saving techniques and power management strategies to optimize the system's energy consumption and extend battery life in case of power outages. Customizable Incubator Settings: Allowing caregivers to adjust incubator settings remotely through the IoT platform based on the baby's needs or medical requirements

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