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An Intelligent System For Infant Incubator Using The IoMT

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ABSTRACT:

Giving birth to a child is one of the most precious moments of life, a moment that brings immense joy and a profound sense of responsibility. The birth of a baby is a wondrous yet intricate process. Both mother and infant undergo a multitude of physical and emotional changes. Every second, a new life enters the world, but not all babies are fortunate enough to be born healthy. Newborns requiring special medical attention are typically admitted to the Neonatal Intensive Care Unit (NICU). Most of the infants in the NICU are premature. The neonatal period is a critical phase in an infant's life, particularly for premature babies or those born with health complications. Providing optimal care during this period is paramount to their well-being and long-term development. A neonatal incubator is a specialized enclosure where a premature infant will be kept in a clean and controlled environment for observation and care. The biological parameters are monitored to ensure the safety of the babies and reduce mortality rates. Traditional baby incubators have played a fundamental role in neonatal care by providing a controlled environment that supports the growth and stability of infants. Advancements in technology, however, present an opportunity to enhance the capabilities of these incubators, transforming them into smart systems capable of intelligent monitoring and intervention. The development of a smart baby incubator utilizes small sensors inside the incubator to keep track of important things like temperature, humidity, and oxygen levels, as well as sound sensors using IoMT. These sensors will send this information to a Microcontroller using the internet. Once the data arrives at the central computer, Python programs will analyse it. These programs will employ algorithms to analyze the data and determine if the baby's environment is within normal parameters. The results will be shown to doctors and nurses on their computers or phones through easy-to-understand charts and graphs. By using Python and IoMT, we're making it easier for healthcare providers to keep a close eye on babies in incubators, ensuring they stay safe and healthy during this critical period of their early lives.

INTRODUCTION:

It is estimated that in 2020, 13.4 million premature babies were born (before 37 weeks gestation) [1]. If the gestational age is not known with certainty, the weight of the baby born is used as a reference in the range of 1,000–2,500 grams [2]. Complications from premature birth are the leading cause of mortality among children under five years of age, claiming approximately 900,000 lives in 2019 [3]. In today's world, with both parents often working, mothers may not be able to stay home and care for themselves during pregnancy. To take care of premature babies in the hospital, a closed apparatus called an incubator is utilized. The baby's health is very important for parents, especially for those having a premature baby, which requires treatment using an incubator. The term incubator originates from a Latin word that means "to lie on." An infant incubator is a device that provides a controlled environment similar to a mother's womb for preterm infants. The incubator maintains the baby's temperature between 31 °C and 36 °C. Generally, premature babies need to be placed in an incubator with a controlled room temperature. This means the babies are kept at the appropriate temperature, similar to what they experience in the womb. The supporting staff in the hospital cannot be looking into the incubators 24/7. They need technical support to monitor the environmental atmosphere in the incubators. The lack of neonatal monitoring facilities in small villages and municipalities, as well as inaccurate monitoring systems, are the main reasons for the deaths of premature babies. Hence, there is a need to develop an incubator monitoring system that monitors environmental factors like temperature, humidity, heart rate, and the essential amount of gas required for the baby to be safe in the incubators. Our project aims to provide a low-cost, practical, patient-friendly, and dependable premature baby incubator, which helps to monitor the vital parameters and store them, in addition to that it will also analyze those parameters and intimate the healthcare providers and family members if it is abnormal. It will help the people in rural areas where there are not sufficient facilities for taking care of infants who have to be monitored continuously for their treatment.

LITERATURE REVIEW:

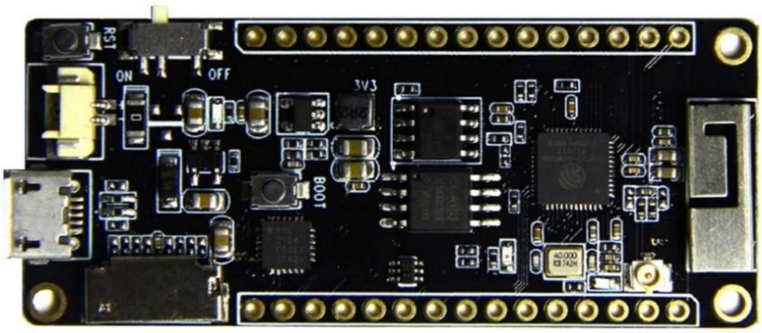
The infant incubator has revolutionized neonatal care, providing a critical life support system for premature and fragile newborns. The historical evolution of incubator technology, tracing its development from early prototypes to modern advancements. This literature review delves into the world of infant incubators, exploring their historical evolution, their impact on neonatal care, and the ongoing advancements in design and functionality. We will examine how incubators have improved survival rates for premature babies and contributed to the field of neonatology. In [4], a system that monitors several parameters, such as temperature, pulse rate, and other measurements, has been proposed to remotely monitor and send the measurements via a global system for mobile communications (GSM) and issue an alarm to the parents in the event of an emergency. Several infant incubator projects have been developed, including one by Prof. Dr. Ir. Raldi Artono Koestoer [5]. These special incubators use a natural airflow system. Because hot air rises and cold air sinks, the warm air naturally moves towards where the baby is sleeping without needing a fan or blower. A very small amount of power, between 20 to 40 watts, is enough to create a comfort environment for the baby. Because it uses so little energy, these incubators don't need advance electronic controls. In Indonesia, during the dry season, even less power, less than 20 watts, can be used. But during the rainy season when it's cooler, the heater might need to use more power, up to 40 watts. A wireless smart sensor system has been proposed in [6] for infant incubator systems. The system utilizes different sensors, the ZigBee wireless protocol, and the IEEE 1451 communication interface to remotely monitor infants. The cost-effective design of an embedded device for real-time tracking of newborn babies in the incubator is addressed by Sivamani D. et al. (2018) [7]. This smart incubator allows physicians and nurses to access a child's medical data remotely through mobile phones or computers. The system continuously monitors the newborn baby and transmits vital signs directly to cloud storage. Medical information can then be accessed from anywhere for informed decision-making. This approach enables close monitoring of health parameters, allowing doctors to easily check the baby's well-being and prevent potential issues. While offering a safe and monitored environment for the newborn, one limitation of some existing systems might be limited display options, only showing values on an LCD and requiring additional steps to send data to a phone. In [8], a temperature control system has been proposed for baby incubators. This system utilizes temperature sensors and an Arduino controller to maintain a stable temperature environment. Additionally, the system sends alerts through an IoT web interface in case of any temperature fluctuations within the incubator. A contactless radar-based system has been proposed in [9] to monitor the respiratory and heart rates of infant patients. The antenna design was limited to the area of interest required for measurement. In [10], an advanced monitoring and control system has been developed to regulate the temperature of both the incubator and the infant's body. This system utilizes multiple temperature sensors, a humidity sensor, and an Arduino controller. Reference [11] proposes an infant incubator monitoring system equipped with temperature, humidity, and weight sensors. These sensors connect to a central network via a long-range communication protocol for medical data archiving. Additionally, the system incorporates a near-field communication interface that allows doctors to identify themselves, monitor patient progress with medications, and update medical records. The proposed infant incubator system utilizes an Arduino Uno microcontroller, along with sensors to measure temperature, humidity, CO2 percentage, and water reservoir level. Additionally, an actuator controls the heater and fan for temperature regulation. However, an error appeared in the humidity data when attempting to isolate the microcontroller's electrical noise from the MATLAB program. This research proposes new methodologies for designing a reliable infant incubator using an Arduino microcontroller. The system is designed using an Arduino microcontroller and connects to a network via Wi-Fi to link with an application on a smartphone or computer [13]. This allows for remote monitoring of air temperature and humidity levels in the infant's incubator using an Arduino microcontroller equipped with various sensors and open-source Internet of Things (IoT) applications. The results demonstrate the successful transfer of real-time medical data to medical staff using Thing Speak, an IoT application. The objective of this study is to develop a portable monitoring system for temperature, weight, and baby heart rate in incubators [14]. The system features both an LCD display on the incubator itself and a web interface accessible from a smartphone or PC for remote monitoring. Real-time data is displayed and saved on a database server. This client-server architecture, utilizing an Ethernet network and web interface, allows medical personnel to access and analyze the data over the internet, providing valuable medical records of baby health conditions within the incubators. The internet-based baby incubator monitoring system utilizes sensor-equipped devices to transmit real-time data to a server and mobile apps, providing monitoring capabilities for parents, including the ability to hear their baby's voice [15]. This study achieved significant success by using energy signal and spectrum analysis to classify over 40 voice datasets into five possible baby conditions: burping, sleepy, hungry, uncomfortable, and pain. The research focused on developing smart incubators that can listen to babies' cries, capture their voices, and leverage artificial intelligence to interpret their emotional state. This research aimed to develop a portable incubator monitoring system for premature babies using a microcontroller, temperature sensor, weight sensor, heart rate sensor, and GSM module [16]. The system displays vital signs on an LCD screen and sends SMS alerts to a smartphone in case of critical conditions, with each message taking about 8 seconds for delivery. This system, designed to monitor a baby inside an incubator using a GSM module, detects the baby's temperature, heartbeat, and weight [17]. In this special type of incubator, certain things like the baby's pulse rate, temperature, or the air quality inside the incubator exceeds the safe limits, a message is sent to the doctor's phone using

GSM (a type of mobile network). The system keeps sending messages every minute until the doctor sees them and responds. This incubator has a built-in device that keeps an eye on important things for the baby's health and lets the doctor know if something is abnormal [18]. An Arduino microcontroller serves as the central processing unit, receiving input from sensors like a pulse sensor, a DHT11 temperature and humidity sensor, and a gas sensor. The processed sensor data is then used to control output devices such as an LCD screen, a buzzer for alarms, and a Node MCU module. Notably, the Node MCU itself can also display information on an LCD and sound alarms. The system leverages cloud storage to accumulate sensor data and send emergency notifications to medical personnel (doctor or nurse) when critical conditions arise. The Internet of Things (IoT) enables continuous monitoring and control of sensor readings, ensuring the efficient and safe operation of the incubator. This paper proposes a baby incubator monitoring system that leverages a separate, wireless module for faster, easier, and more practical monitoring [19]. This independent module allows for use with any brand of incubator. The system utilizes Wi-Fi for data transmission and employs multiple ESP32 modules. Each ESP32 acts as a client, collecting data from its assigned sensors. This data is then transmitted to a central ESP32 server using the internal Wi-Fi network of the ESP32 modules. Finally, the processed information is displayed on a TFT Nextion display. This paper describes an incubator monitoring system developed using IoT technology to monitor critical parameters for newborns, such as temperature, humidity, heart rate, and essential gas levels [20]. The system continuously monitors these parameters and sends alerts to doctors or nurses via the Blynk App, an open-source platform, in case of any deviations. This paper proposes an infant incubator monitoring system that measures temperature, humidity, and noise levels [21]. The system leverages the Internet of Things (IoT) for data transmission. Three ESP32 modules, configured for data collection, transmit information to a central server (Raspberry Pi Zero) using IoT technology. The processed data is then displayed on a web interface.

Components Specification:
Hardware specifications
- i3 processor
- 4 GB Ram
- ESP32 Microprocessor
- Temperature and Humidity sensor (DHT11)
- Pressure sensor (BM180)
- Pulse sensor
- Sound Detection Sensor
- SPO2 (MAX30102)
- Blood Glucose Sensor

Software Specification
- OS (windows 7/8/10)
- Python language
- IDE – Anaconda, Notebook

EPS32 Microprocessor: The ESP32 microcontroller is a small but powerful chip used in gadgets that connect to the internet. It's like a smart brain that can handle many tasks at once. It communicates with other devices using Wi-Fi and Bluetooth and can easily connect to sensors and buttons. As it is a powerful yet energy-efficient microcontroller, it is great for projects like controlling home appliances with a smartphone or creating wearable gadgets. Its small size, affordability, and ease of use make it a popular choice for building smart devices.



Temperature and Humidity Sensor (DHT11): The DHT11 temperature and humidity sensor for infants is a specialized version of the DHT11 sensor adapted for monitoring environmental conditions specifically in neonatal care units or for infant care at home. It employs the same working principle as the standard DHT11 sensor, utilizing a capacitive humidity sensor and a thermistor to measure temperature and relative humidity. However, it may feature modifications or enhancements tailored to the unique needs of infants, such as smaller form factors, improved accuracy, or additional safety features. This sensor enables caregivers to monitor temperature and humidity levels in the infant's environment accurately, ensuring optimal comfort and well-being.

Pressure Sensor (BM180): The BM180 pressure sensor is a key part of incubators, which are special beds for premature babies. It measures air pressure inside the incubator very accurately. Using advanced technology called MEMS, it can detect even small changes in pressure. This helps keep the air inside the incubator just right for the baby's health. The sensor helps control oxygen levels, temperature, and humidity, which are super important for the baby's growth. Because it's small and sensitive, the BM180 sensor keeps a close eye on things, so doctors and nurses can quickly fix any problems and make sure the babies are safe and healthy in the incubator.

Pulse Rate Sensor: A pulse rate sensor for infants is a medical device that monitors a newborn's heart rate continuously and non-invasively. Utilizing technologies like photoplethysmography (PPG) or electrocardiography (ECG), these sensors measure the pulse rate by detecting changes in blood volume or electrical signals produced by the heart with each beat. Placed on the baby's skin, typically on the chest or foot, they provide real-time monitoring of heart activity, vital for early detection of any irregularities or changes. Essential in neonatal care units and pediatric settings, pulse rate sensors ensure prompt intervention and optimal care for infants, enhancing their health outcomes.

Sound Sensor: A sound sensor for babies is a device that listens to the noise around a baby. It picks up sound vibrations and turns them into signals. These signals help measure how loud or frequent the noise is. You often find these sensors in baby monitors or nursery gadgets. They alert caregivers when there are loud noises, like crying or sudden sounds, so they can help the baby quickly. Sometimes, these sensors are also used in devices that track how babies sleep, making sure they have a peaceful environment to rest and stay healthy.

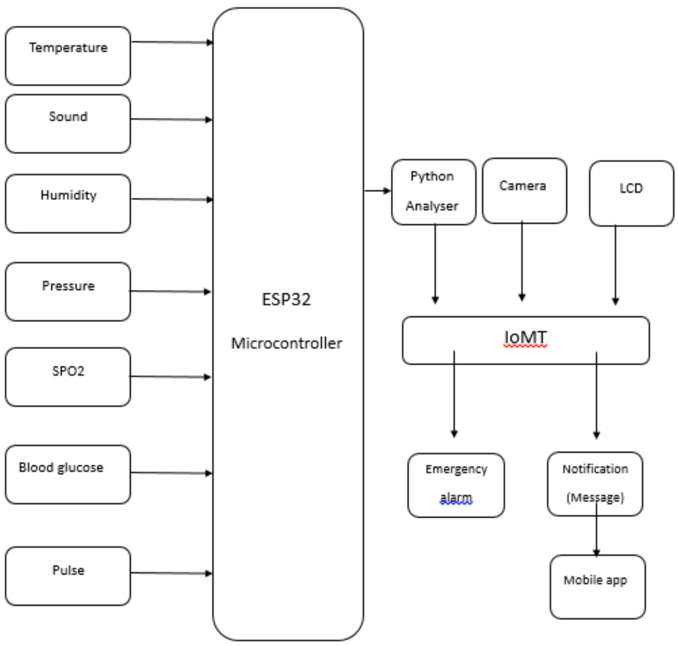
SPO2 (MAX30102): A SpO2 (blood oxygen saturation) non-invasive sensor for infants is a medical device designed to measure the oxygen saturation level in a newborn or infant's bloodstream without the need for invasive procedures. Utilizing spectrophotometry or pulse oximetry, these sensors typically consist of a probe placed on the baby's skin, often on the foot or hand, which emits light and measures the absorption of oxygenated and deoxygenated blood. This information is then used to calculate the percentage of oxygen saturation in the blood. Crucial for monitoring respiratory function in neonatal care units, SpO2 sensors enable early detection of hypoxemia or respiratory distress, ensuring timely intervention and optimal care for infants.

Blood Glucose Sensor: A non-invasive blood glucose sensor for infants employs advanced technology like optical or electrochemical sensors, or microneedle arrays to measure glucose levels through the skin without blood draws. It offers continuous monitoring, reducing discomfort and infection risks associated with traditional methods. These sensors are vital in neonatal care units and home monitoring, providing accurate glucose readings for early detection of abnormalities in newborns and infants. Challenges include ensuring accuracy amidst skin variability and motion artifacts. However, ongoing research aims to enhance sensor performance, promising a pain-free and reliable solution for monitoring blood glucose levels in the pediatric population.

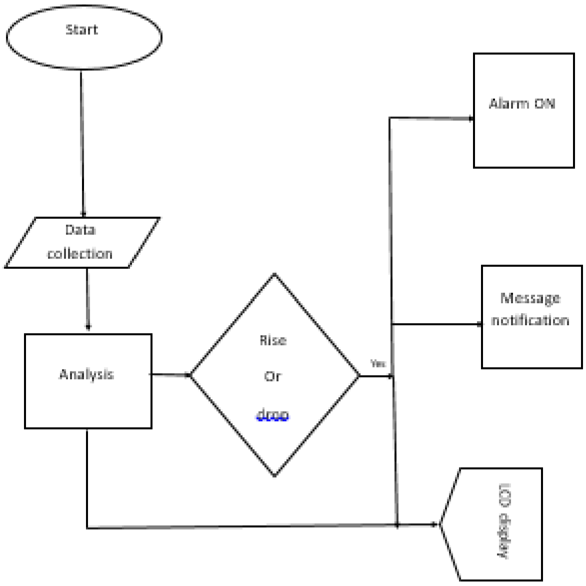
Working: The intelligent system for the infant incubators is implemented with different sensors such as Temperature and Humidity sensors, Pressure sensors, Pulse rate sensors, Blood glucose sensors, SPO2, and Sound detectors to measure and detect certain parameters. The microcontroller ESP32 is used to collect the data from the sensor and transfer it to the system where the parameters are recorded and stored in python. There the measurements are analyzed for certain normality, if it exceeds the normal value then there will be a notification sent to the health care providers and family members through the mobile app, and in addition to that there will be an alarm to indicate the deviation in the parameter to the nurse who is in charge of that cabinet with the voice note. Here the IoMT (Internet of Medical Things) is used to transmit the data and send notifications to the mobile app. Also, there is a camera fixed to monitor the baby continuously. All the recorded details will be displayed on the LCD. Here as Python is used to store and analyse the data it will be easy to access the data for further uses, as the data are stored in python the health care provider can access those data for verification and give better treatment to the baby. It will be easy and fast to analyse of the measured parameters as we use Python which is the easiest and fastest mode. As the sensors used are mostly non-invasive and slightly invasive, they will not make the baby uncomfortable so we can able to measure the parameters without causing any discomfort to the baby.

Future Scopes: The future scopes for this project are that it can be implemented with more advanced sensors and also can add the more vital parameters. It can be improved by using different analysers like the machine learning or any other platform which that more advanced than Python.

Design Block:



Flow chart:



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