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DEVELOPMENT AND CONTROL OF SMART INCUBATOR SYSTEM FOR PREMATURE BABIES

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ABSTRACT

Smart incubator systems (SIS) for infants are designed to provide the best possible care for premature and critically ill newborns. It uses advanced technology to monitor and regulate the temperature, humidity, and other environmental factors in the incubator for the neonates. The essential goal of this paper is to build a low-cost, efficient, and dual-powered incubator that saves premature neonates ' lives. An open-source Internet of things (IoT) application and an Arduino Nano microcontroller equipped with several sensors are used to remotely monitor and control the environment levels inside an infant incubator.

This study examined the effect of temperature and Humidity on the infant incubator control system. It employed a DHT11 Temperature and Humidity sensor, which was processed by an Arduino NANO microcontroller and presented on a PC. The average value of the minimum difference for DHT11 sensor readings was 34°C and 25%, and the average maximum value difference was 37°C and 65%. The DHT11 sensor was found to have lower oscillations and higher accuracy. The BLYNK application server is used to a network so that it is linked to a smartphone and sends notifications to the registered medical staff and parent's mobile number if any abnormalities are detected. The outcomes of this research have demonstrated that using Thing Speak IoT apps, real-time updated medical records were transmitted to the medical team and parents.

1.0 Introduction

Temperature and humidity are two of the most important factors for maintaining a healthy environment for neonates. Infants' body temperatures can affect their health in a variety of ways, such as hyperthermia, dehydration, and apnea [2]. To create an appropriate environment and keep the infant's core temperature steady at 37 ºC, the temperature and humidity in the newborn incubator should be regularly maintained. Modern technology places a lot of emphasis on health monitoring systems, which use sensors to receive and send biological information [3]. Remote patient monitoring (RPM) allows for patient monitoring outside of the traditional clinical setting or patient room [4]. A system that remotely monitors and transmits measurements of various parameters, such as temperature, pulse rate, and other measurements, has been proposed in [5]. A smart incubator system that communicates measures to the cloud and continually monitors has been presented in [6]. A wireless smart sensor system has been presented to remotely monitor the newborns in the infant incubator system using various sensors, the ZigBee wireless protocol, and the IEEE 1451 communication interface.

This work discusses a temperature control system that uses temperature sensors and an Arduino controller to regulate the temperature of infant incubators [8]. Using an IoT web system, a preterm infant's incubator temperature can be remotely monitored. A contactless radar-based device has been presented to monitor the infant patient's respiratory and cardiac rates [9]. A sophisticated monitoring and control system has been employed to regulate the temperature of the incubator and the infant's body [10]. Temperature, humidity, and weight sensors are connected to a central network to save medical data through a long-range network [11]. This study created an efficient, low-cost newborn incubator with IoT-based remote monitoring. It uses a near-field communication interface to identify physicians, track patient medication progress, and allow doctors to add new information to patient records [12-19]. An ESP8266 wireless module and an Arduino IoT application are used to monitor changes in the temperature and humidity of the incubator, which can be used to protect premature babies who are born alive before the 37th week of gestation or babies born with weight criteria of less than 2500 grams [20-24].

2.0 Method and Material

The existing system proposes the use of a temperature sensor to sense the temperature of an incubator. Any increase in the temperature beyond the specified range turns the alarm on and the heater in the incubator gets turned off. This only ensures the maintenance of temperature, but other parameters require being monitored and controlled to provide safety to the infant. This study aims to overcome the drawbacks and provide a safe and affordable mechanism for monitoring the incubator, which will help in reducing the mortality rate of neonates. The Arduino NANO has a microcontroller, liquid crystal display (LCD), and Node MCU module to transmit the temperature and humidity data remotely to the app. A relay is a programmable electrical switch, which can be controlled by Arduino or any microcontroller, and Low Voltage Relay 5v is used as shown in Figure 1. The proposed system involves the use of Node MCU integrated into various sensor units such as temperature and humidity sensors as illustrated in Figure 2.

respectively and hence to reduce the current, two current limiting resistors are kept in series between the RX and TX pins of Arduino NANO and NodeMCU.

R = (5-3.3)/10mA ➔ R = 1k

Maximum permissible current and voltage of LED: Voltage = 1.25V, Current = 10Ma

R = 1.25V/10mA = 1k

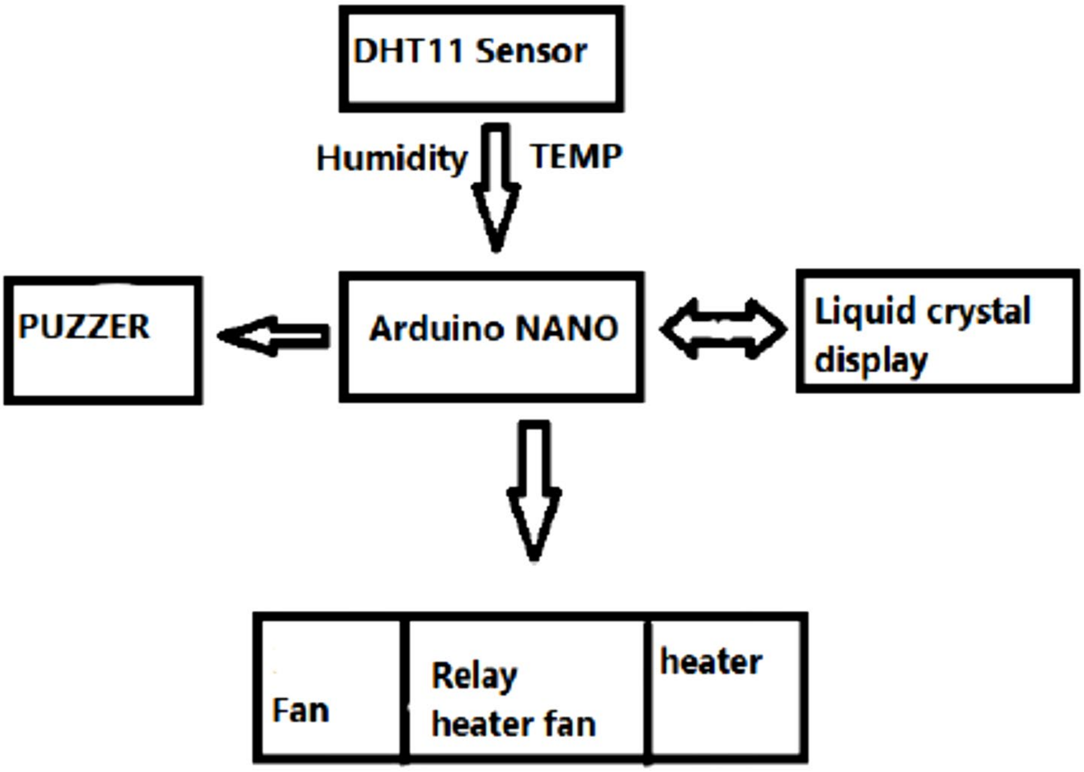

Figure 1 Block diagram of the temperature and humidity sensor DHT11 for the incubator.

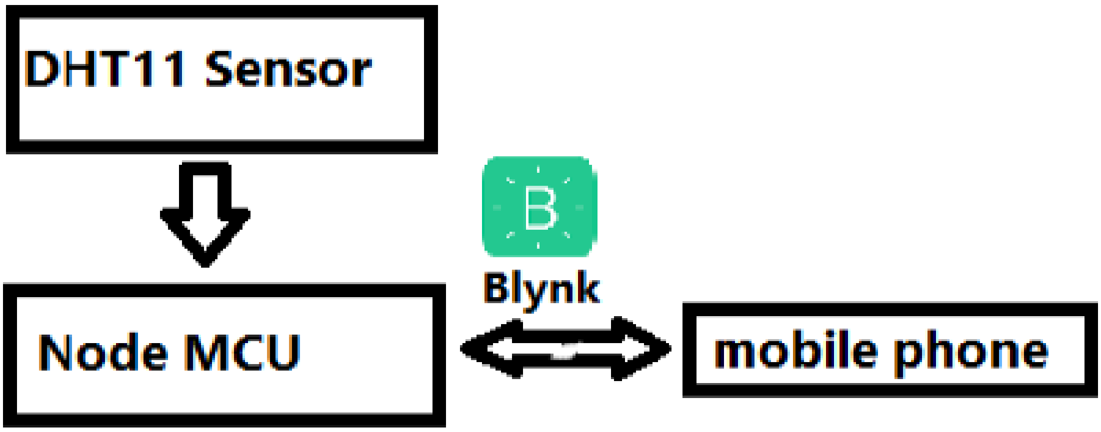

Figure 2 Block diagram of the temperature and humidity detector with the NodeMCU and IoT application.

3.0 Results and Discussion

The most important details in this text are that the environment in the infant incubator should be monitored and the real-time situation of the body should be provided. During the execution of the system snapshots of Blynk were taken. The system is a complete hardware design and the data available on the laptop and Blynk monitor have been captured. Test results of the system are given in Figure 3, showing the successful implementation of the system.

Figure 3 Existing System Incubator: Temp=35, Humidity= 36%

3.1 Variation of Incubator's temperature with respect to Time

The temperature control unit as shown in Figure 4 consists of four parts: temperature sensor, microcontroller, fan, heater and LCD. If the temperature exceeds the threshold, the fan will switch on automatically until returns to normal, while if it decreases below the threshold, the Bulb will be switched on to create heat. The threshold is set manually by using a Potentiometer.

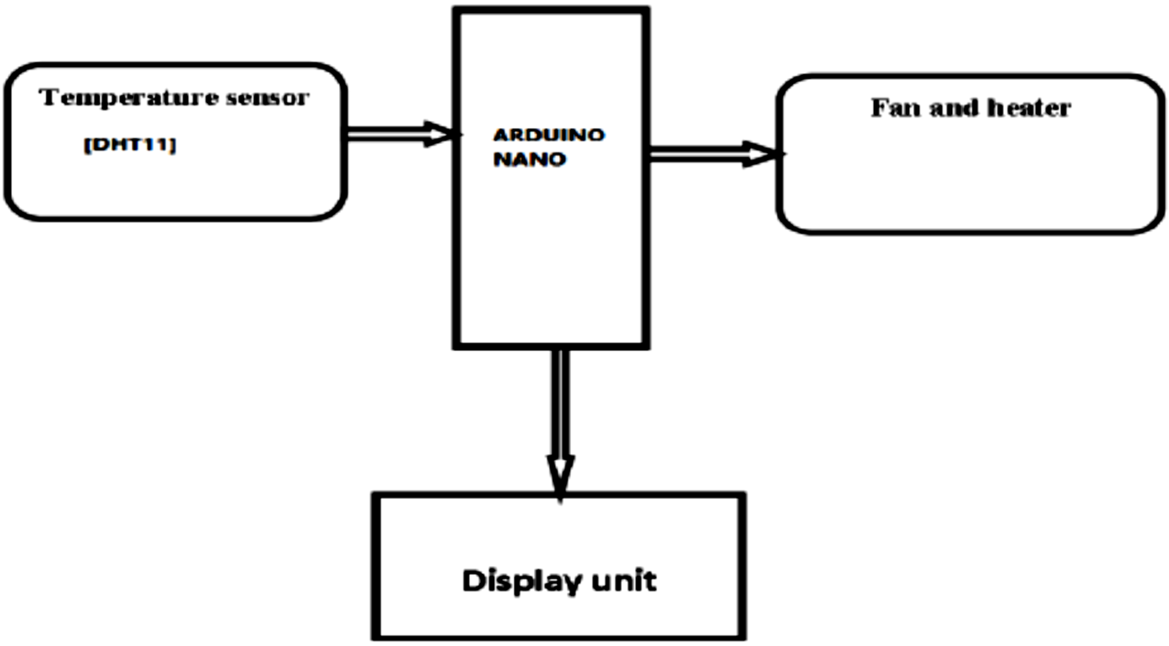

Figure 4 Variation of Incubator's temperature

3.2 Relative Humidity Achieved by the System

Figure 5 illustrates the humidity that can be increased or decreased by using water content in the Air. The sensor is designed for high volume and is converted into digital values and calibrated according to high and low ADC voltage references.

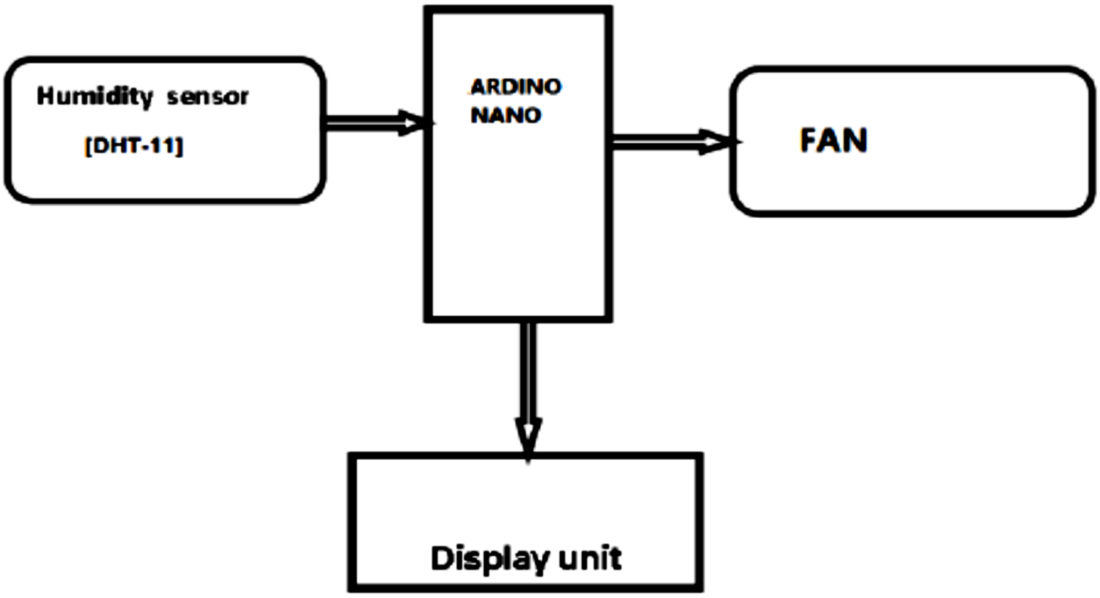

Figure 5 Variation of Incubator's humidity

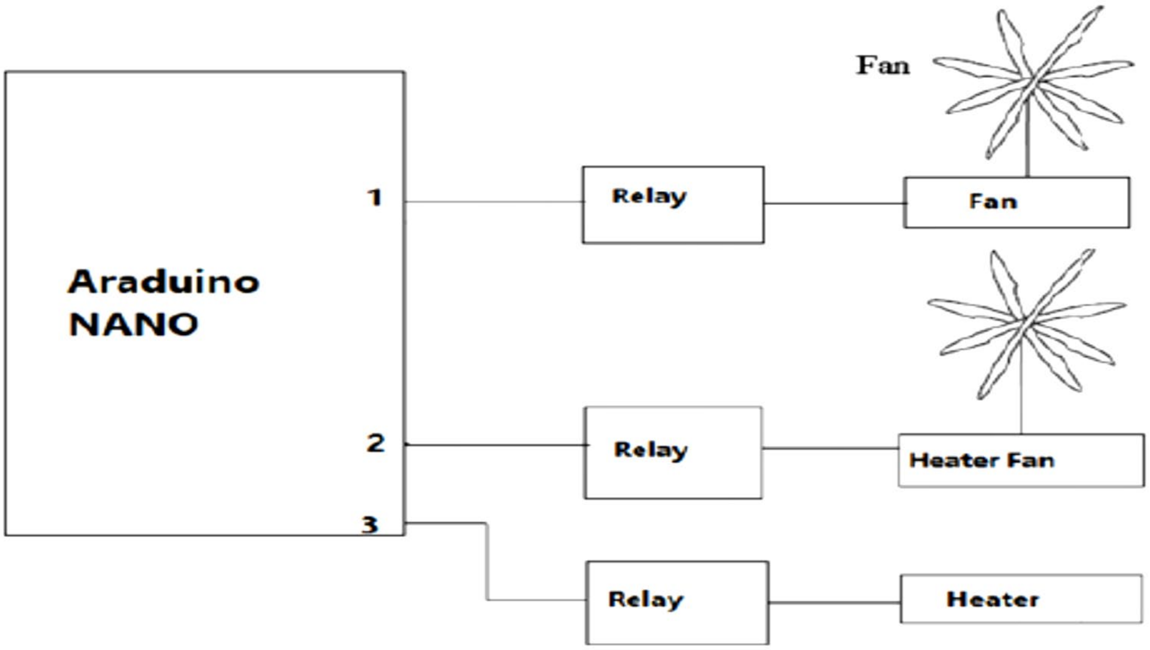

Figure 6 Arduino Nano and relays with fans interface

Table 1 illustrate the temperature control in the incubator

Fan	Heater Fan	Heater	Temperature inside incubator
OFF	ON	ON	Below 25 ºC
ON	OFF	OFF	Between 34 to 37 ºC
ON	OFF	OFF	Above 37 ºC

Figure 6 shows the fan and heater interface that was used for ventilation and heating, with three relays used to power them and connect them to the Arduino NANO. The elements control the temperature and humidity of the incubators, and certain terminals have been set for each of them. Table 1 shows the conditions of the temperature with heater and fan, when it rises to more than 37°C, the Arduino Nano gives a command to the relay to turn off the voltage from the heater fan and trigger the alarm. When the humidity rises above 65%, the Arduino Nano commands the relay to block the current to the fan.

The system consists of an MCU node connected to the incubator, DHT-11 sensors connected to the Node MCU, and a portable software called Blynk. DHT11 is a temperature and humidity sensor and is connected to the Node MCU to give readings by sending data to the phone. Random readings were taken in intervals and inserted into Excel sheet programs for two hours every five minutes as shown in table 2. If the temperature and humidity values exceed the specified range (34 - 37°C) and (25% - 65%) then the buzzer will turn on.

Table 2 Relative Humidity Vs. Temperature as data read of Arduino serial port

Relative Humidity %	**Temperature °C**	**Time**
31	35	7.00
39	44	7.05
38	43	7.10
39	44	7.15
38	42	7.20
37	41	7.25
32	35	7.30
33	36	7.35
33	35	7.40
37	39	7.45
35	37	7.50
36	39	7.55
37	39	8.00
34	37	8.05
36	35	8.10
34	34	8.15
33	33	8.20
33	33	8.25
32	32	8.30
30	30	8.35
35	35	8.40
30	30	8.45
29	29	8.50
29	29	8.55
29	29	9.00

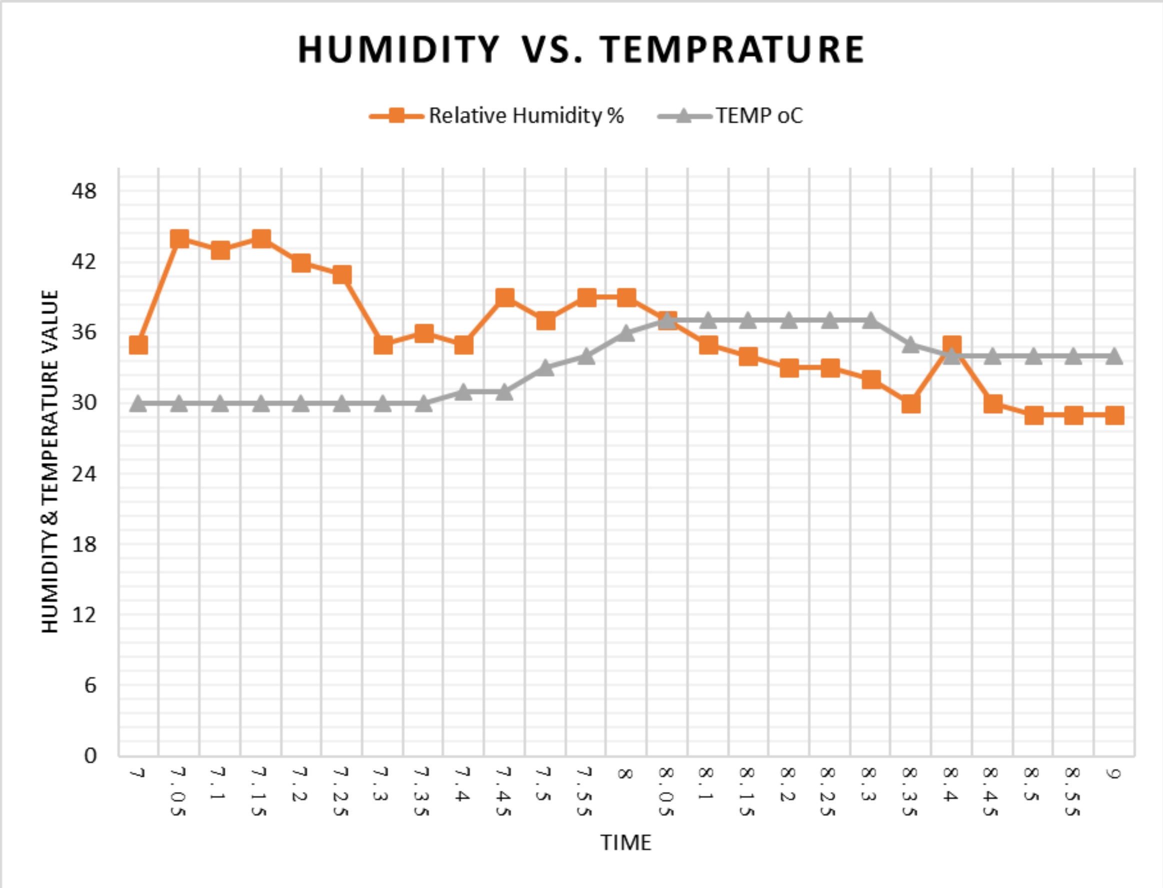

Figure 7 Relative Humidity Vs. Temperature with Time

Table 2 and Figure 7 show the continuous controller readings of temperature and humidity and it is very clear to show them on the LCD and Blynk application. If any parameter exceeds their reference values, the hospital staff can take immediate action to save an infant from imminent danger. The system consists of an MCU node connected to the incubator.

The smart infant incubator is equipped with sound, temperature, and humidity sensors, which are updated to the net and can be accessed through the Blynk server and its mobile App. The Blynk server address is required to synchronize the system, and the incubator starts swinging when sound is detected [25].
The parents and hospital's staff can remotely manage the baby incubator to swing manually by changing the switch in the Blynk server or cellular apps. They receive a notification when the infant's body temperature exceeds 37 degrees Celsius, or when the baby's nappy gets overfilled and makes the clothes wet.

Figure 8 IoT application (**Blynk Monitor**)

The figure 8 illustrates how data is retrieved from exploited sensors and actuators of a smart infant incubator while monitoring and controlling processes. The incubator model is tested for the appropriate functioning of all sensors. An evaluation of several experiments has revealed that the occurrence of time delays depends on the strength of the connected network. In the case of traumatic incidents, an emergency switch must be operated manually by the nearest available person to bring it to a standstill condition.

4.0 Conclusions

A Blynk IoT platform is used for the smart incubator to display the infant's conditions, including moist situations, and body temperature. IoT concepts such as Arduino Nano, ESP8266 Node MCU, and Blynk mobile app are used to implement IoT concepts in the automated incubator system. A locally manufactured, conventional incubator is taken for automation first. Sensors are used to detect humidity conditions, and body temperature. The proposed model is tested with a mobile phone. The signals for humidity conditions and the baby's temperature are transferred to the cellular cell phone so that the user can acknowledge the reason for any problem occurs. This IoT-based Smart Infant incubator offers huge scope for further modifications from an operational and monitoring point of view, which will make it a more attractive and customer-preferred product.

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