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Investigation Smart Infant Incubator with Multi-Sensors Control System

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Abstract The purpose of this article is to explore the feasibility and practicability of examinations in the fields of biomedical engineering, electrical engineering, computer engineering, pediatrics, and neonatology. A smart baby incubator is develops by using sensors inside to monitor infant babies, including temperature, humidity, gas level, sound level, liquid (wet bed), etc. In addition, the sensors used in this system are inexpensive and simple to replace as part of regular maintenance. The results show that the system is reliable and provides help for the medical staff. However, the system is a prototype not applied to infants, so in the future it may be applies to them.

Keywords: *Incubator, Jaundice, Microcontroller, Sensors, Temperature, Ultraviolet ray*

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1. Introduction

Infant incubators are devices that help premature infants keep their body temperatures steady, heart rate, breathing, pulse, temperature, and humidity are the fundamental characteristics that must be regulated. Babies born before their time need room conditioning that simulates the environment in the womb. Babies born between the 22nd and 37th weeks of pregnancy are prematurely born by the World Health Organization (WHO). Extremely preterm babies refer to births occurring before the 28th week of pregnancy. The weight of the premature new-born is often less than 2,500 grams. There have been instances where the premature infant weighed less than 1,000 grams. Premature birth results in underdeveloped respiratory, central nervous, and cardiovascular systems in infants [1]. Lately, some premature new-born died as a result of improper incubator monitoring that causes accidents. A clean, sterile environment is provided for a premature baby to be observed and cared for in an enclosed facility called a neonatal incubator. In order to protect the health of the infants and lower the mortality rate, the biological parameters are tracked [2].

Due to their ability to provide a regulated environment that promotes new-born growth, classic baby incubators have been essential to the provision of neonatal healthcare. Nevertheless, technological advancements offer a chance to improve these incubators' capacities by turning them into intelligent systems that can monitor and intervene intelligently. So, a summary for predicted with identified neonatal pathology by continuously analysing single or multiple vital signs and the combination of vital signs as well as clinical diagnostic methods was illustrated. It was shown that analytical techniques based on big data had great potential with further development and could develop into an effective instrument to reduce new-born illnesses [3]. In order to monitor the conditions of babies who were premature in a medical facility, detectors, and electrodes were needed. The notification system would sound to alert individuals to any abnormalities in the parameters. Therefore, a survey focuses on the many incubator monitoring devices that are now available, the biological indicators that were analyzed, and an analysis of the methods utilized for continuous monitoring and information transfer [4]. Furthermore, in order to create incubators that were customized to satisfy the demands of every participant in healthcare; an incubators could come with specified characteristics. Like improved safety, monitoring capabilities, comfortable design, environmentally friendly, sustainable components, intelligent technology, advanced control measures, and audio-video abilities that enable caregivers to access the unit from a distance [5]. Moreover, an incubator with vital indicators was presented. The aim of this study was to use an LCD to measure and display oxygen consumption and heart rate in premature new-born. Who may exhibit initial signs of congenital abnormalities when the measurement results were abnormal? [6]. The establishment of an incubator makes use of IoT to connect sound detectors and small instruments located within the incubator to monitor vital signs, including humidity, temperature, and levels of oxygen. These sensors will transmit the data to a microcontroller. Doctors and nurses would be able to view the results on their laptops or phones with simple-to-read charts and graphs. By employing it, medical professionals may more easily monitor infants in incubators, assuring their safety and well-being throughout this crucial stage of infancy [7]. Using the Internet of Things, a proposed device was evaluated in real time. The created model achieves the desired temperature with encouraging results. Furthermore, the working model and the mobile application display all of the environmental sensor data, humidity, and Peltier state on the device. The created incubator was appropriate for nations with limited resources and working parents [8]. Nowadays, as the number of patients has increased, so has the health care provider's workload. The study was offered an approach to the aforementioned issue by informing the new-born nurses so that preventive actions might be performed. It gave a baby's vital signs, including heart rate, temperature, blood pressure, moisture, and activity [9]. When developing a device for recording the physical characteristics of premature infants, factors must be considered, such as ease of use, physical appearance, size, and technical issues. In addition, safety during use, ability to disinfection, and measurement of vital signs must be made. The material used for premature new-born must be safe in addition to guaranteeing user comfort [10]. A suggested IoT-based incubator monitoring device tracks vital signs including temperature, humidity, heart rate, and the critical gas level needed in the incubator to keep the baby safe. The data would be analyzed via the open-source server Blynk App, and the system would be continually tracked. Should any changes occur in the parameters, a notification would be forwarded to the physician or caregiver [11]. The goal of developing this type of equipment is to enable nurses and other medical personnel to monitor infants simultaneously in the baby incubator in the PICU or NICU. The information gathered from the monitor was shown on a computer via a website. That facilitates the medical staff members' duties by increasing the speed at which measures of temperature, moisture, noise level, and incubator temperature could be collected [12]. A novel incubator design that includes an embedded device to monitor multiple parameters, including air quality, temperature, as well as the baby's heart rate. The information was uploaded on the hospital's website or Android app via IoT in order to preserve the environment within the incubator and guarantee the protection of the baby's health. This allows for the pre-planning of suitable actions. Therefore, the goal of this effort was to mitigate the aforementioned flaws and offer a reasonably priced, safe method of incubator observation [13]. With a focus on the implementation of noise and ventilation measures, this study attempted to build an infant incubator analyzer. It conducted experiments to determine the sensitivity level of many processed sensors in order to select a sensor with good sensitivity for the incubator analyzer module [14]. To develop and test a non-intrusive respiration monitoring device using e-textile pressure meters to track variations in the new-born' breathing patterns in the neonatal intensive care unit was illustrated [15]. The investigation was proposed to monitor and notify the state of preterm neonates in incubators using a microcontroller, temperature detector, weight detector, heart rate detector, and GSM component [16].

A new-born incubator is conditioned by maintaining a consistent temperature, controlled relative humidity, controlled air flow and etc. It is necessary to regulate this parameter to avoid harming the infant. The baby incubator needs to have its calibration checked on a regular basis to ensure proper operation. It is vital to test (calibrate) using an incubator meter in order to guarantee the availability of baby incubators in accordance with service standards. Therefore, as mentioned in the introduction section, there are many drawbacks in the designs, such as the limited sensor for two or three sensors to monitor the infant and the lack of a system to return to the setting condition, as illustrated in this paper.

The purpose of a smart infant incubator (SII) is to provide an environment just like the mother's womb for the new-born. Whereon the baby-appropriate temperature, humidity sensors in the baby's room, ventilation, liquid, and oxygen levels are adjusted to a certain setting degree. Moreover, the readings are sent to the microcontroller (Arduino) to process them. Additionally, it recognizes sounds and gases, regulates them to the optimal level in the setting, and then adjusts its operational settings to bring them back to the designated degree.

Table 1. Font Sizes for Papers

Font Size	Appearance (in Time New Roman)		
	Regular	Bold	Italic
8	cell in a table reference item	table caption, figure caption,	
9	author affiliation		author email address
10	paragraph abstract body	author name level-3 heading,	Received Line
12		level-2 heading,	
14		level-1 heading,	
20		title	

2. Methodology and Confirmation

The idea of creating and developing a Smart Incubator Interface (SII) with the tools and capacity to help medical professionals in their work and ensure the highest quality of care for neonates emerged. The SII monitors and regulates the temperature, humidity, and air flow of the incubator and also treats erythema illness. The SII consists of a microcontroller [17], a gas sensor [18], humidity sensor [19], temperature sensor [19], baby temperature sensor [20], sound sensor [21], liquid sensor [22], keypad [23], LCD [24], fan and filter [25], water incense burner [26], air heater [27], ultraviolet light [28], and buzzer [29] which are the inputs and outputs that make up the SII. Figure 1 illustrates the block diagram of the SII, while Figure 2 presents the complete SII system.

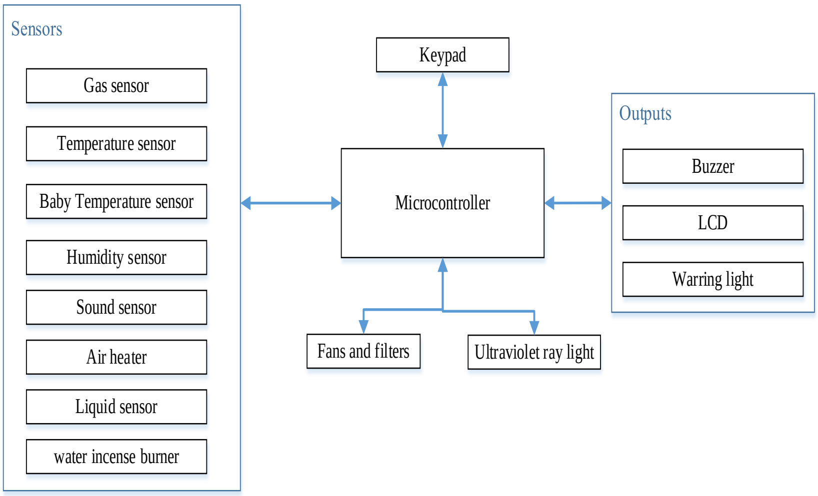

Figure 1. Block diagram of SII system

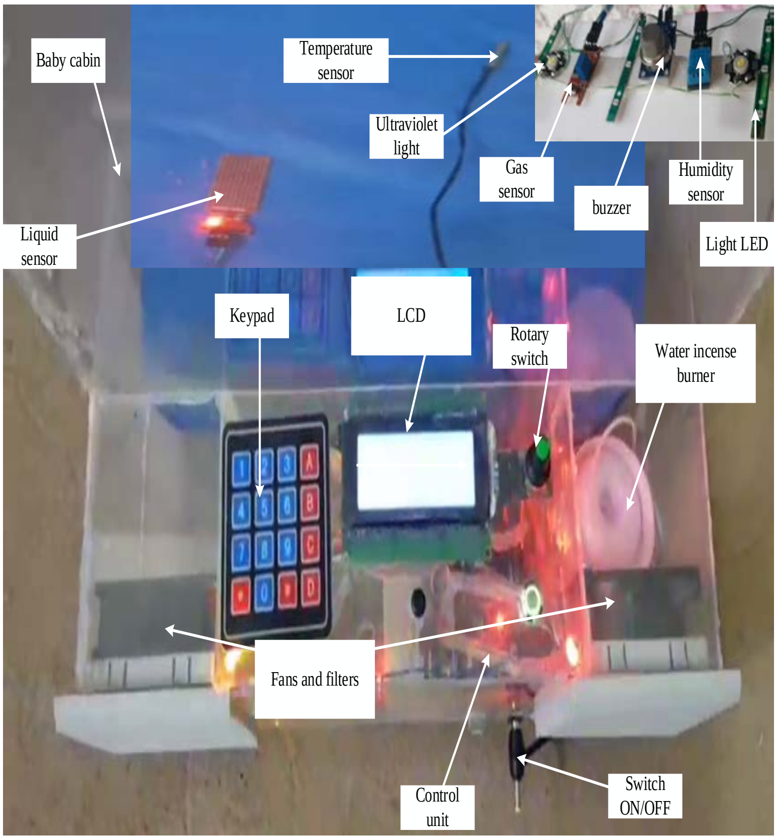

Figure 2. Real parts of SII system

3. Results and Discussion

An SII is used by medical staff in their work and guarantees high-quality care for infants and babies. Figures (3-6) illustrate the flowchart of each case for the sensors. If the temperature is higher than 37, fans will be turned on at maximum speed to cool the cabin room, and if reduced below 35, the air heater will be turned on to heat the cabin room, and it will go back to setting degrees. The same goes for the air humidifier. If the humidity drops below 41%, the humidifier will turn on automatically, and if it exceeds 71%, the fans will be operated continuously to reduce the moisture occurring. If the baby's body temperature sensor detects that his temperature is higher or lower than 37 degrees, a buzzer will turn the sound on, and a warning light will light up with a sentence written (body temperature is high or low) on the LCD. Another addition is a gas sensor, and if harmful gases are sensed or there is a fire inside the cabin, the warning system will be triggered, and the buzzer will work with lighting and printing the phrase (smoke level is too high) on the screen. A new feature is added to the incubator, a liquid sensor that works. As long as any liquid coming from the baby, such as diuresis, removal of a feeding tube, etc. The incubator's bed will be sensed through this sensor and will begin to inform the pathogen via sounding a beep, lighting up, and printing the type of problem (the bed is wet) printed on the screen. A new feature is added to the incubator, a liquid sensor that works. As long as any liquid coming from the baby, such as diuresis, removal of a feeding tube, etc. The incubator's bed will be sensed through this sensor and will begin to inform the pathogen. A sounding beep, lighting up, and printing the type of problem (the bed is wet) printed on the screen. Sound sensitivity works to sense any loud sounds inside the incubator room, such as a malfunction in the fans or a problem inside or outside the incubator. Loud sounds affect the infant's ear, health, and nervous condition, so this feature is added to recognize sounds with high levels and eliminate them before they completely affect the baby. When these are identified, a buzzer and light will be on and (audio noise detected) printed on the LCD.

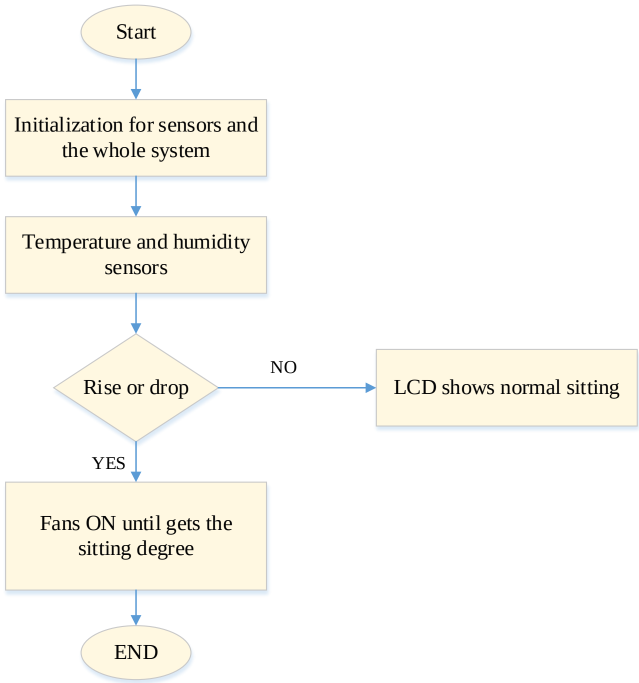

Figure 3. Temperature and humidity flowchart

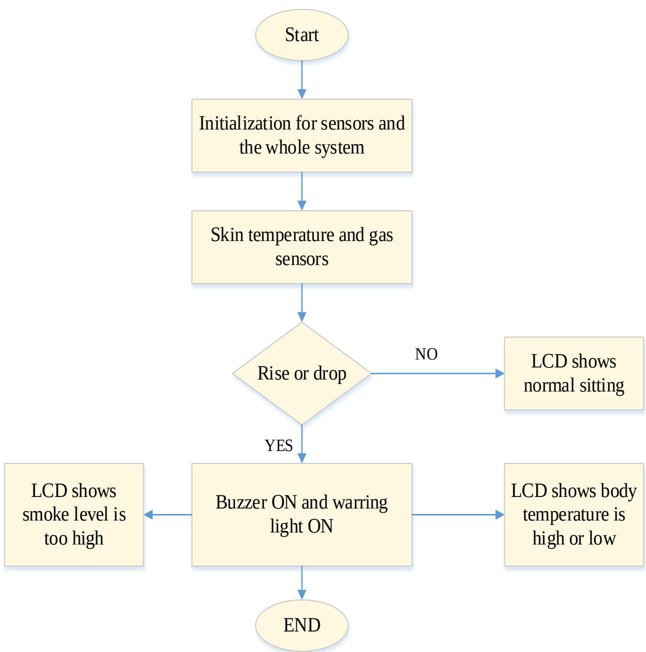

Figure 4. Skin temperature and gas flowchart

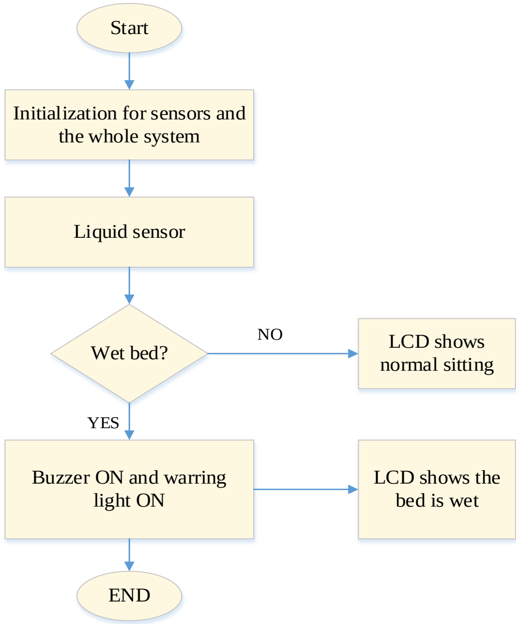

Figure 5. Liquid sensor flowchart

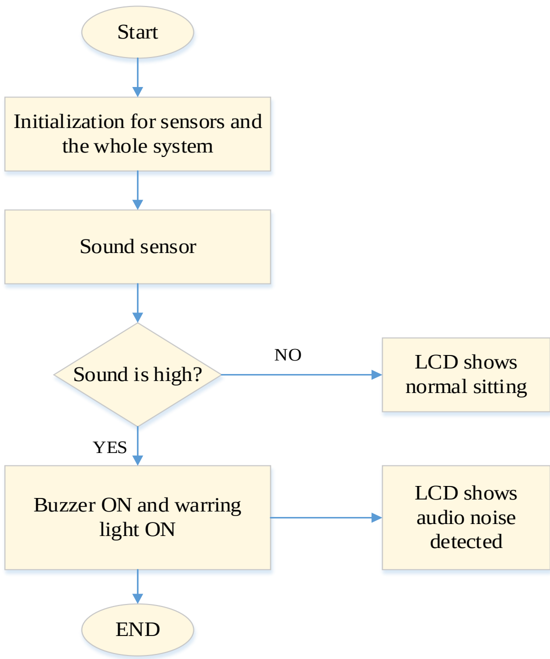

Figure 6. Sound sensor flowchart

The SII contains a treatment system for babies suffering from jaundice (erythema therapy). Through the phototherapy system, which treats patients by emitting ultraviolet rays, they have UV light on them, therefore the operating time can be controlled. Accurately extinguish them automatically, and it is also possible to control the intensity of the release of these rays from 1% to 100% to guarantee the best result and treatment. The incubator also contains a keypad, which has three letters (A, B, C, and star (*). Each letter shows a window and different options, which are composed of several interfaces; each interface displayed on the screen contains various options. These are arranged in order: (1. state of ultraviolet rays if they are ON or OFF; 2. incubator room temperature; 3. degree of humidity in the incubator room; 4. baby's body temperature). As shown in Figure 7.

Figure 7. Main LCD interface of the system

The keypad also contains a group of symbols, which are: (letter A) When pressing this key, the LCD interface will be open, which displays the results for all sensors in succession, regardless of whether this degree is normal, low, or high. The same mechanism is applied to all sensors. The first interface relates to the temperature of the incubator room, so it displays that temperature. If the temperature is higher than 37 degrees, it will be displayed that the temperature is now high. Moreover, if it is less than 25, it will be displayed low. (NORMAL) If it is normal, it will be displayed. Whereas, the second LCD interface will be a degree of humidity. The third LCD interface is the baby's temperature. The fourth LCD interface is the interface of the ratio of oxygen and gases. The fifth LCD interface is the interface of the state of the mattress, whether it is wet or dry. The last LCD interface is the status of the sound sensor, whether there are loud sounds inside the incubator or not. As shown in Figure 8.

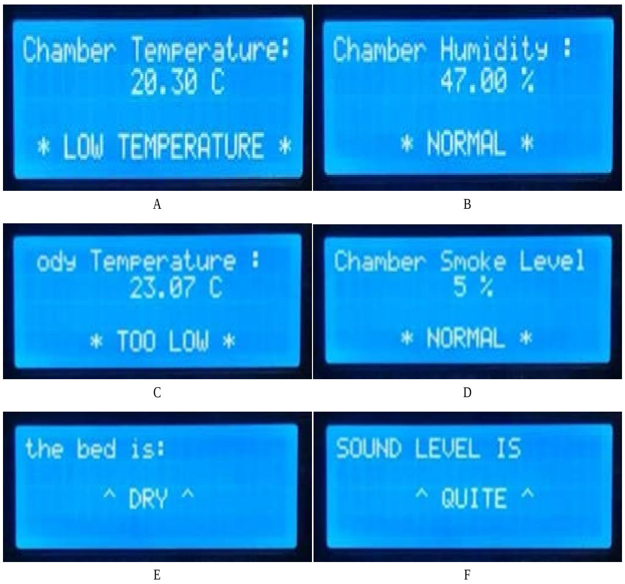

Figure 8. LCD interface with (letter A): A) chamber temperature B) chamber humidity C) body temperature D) chamber smoke level E) liquid sensor F) sound level

Letter (B) when pressing this key, its shows control the incubator's elements, which are (fans, air heater, humidifier, and lighting), will be displayed on this screen. The elements and their status, whether they are on or off, with the possibility of turning them on or off through this interface as shown in Figure 9.

However, before entering this mode, it will be transferred to the protection system. It consists of a pass ward in order to prevent tampering by any intruder who requests the pass ward. If it enters the pass ward incorrectly, it will appear that the pass ward was entered incorrectly incorrect, please try again. If it enters the incorrectly four times in a row, it will be banned from trying for 10 seconds. Upon expiration of that period, a retry will be permitted... if the code is then entered incorrectly for four consecutive times, you will wait for another 5 minutes and try again. After that, if the pass ward is enters correctly, it will open the required interface as shows in Figure 10.

Figure 9. LCD interface (with letter B)

Figure 10. The processes of entering the password

For letter C when pressing this key, therapeutic system is controlled by it. When you press the C key, it will be transfers to the secret code protection system. When entering the secret code correctly, the control interface will open, to enter the number of minutes to activate the ultraviolet rays. The last symbol (*) when pressing this key, it will be transferred to the second interface, through which it is possible to determine the percentage of ultraviolet ray projected. It can apply the ultraviolet ray on the baby accurately from (1%) to (100%) by moving the rotary element encoder counter clockwise, and clockwise. Alternatively, by pressing once, the percentage will be increased by 10% each time, or by the pressure after two consecutive clicks can be increased to 100% or by one long press will return it to 0%.When selecting the required percentage and press the (*) key, it will be transferred and desired seconds are selected. When pressing the (*) key, the ultraviolet rays will start turning on and counting as presents in Figure 11. Countdown number of minutes and seconds entered. When the time expires, an audio alarm will sound for a few seconds, alerting that the time has done. Print the sentence (the time is up) on the screen, then turn off the rays and return to the main interface.

Now we are transferred to the last screen interface as shows in Figure 12, which is similar to the main interface and contains: (1- The radiation intensity selected by the user; 2- The number of minutes and seconds remaining; 3- Incubator room temperature; 4- The baby's temperature).

Figure 11. LCD interface with symbol (*)

Figure 12. LCD interface with all indications

From the result, it is notice that the SII system has an ability to give a good environments for the babies and monitoring them with a little effort from the medical staff. So for future work can be done by adding more sensor and artificial intelligent to improve the SII system.

3. Conclusions

Due to the necessity for society to create and acquire the finest means of preserving health for individuals and children. In order to monitor numerous features of a baby's environment, such as temperature, humidity, gas level, sound level, liquid (wet bed), etc., sensors have been built into the SII system. Furthermore, as part of routine maintenance, the sensors employed in this system are inexpensive and simple to replace. The outcomes demonstrate that the system is dependable and helpful to the medical team. Since the technology is still in its prototype stage and has not yet been used on infants, it might be used on them in the future. Furthermore, the SII system can be enhanced by including additional sensors and artificial intelligence.

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