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Baby Incubator Monitoring System using Global System for Mobile Technology

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ABSTRACT

Giving birth to a child is one of the precious moments in life. Every second a life is brought into the world and not many children are lucky enough to be healthy. Monitoring the health conditions of a baby in the incubator is a critical medical issue. Many researchers are working in this area to improve the safety of newborn babies. As far as the study that we proceeded with, there exists a fundamental issue in ensuring whether the doctor has attended the emergency or not. In this paper, a system is proposed to monitor the baby inside the incubator using a global system for mobile technology (GSM). The proposed system detects 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, an 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. This system will enhance the safety of newborn babies by addressing the above-said issue, thereby reducing the risk involved in monitoring the babies inside the incubator. A prototype is developed and it was tested for functional verification.

Keywords: Incubator; GSM; temperature; heartbeat; weight; sound; baby

INTRODUCTION

Blencowe H et al. (2012) Preterm or premature babies are infants delivered before the 37th week of pregnancy. Liu L et al. (2016) According to research, about 1 million babies die every year globally. Prematurity-related illnesses are responsible for the majority of deaths. Dr. Martin Couney, a pediatrician and neonatology pioneer, is credited with inventing the modern infant incubator. The invention of the incubator sparks a wave of public and professional enthusiasm for the possibility of lowering premature infant mortality. Mathews et al. (2013) Premature birth was one of the leading causes of infant mortality in the early twentieth century; in 2013, premature birth accounted for 36 percent of all infant deaths globally. The lack of neonatal monitoring facilities in small villages and municipalities, as well as inaccurate monitoring systems, are the main reasons for this. The current technique requires a nurse or a doctor to attend to the newborns regularly, which is a time-consuming process. Our project aims to provide a low-cost, practical, patient-friendly, and dependable premature baby incubator, particularly in low-income countries. If the temperature rises above the normal range, it will alert the doctor via GSM. When the pulse, body weight, or baby's sound surpass the normal range, it will send an alert message to the doctor. Until the doctor accepts the baby's condition, the GSM will send an alert message to the doctor every two minutes. After six minutes of doctor acknowledgment, the GSM module will respond to the controller's output. When any of the above-mentioned parameters are abnormal, the LED outside the incubator illuminates.

LITERATURE REVIEW

One of the most influential, delegates, and sensitive areas in the biomedical field is preterm infant care. Because of their gestational age and birth weight, some newborns have a greater risk of sickness and death and are referred to as high-risk babies. To cope with the external environment, a preterm baby needs an environment that is identical to that of the womb. The incubator will, to some extent, serve as this atmosphere.

Kale et al. (2018) say that an infant incubator maintains a consistent temperature, relative humidity, and light level, allowing the preterm to experience conditions similar to those found in the womb. As a preterm baby demands, the air temperature, relative humidity, and light conditions must be preserved. This parameter should be measured, and in a high-risk situation, the alarm system and GSM technology can alert the parents. The primary goal of this project is to develop and implement a closed-loop control system that regulates temperature, relative humidity, and light intensity

within the neonatal incubator using LEDs to prevent jaundice. The hardware was implemented using Arduino and Pulse Width Modulation. The benefit of this project is that it is simple to implement because it has smaller components and is small in size. The downside is that it can only control temperature and humidity. There isn't any kind of notification.

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). In a smart incubator, physicians and nurses can access a child's medical data through mobile phones or computers from a location where they can access cloud storage through the internet. The smart incubator is one that constantly monitors the newborn baby and sends medical data directly to cloud storage, where it is stored. Medical information can be accessed through mobile phones and computer systems from wherever they are and from which they can take action. This approach allows for close monitoring of changes in health parameters. The precise values are shown so that doctors can easily check the baby's health and prevent health issues in the future. It has the advantage of being able to monitor and maintain a safe environment for the newborn. The downside is that it will only show the value of the LCD and take the message to the phone.

In our day-to-day lives, health is paramount. To do every day's work well, you must be in good health. Patil et al. (2018) proposed a project that aims to create a system that measures body temperature and heart rate using an LM35 precision centigrade temperature sensor and a pulse sensor. These sensors are connected to an Arduino Uno controller board. The Arduino Wi-Fi module was used to transmit data wirelessly. On IoT platforms, such as stuff talk, the SP8266 ESP-12E ESP-12 Micro Controller Board is used for wireless data transmission. Thing speak is used to visualize data. So that data records can be kept for a long time. This information is saved on a web server and can be viewed and logged. The drawback is that the information is stored on the webserver and no alert message is sent.

Care for a critically ill patient necessitates quick and correct decisions so that life-saving and life-prolonging treatment can be administered correctly. According to statistics, human life is lost every minute in the world. Human beings are affected by heart attacks, particularly in India, and this is exacerbated by the fact that patients do not receive timely and appropriate treatment. The project is built around patient tracking. We designed and operated a patient monitoring system that is both reliable and efficient. It can transmit real-time patient parameters. It allows doctors to track the patient's vital signs (temperature, heartbeat, and ECG) in real-time. The patient's parameters (temperature, heartbeat, and ECG) are continually measured and wirelessly relayed using Bluetooth. By enhancing the performance and power management of the patient monitoring system, Prema S, et al. (2013) provide excellent reliability and flexibility.

Akant et al. (2017) suggest a system that constantly monitors and collects data on the patient's health. The collected data is processed by a centralized AtMega16 microcontroller. This information is constantly relayed to the doctor through Bluetooth. The Doctor should obtain a record of a specific patient's information by simply accessing the patient's database in the established Android application on his mobile phone, which is constantly updated through the Bluetooth receiver module. The benefit is that they constantly monitor the parameters. The drawback is that it can only transmit information through Bluetooth, and it is only applicable in a line of sight and is not suitable for long-distance communication.

As there is a huge increase in the death of newborn infants, preterm birth is responsible for at least 30% of neonatal deaths, either directly or indirectly, and newborns are at risk due to low birth weight (lbw). Every year, 1.8 million infants die due to a lack of coherent heat, despite having the body fat and metabolic rate to keep warm. In such situations, it is necessary to provide a healthy environment for newborn babies that is appropriate for their body temperature. The project aims to keep those newborn infants from dying. The microcontroller-based infant incubator, which is powered by solar energy, can assist all individuals in protecting their baby's life from toxic environments. Suthagar et al. (2012) convey, when compared to other baby incubators used in super-specialty hospitals, the cost of this system is very low. As a result, everyone from the politically disadvantaged class who cannot afford the costs of hospitals will benefit from this system. The work proposed by Rutuja G., et al. (2017), is not only used for tracking and controlling temperature, but it also adds other benefits such as controlling temperature, the weight of the infants under observation, and so on. The drawback is that it can only measure two parameters, and solar is not suitable for all situations.

Microcontroller Incubator Preterm infant care is one of the most relevant, delegated, and sensitive areas in the biomedical field. To cope with the external environment, a preterm baby needs an environment that is identical to that of the womb. To create a comparable environment to that of the womb, babies must be preserved in a device known as an incubator. Suthagar et al.(2019), propose that the air temperature must be kept around 35°C. The relative humidity should adhere to preset values based on the incubation day number. The objective of this project is to design and build a closed-loop control system for regulating the temperature and humidity within a neonatal incubator. It is also used to monitor and regulate the levels of light and oxygen in the incubator. The hardware can be implemented using a microcontroller and a PID processor. The downside is that it can only monitor a baby's temperature and humidity and does not have a threshold value. Mageshkumar G et al. (2020), mentioned that Arduino is effective hardware for the development of a simple embedded system as it is easily programmable.

Hashmi et al. (2015) say, in the last decade, there has been a lot of progress in the implementation of wireless patient tracking systems. This new approach reduces power

consumption as well as the costing problem. The Zigbee modules are used for full-duplex connectivity between the hardware and software systems. According to the findings, the Zigbee module connected with the whole system as well as the monitoring software. The current research can be enhanced by using an actual ECG machine, allowing the system to be ready for real-world use. The benefit is that power consumption and costs are reduced at both the patient and doctor ends of the telemedicine system, there are hardware and software components as explained by Sebastian et al. (2012). Image processing methods were used to retrieve and analyze the captured ECG signal. The captured image is sent through the internet to a mobile phone running the Android operating system as such in Suthagar et al. (2012). A notification is sent to the doctor's phone in the event of an anomaly. Using the heart rate, the project generates an alert about the patient's condition and makes the captured image available to the physician. The drawback is that it is only appropriate for heart patients. Table 1 summarizes the sensors used, the advantages and disadvantages of the related work, and the proposed work.

TABLE 1. Summary of the existing system

Authors	Sensor used	Advantage	Disadvantage
Kale et al. (2018)	Temperature, relative humidity, and light intensity	It is simple to implement because it has smaller components and is small in size.	The downside is that it can only control temperature and humidity.
Sivanani D, et al. (2018)	Temperature, relative humidity, pulse, and light intensity	This system can monitor and maintain a safe environment for the newborn.	It will display the value on LCD and send the message to the doctor's phone.
Patil et al. (2018)	Heartbeat sensor and body temperature sensor.	Information is saved on a web server and can be viewed for later reference and logged.	Information is stored on the webserver and no alert message is sent.
Prema S, et al. (2013)	Temperature sensor, Heartbeat sensor, and ECG	This system just monitors the incubator.	Information is transferred through Bluetooth which is not suitable for long-distance communication.
Akant et al. (2017)	Temperature sensor and Heartbeat sensor	This system constantly monitors and collects data on the patient's health.	It can only transmit information through Bluetooth, and it is only applicable in a line of sight and is not suitable for long-distance communication.
Rutuja G., et al. (2017)	Temperature and weight sensor	It monitors temperature and weight and controls only the temperature.	It can only measure two parameters, and a solar power supply is used which is not suitable for all situations.
Hashmi et al. (2015)	ECG machine	It monitors ECG	Information is transferred through Zigbee which is not suitable for effective communication.
Proposed System	temperature, Humidity, Heartbeat, Weight, sound sensor, and switch.	The proposed system not only monitors the incubator but also controls the incubator physically by the doctor by sharing proper information through GPS.	Information monitored is not stored in the cloud but is logged in ROM.

METHODOLOGY

The proposed system will monitor the temperature of the incubator, heartbeat rate, weight, and sound of the baby inside the incubator. The study has been done from various pieces of literature to understand the optimal threshold limits for various sensors. An alert message is sent to the doctor as an SMS and turns ON the LED in the incubator if there is any kind of abnormalities in the parameters observed. The duty doctor should respond to the message as earlier as possible, otherwise, the system will send alert SMS to the doctor every minute. Alert SMS contains the monitored parameter values as shown in figure 5. Once the doctor has acknowledged, then the system will be reset by the doctor.

SENSORS

The temperature of the incubator is monitored using an LM35 precision centigrade temperature sensor. According to an article published by Infant Centre (2018), the threshold range of temperature to be maintained inside the incubator is 37.2°C to 37.8° C. A reflection-type pulse sensor is used to monitor the heartbeat rate of the baby. The heartbeat rate of the premature baby has been fixed from 140 to 170 which is considered to be normal for a baby born at 24 to 28 weeks of pregnancy. The weight of the premature baby inside the incubator is monitored using a load cell and HX711 weight sensor module. HX711 is a widely used industrial standard precision sensor interface module with a 24-bit analog to digital conversion, which provides the required resolution suitable for the proposed system's requirement. The discomfort of the baby inside the incubator is monitored using a sound sensor. If the baby cries due to discomfort, the sound sensor will generate a signal to the controller, which in turn alerts the doctor. A slide switch in the system is used by the doctor to let the system know that he/she has acknowledged the abnormalities. The system will change its state from monitor mode to idle mode. After treatment, the baby is kept inside the incubator. Then the doctor has to press the slide switch it back from idle mode to monitoring mode.

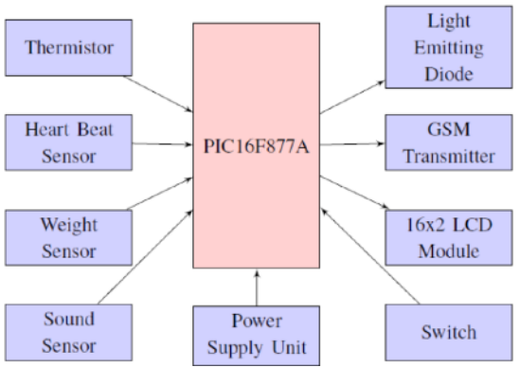

FIGURE 1. Block diagram of the transmitter section

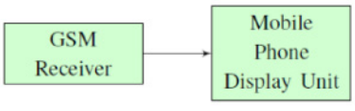

FIGURE 2. Block diagram of the receiver section

OUTPUT DEVICES

A Light Emitting Diode (LED) is used to indicate the abnormal condition of the baby. If any one of the parameters that are being monitored by the system crosses the above-specified threshold levels, the LED will be turned on and the alert message will be sent to the doctor via the GSM module. For every minute the alert message with abnormal values of the parameter is sent continuously to the doctor. Once the doctor acknowledges using the slide switch, the LED will be turned off and the system will stop sending the alert message to the doctor. The significance of sending the alert every minute will be helpful for the doctor to understand the health condition of the baby.

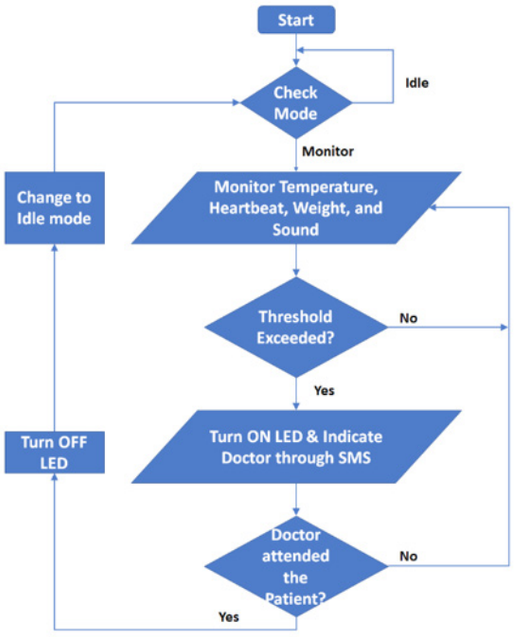

FIGURE 3. Workflow of the proposed system

The flowchart of the proposed system is shown in Figure 3. This flowchart, clearly explains the process followed in GSM based baby incubator monitoring system. The corresponding algorithm is given below.

Step 1: Switch on the device.

Step 2: Check the mode of operation (Monitoring/Idle)

Step 3: If the system is in idle mode (When the incubator lid is open), it does need not read sensor values or send an alert message.

Step 4: If the system is in monitoring mode (When the incubator lid is closed), the device monitors the temperature, Heartbeat, Weight, and sound of the baby inside the incubator.

Step 5: If these parameters (temperature-37oC, Heartbeat-150 beats per Minute, Sound-36 dB, Sudden increase in weight(Weight measured before placing the baby in incubator)) exceeds the threshold value, Sudden intimation will be sent to the doctor through GSM.

Step 6: At the same time LED will glow to indicate the emergency condition.

Step 7: The GSM will send the alert message to the doctor every two minutes until the doctor acknowledges the baby's condition.

Step 8: GSM module will respond to the output from the controller after six minutes of doctor acknowledgment.

Step 9: Display the value in the LCD.

Step 10: Stop the device.

RESULTS AND DISCUSSION

The block diagram of the transmitter section of the proposedsystem is shown in Figure 1. The transmitter section continuously monitors the parameters like temperature, weight, heartbeat, and sound of the baby inside the incubator and displays the value in the LCD. If anyone of the abovesaid parameter values goes abnormal then values of the corresponding parameter were sent to the doctor through GSM at regular intervals. During abnormal conditions LED placed outside the incubator will glow until it becomes normal or the doctor changes the mode of operation. The mode of operation is decided by the doctor with the help of a slide switch.

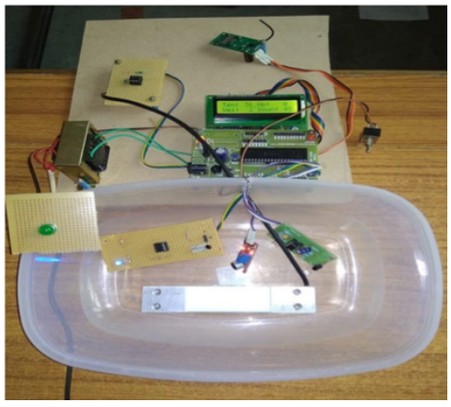

FIGURE 4. Prototype of the hardware design

The doctor receives the alert message as shown in Figure 5. It shows the abnormal condition inside the incubator; where, the message contains the values of all the parameters during abnormal conditions like temperature, Weight, Sound, and Heartbeat. The transmitter module sends the alert message to the doctor every minute until the doctor acknowledges the baby's condition. Here acknowledgment means, the doctor has to pay a visit to the incubator and physically change the position of the slide switch. Once the doctor has acknowledged, the system will know that the doctor has arrived for diagnosis, hence there is no need to send the SMS. The SMS received every minute can be vital for diagnosis purposes and can help understand the criticality of the situation.

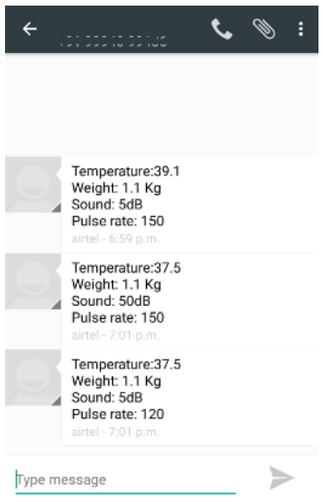

FIGURE 5. The output of the system

The prototype hardware implementation of the proposed system is given in Figure 4. In Figure 5, the first alert message is received as the temperature inside the incubator is above the threshold limit. It indicates that care must be taken to protect the life of the baby in the incubator immediately. Notice the second SMS received by the doctor, where the sound parameter is varied.

CONCLUSION

The GSM-based Baby Incubator Monitoring System was created primarily for the medical conditions found in rural areas. A caretaker in a small health care facility should efficiently use this equipment. It has the potential to save the lives of low-birth-weight infants and premature babies. The constructed system is simple to incorporate with existing incubation chambers. The continuous capture of several biological parameters of the baby and analysis of overall health aids the doctor in understanding the baby's medical conditions. In the event of an emergency, the doctor can recognize the baby's condition and treat it accordingly.

In the future, the ECG monitoring system must be designed with a proper oxy controlling system, and also, the parameters can be stored in cloud storage. So, it will be useful for further treatment of the baby in case of any nutritional malfunctioning. The stored data can be acquired during further treatment of the baby. This data provides a sufficient history of the diseases in the baby and medicates it accordingly. Internet of Things (IoT) can be used to record the data in a database. Artificial Intelligence (AI) enabled system can be implemented to analyze the data stored in the database to assist the doctors in diagnosis purposes. If this system is implemented in all the incubators around the world, the death of premature babies and babies born with abnormal weight or other health conditions can be saved.

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DECLARATION OF COMPETING INTEREST

None

REFERENCES

Akant, P., Sengar, G., Zade, G., Ganvir, R. and Bharkade, N., 2017. Design and development of patient monitoring system using Android application, 226 (1) pp. 012094. IOP Publishing.

Blencowe, H., Cousens, S., Oestergaard, M. Z., Chou, D., Moller, A. B., Narwal, R., Adler, A., Vera Garcia, C., Rohde, S., Say, L. & Lawn, J. E. 2012 .National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: a systematic analysis and implications. *Lancet* 379(9832): 2162-72.

Hashim, N.M.Z. and Sizali, M.S. 2013. Wireless patient monitoring system. *International Journal of Science and Research (IJSR)* 2(8): 250-255.

Hitu Bansal, D., Mathew, L. and Gupta, A. 2015. Controlling of temperature and humidity for an infant incubator using microcontroller. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering* 4(6): 4975-4982.

Infant Centre. 2018. What Preterm Babies Look Like,https://www.infantcentre.ie/research/research-studies/what-to-expect-in-the-icu/premature-babies/what-preterm-babies-look-like

Kale, A.W., Raghuvanshi, A.H., Narule, P.S., Gawatre, P.S. and Surwade, S.B., 2018. Arduino based baby incubator using GSM technology. *Int. Res. J. Eng. Technol*. 5(4): 462-465.

Liu, L., Oza, S., Hogan, D., Chu, Y., Perin, J,. Zhu, J., Lawn, J. E., Cousens, S., Mathers, C. & Black, R. E. 2016. Global, regional, and national causes of under-5 mortality in 2000-15: an updated systematic analysis with implications for the Sustainable Development Goals. *Lancet* 388(10063): 3027-3035.

Mageshkumar, G., Kasthuri, N., Tamilselvan, K., Suthagar, S., and Sharmila, A. 2020. Design of industrial data monitoring device using IoT Through MODBUS Protocol. *Int. J. Sci. Technol. Res*. 9: 1392-1396.

Mathews, T. J., MacDorman, M. F. and Thoma, M. E. 2015. Infant mortality statistics from the 2013 period linked birth/infant death data set.

Meeravali, S., and Suthagar, S. 2012. Automatic SolarTracker robot. *International Journal of Engineering Research & Technology* 1(6): 2278-81.

Patil, S. and Pardeshi, S. 2018. Health monitoring system using IoT. *Int. Res. J. Eng. Technol.(IRJET)* 5(04).

Rutuja G. Shelke, Dipali S. Sarode, Shital K. Mathpati, 2017. IntelligentBaby incubator using solar. *International Journal for Research in Applied Science & Engineering Technology (IJRASET)* 5(06): 2224-2227.

S.Suthagar, T.Jesammal, J.Alphiya Grace. 2017. Aadhar based electronicvoting system and providing authentication on internet of things. The Third International Conference on Electrical, Electronics and Computer Engineering (ICEECE - 2017).

Sebastian, S., Jacob, N.R., Manmadhan, Y., Anand, V.R. and Jayashree, M.J., 2012. Remote patient monitoring system. *International Journal of Distributed and Parallel Systems* 3(5): 99.

Sivamani, D., Sagayaraj, R., Ganesh, R.J. and Ali, A.N. 2018. Smart incubator using internet of things. *International Journal for Modern Trends in Science and Technology* 4(09): 23-27.

Sundaram, P. 2013. Patient monitoring system using android technology. *International Journal of Computer Science and Mobile Computing* 2(5): 191-201.

Suthagar, S., Tamilselvan, K.S., Mageshkumar, G. and Muthupandian, S. 2019. *Automated Milk Quantity and Quality Checking and Vending Machine.*