



# Smart Neonatal Supine Monitoring System with Vital Signs and Thermal Regulation

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**Abstract.** The Smart infant-care system that continuously monitors critical health and safety indicators and is equipped to provide alerts and improved care. The intention of the system is to monitor an infant's heart rate, body temperature, blood oxygen saturation, IV fluid status, and presence using a network of biomedical and environmental sensing modules with audible alerts through a buzzer and notifications sent to caregivers via a Blynk application and an automated messaging bot. The procedure consists of collecting real-time data from multiple sensors, analyzing data with unified control capabilities, and evaluating against thresholds to distinguish when deviations from normal, or adverse conditions exist. The system is powered by a regulated power source and the system was assembled in a lightweight enclosure designed for infant use. The information obtained from the sensors are displayed on a cloud-based dashboard, and when parameters deviate from a predefined range, audible warnings and remote alerts are generated simultaneously. Experimental data support that all targeted parameters are monitored accurately, abnormal conditions are detected and alerts were triggered, while reducing the need for monitoring by care providers. The study presents evidence that the smart infant-care system is a viable option which enhances safety, is low-cost, and scalable.

**Keywords:** Smart Infant Care Device, Vital Signs Monitoring, ESP32-CAM, MAX30100 Sensor, LM35 Sensor, Real time alerts.

## 1 Introduction

The "Smart Infant Care Device for Monitoring Vital Signs, IV Fluid Level, and Temperature Regulation" project intends to support continuous real-time monitoring and alerting to allow for better health and safety of infants in neonatal care facilities using automated real-time sensing and control to mitigate human error [1]. The Smart Infant Care Device used several sensors and automated control. A ESP32-CAM module was used to observe the infant's movements and positional data. The infant's heart rate and oxygen saturation (SpO<sub>2</sub>) data were gathered using a MAX30100 sensor and a LM35 sensor collected body temperature [2]. A load cell with HX711 converter

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S. P. Vijayaragavan et al. (eds.), *Proceedings of the Global Conference on Sustainable Energy Systems, Smart Electronics and Intelligent Computing (GCSESEIC 2025)*, Advances in Engineering Research 297,  
[https://doi.org/10.2991/978-94-6239-654-8\\_66](https://doi.org/10.2991/978-94-6239-654-8_66)

was utilized in conjunction with the other sensors to provide accurate readings of the IV fluid levels to avoid over- and under-infusion [3]. All sensor data was processed using algorithms developed in Python. If any of the abnormal conditioning variables were identified (i.e. increased temperature, irregular heart rate, reduced IV fluid) an alert was sent to the nurse's mobile device using the mobile application called Blynk and movements and positional data of infants are sent through an automated messaging bot Fig.1.



Fig. 1. smart infant care device

## 2 Literature Survey

EllaDwiAndriani (2025), presents an infant monitoring system that applies 10T technology to monitor heart rate (BPM), blood oxygen saturation (SpO<sub>2</sub>), skin temperature, and respiratory rates on Infants. The article is concerned with monitoring high-risk premature infants continuously due to their immature organ maturity. M. Subramanian et al. (2018) presented a simple monitoring framework for an incubator using infrared(light) sensors, arduino technologies/devices. Sukamto (2020) presented a weight and temperature infant monitoring system incubator designed to use 10T technology to monitor. Hanifa Septa Gisella (2021) presented a design for a wireless BPM and temperature measuring system, with no application of SpO<sub>2</sub> measuring [4]. Mirza Fissabila (2020) presented a design and testing application of IC technologies and the HC - 05 wireless system which was able to test SpO<sub>2</sub> level measurement wireless using a MAX30100 & HC-05 technology / devices, with no infant related measurement (BPM, temperature, respiratory rates and SpO<sub>2</sub>) presented in their study [5]. Finally, Andriani et al. (2025) designed an inexpensive mini device that employs the ESP32 microcontroller using neonatal fingertip sensors, a Nextion TFT, and smartphone application as two components, with the addition of a Wi-Fi (or network device) to send an e-mail (alert) based upon predetermined thresholds.

Venu P S (2025) describe a compact, IoT-based infant monitoring system that combines an ESP32 microcontroller, temperature (DHTI 1), sound (LM393 mic), camera (ESP32CAM), servo-controlled cradle, and LCD screen, to allow parents to monitor their infants locally and via the internet; the authors' literature review places this effort in the context of previous exploration of Raspberry Pi— and Arduino-based baby

monitors, smart cradles, and health monitors, and stresses the functionality of the ESP32 as a dual-core processing platform that supports Wi-Fi and is capable of sending alerts and can-ying out automatic soothing actions (i.e., rocking the cradle to varying extents); safe monitoring was reinforced by the inclusion of previous proposals (Raspberry Pi based camera systems, visual lot cradles, and caretakers tracking pulse/SpO<sub>2</sub>) and positioned as a pragmatic and more accessible and less expensive approach to explore environmental sensing, detecting crying detection, and actuation; the practical nature of this paper also highlights limitations reported in prior works (false alarm rate due to sound sensor simplicity, limited reliability of the temperature sensor, and limited rocking patterns) while offering suggestions for improvements particularly sound filtering, ML and more advanced means of action in support of a more tailored soothing pattern; overall this work adds a practical prototype and implementation design parameters (hardware choices, data processing flow, and communication interfacing with their integration with the Blynk dashboard tool) that provide some solutions to move infant care systems from just video/audio monitoring to more autonomous systems, though the authors point out a need for assessment in general [6].

Alex Grafton et al. (2022) supply a comprehensive survey of the literature on the problem of infant pose estimation in clinical settings in their paper titled "Neonatal pose estimation in the unaltered clinical environment with fusion of RGB, depth and IR images" (Grafton A., Warnecke J. M., Li M., He E., Thomson L., Beardsall K., ... Lasenby J., 2025)

They acknowledge that while pose estimation has been relatively well established for older infants and adult populations in two-dimensional and three-dimensional settings (e.g. MPII and COCO datasets, as well as models such as HRNet, ViTPose, and Swin) the neonatal population presents unique challenges: infants in the neonatal intensive care unit (NICU) are often partially obscured by coverings (e.g. blankets), lying in a supine or side-lying position, occluded by other clinical equipment or obstruction due to changing light and bedding conditions, while most other infant or neonatal datasets will assume uncovered limbs, plain backgrounds, and controlled visual environments [8]. To investigate this, the authors discuss prior works or datasets such as the BabyPose dataset (neonates lying in incubators but not with coverings), as well as depth-based estimation approaches (e.g., Moccia et al.) who typically found median root mean square limb joint position error around 9-10 pixels but did not have accounting for the full clinical visuoenvironment complexity. They conclude that the field has made significant progress in pose estimation with older populations [7].

Mauricio Villarroel (2019) undertook an extensive research project to non-contact monitor the physiological status of preterm infants in the Neonatal Intensive Care Unit (NICU). One challenge that many health care professionals face is the use of traditional

monitoring systems using sensors that can irritate or lead to infection - detection can be complicated by the fragile skin of preterm infants [9]. To solve this challenge, the authors proposed a video-based monitoring system that employed a multi-task deep learning algorithm to monitor the preterm infant's vital signs. This system could detect the presence of the infant, segment skin areas, and estimate heart rate and respiratory rate without any contact with the patient. Data was collected on 30 preterm infants over a video recorded time of 426.6 hours. Overall, the system produced a mean absolute error from the actual readings of 2.3 beats/min for heart rate and 3.5 breaths/min for respiratory rate [11]. Overall, monitoring could be performed with good accuracy, even with environmental changes such as lighting. The authors proposed that the video-based monitoring system was effective for long-term monitoring, and that the data could distinguish between valid and poor quality data by implementing a signal quality assessment algorithm[10]. The authors concluded that video based monitoring could benefit neonatal intensive care nurses as continuous physiological monitoring of infants could be performed accurately, alongside the every-day clinical care required of neonatal intensive care, while also being non-invasive to the infant. These findings provide future avenues of real-time, contactless physiological monitoring in a NICU context.

Yang (2024) developed several AI predictive models and treatment protocols in order to prevent a clinical alarm associated with late-onset sepsis (LOS) in premature Infants; this approach would also allow the nursing staff to monitor risks through non-invasive vital signs as supplemental monitoring in the clinical setting. The study took place in Máxima Medical Center, Netherlands, where 492 preterm infants or those born less than 32 weeks gestation were enrolled. The aim of the study was to develop risk of developing LOS hour by hour. The predictor models (AI) they created or developed for prediction of LOS utilized heart rate (HR), respiratory rate (RR) and oxygen saturation (SpO<sub>2</sub>) based on non-invasive vital signs monitoring recorded every second (1 Hz) [12]. The final predictive model demonstrated the best performance, XGB (extreme gradient boosting), which indicated a .875 area under the ROC curve, and provided predictive benefit up to 6 hours prior to the clinical detection of LOS with greater predictive accuracy than traditional models. In conjunction with the predictive models that alert the team of an increased LOS risk, the study evaluated simulated predictions and alarm management strategies, inclusive of multi-threshold management, to enhance the detection sensitivity and reduce resultant unnecessary alarms. In addition, the interpretable as SHAP (SHapley Additive exPlanations) values of the AI model revealed clinical insight into physiological characteristics associated with LOS risk, including decreased variance of HR and increased HR and SpO<sub>2</sub> correlation. In summary the authors provide a detailed overview of all the AI models developed and their clinical significance.

J. Randall Moorman (2022) predictive analytics has developed and been put into practice in the neonatal intensive care unit (NICU). The emerging literature describes both recent - but increasingly more common - plan to identify early warning signs of sepsis through continuous cardiorespiratory monitoring in the area of innovation. Moorman and the University of Virginia researchers have shown that real-time AI and machine learning monitoring of heart rate characteristics can substantially decrease neonatal mortality. In reviewing the growing literature, the Moorman team identified abnormal heart rate variability and transient decelerations in foetal heart rate as early warning signs for neonatal sepsis, potentially allowing medical teams to intervene before a baby has clinically deteriorated . The predictive analytics monitoring plan was developed with physiologic signal analysis that drew on state-of-the-art statistics, recognizing that models based solely on data obtained from EHRs cannot replicate the insights that may normally be derived from high-resolution data acquired from clinicians. Moorman indicated predictive analytics monitoring could be completed in many hospital systems as a means to anticipate catastrophic illness and stressed that the predictive analytics monitoring plan should have relevant clinical context.

### **3 Proposed Method**

The proposed procedure has been created as a smart infant care system that will automatically monitor an infant's vital signs, IV fluid level, and body temperature using multiple sensors [1]. The ESP32-CAM will monitor position and movement of the infant while the MAX30100 sensor monitors heart rate and SpO2 levels of the infant. Body temperature will be monitored with the LM35 temperature sensor, while a weight sensor (load cell) monitoring with an HX711 microcontroller will monitor the IV fluid level. The data from the sensors will be processed with Python algorithms so abnormalities can be detected by either the three use cases, for example a high fever, low oxygen level, or low fluid level [7]. Upon detection of an abnormality, the system will sound a buzzer and LED light for localized alerts and simultaneous notifications will be sent to the nurse's mobile device in real-time, using the Blynk application, to allow for remote monitoring. The Blynk application will allow monitoring of the parameters of interest on mobile devices and lets nurses react to alarms that are received from the Blynk application to allow for real-time intervention if needed[12]. Additionally, Blynk will integrate with automatic temperature control using a heater or fan for the infant to stay at a safe, comfortable temperature Fig.2.

### Block Diagram

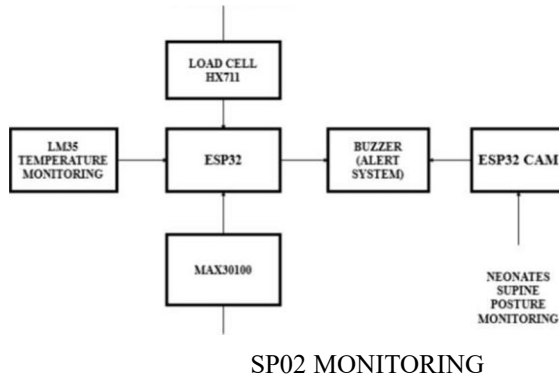


Fig. 2. Block Diagram of Proposed Method

## 4 Hardware Implementation

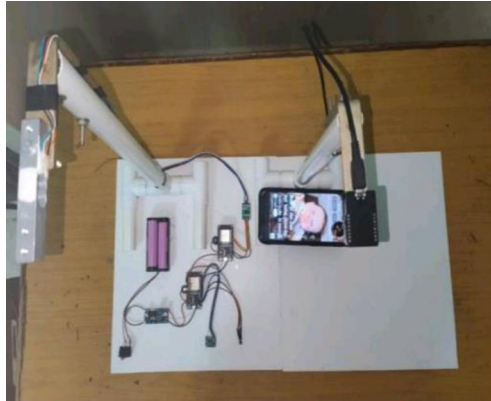
The primary processing unit of the system is an ESP32 (30pin) microcontroller with a powerful 32-bit processing core and integrated Wi-Fi and Bluetooth capabilities for IoT applications. The ESP32 allows for real-time monitoring of their sensor data and can send it wirelessly to the Blynk mobile application. The MAX30100, LM35, and HX711 sensors can communicate with the ESP32, and there are also multiple GPIOs available to allow multiple sensors to be wired for simultaneous input to the ESP32. The ESP32 /microcontroller's power rating is low enough to permit the monitoring process to be powered continuously using batteries. The HX711 module is a 24-bit ADC (analog to digital converter) designed for weight measurement to provide a stable digital output from a load cell small analog signal while minimizing noise and drift during conversion, making it suitable for monitoring IV fluid levels.

The ESP32 with a camera module (ESP32-CAM) is an ESP32 combined with an OV2640 camera that can wirelessly send images, uses microSD storage, has built-in flash LEDs for lighting, and additional GPIO pins for other add-ons with built-in voltage regulator for 5 V power supply, the LM35 temperature sensor provides a very accurate analog temperature reading based on a 10 mV/°C scale, which can be used to measure infant body temperature and ambient temperature indicating if the infant may be facing hyperthermia or hypothermia. The MAX30100 sensor measures heart rate and pulse rate. It has the ability to measure both of these vital signs in a single sensor connected to the ESP32, while the temperature and HX711 sensors would have had to be considered and contacted separately; however, they could be added at later dates. The information obtained from the sensor is displayed on the cloud based

dash board and when parameters deviate from predefined ranges, audible ranges through an integrated buzzer.

## 5 Working

The smart infant-care system operates with the help of a coalescing framework that is designed to continuously surveil an infants vital functions and the safety characteristics of the Immediate environment. Biomedical sensors are used to measure heart rate, body temperature and blood oxygen saturation levels, while sensing modules are used to monitor IV fluid levels and the presence of the infant. These sensors are interfaced to a microcontroller that allows for continuous data acquisition and preprocessing, including noise filtering and signal conditioning. The preprocessed signals are then evaluated against clinically established threshold values using embedded decision-making algorithms, under the assumption that this approach could demonstrate support for clinically recommended care. Once the value of any parameter is outside the previously defined safe range, the system will trigger a dual-alert system: an alert via a buzzer to notify individuals in the Immediate space, and alerts that will be sent to caregivers through the Blynk mobile application and a automatic messenger bot. Additionally, at the same time, all readings from sensors are sent to a cloudbased dashboard, enabling real time remote monitoring, or the opportunity to log data for long-term monitoring of trends in infant care. The system is powered by a regulated supply so that steady performance can be ensured, and is housed within an infant-friendly, lightweight, child-safe enclosure. During operation, the microcontroller continuously polls sensors, implements control logic, and communicates with hardware and cloud services. During experimental testing, the system was verified to accurately measure all physiological and environmental variables, detect discrepancies in performance in a timely manner, and alert caregivers without fail, thereby reducing the parent or caregiver burden of hours of continuous watching, and assisting in quick response time during emergencies. The overall design shows the smart-infant care system to be a practical, low-cost, scalable approach to providing enhanced safety for infants Fig.3.



**Fig. 3.** Smart Infant Monitoring System

## 6 Result And Discussion

The smart infant care system was successfully designed and evaluated for continuous monitoring of vital signs, IV fluid levels, and body temperature. In the course of testing, the MAX30100 sensor provided accurate reading of heart rate and SpO<sub>2</sub>, matching with reference pulse oximeters within acceptable ranges. The SpO<sub>2</sub> value measured was 93%, which is below normal (95—100%) and suggests low oxygen saturation; ongoing monitoring is required. Any discrepancy in readings was solely due to motion artifacts.

The LM35 temperature sensor recorded reliable temperatures for both body and environment. The body temperature was 38.2<sup>0</sup> C, which is outside of the normal range of 36.5—37.5 <sup>0</sup>C and shows the infant is presenting with high fever. The load cell with the HX711 amplifier accurately measured IV fluid levels. The IV fluid level indicated 18% of total volume, which is less than the acceptable level (>10%), and shows the IV fluid is low and needs replenishing and was able to send an alert as the fluid level dipped below preset thresholds through an integrated buzzer. The ESP32-CAM was able to monitor infant movements and postures. The camera-based presence detection module accurately identified the infant's face in the video, assuring normal presence. The readings indicate that the system adds accurate interpretation of normal and abnormal conditions and provides an appropriate health-status assessment. For example, it was possible to detect prolonged prone postures, which would be unsafe. The Blynk application was used to send notification to an application on mobile device. Realtime notifications to mobile devices were installed with both the Blynk application and alarm systems that sent real-time notifications. The Blynk application also enabled the healthcare team to monitor the infant in real-time and respond quickly with direct notification of abnormal parameters. There were both local notifications with a buzzer alarm and an LED light that indicated the health of the infant Table 1.

The continuous operation of the system was supported using the LM7805 voltage regulator in conjunction with a lithiumion battery which allowed prolonged operations.. The ESP32 Wi-Fi access point ensured reliable communication between the real-time cloud-based monitoring interface and the smart infant-care system itself, which was shown, without doubt, to be convenient during real-time cloud monitoring. Users were able to monitor vital indicators as an efficient summation at 30-minute intervals on the monitoring interface, and parental anxieties about long-term efficacy were alleviated after witnessing the system operate through real-time monitoring over extended consistent intervals. For an Infant, the collection of data on a variety of organ systems initiated is extensive and cumulative and will support future and collaborative use of a remote village preparation user interface of the remote monitoring infant-care system once thoroughly understood.

Further assessments of usability and efficacy were needed once the smart infant-care system proved useful by following the chronicle and further alarming of monitoring over multiple days in a progressing environment. Future studies could further assess transparency, facilitate usability inquiries, and shared pivotal chronology with each document. While conducting those control testing ofthe prototype for an infant-care system of parent interface, parents consistently logged back to the cloud-based interface after receiving alarming notifications to check for inaccuracy which initiated a trust that is suggestive of long term theoretical trust Table 1.

**Table 1.** Tabulation of Sensor Readings and Health Status of Infant.

<b>Parameters</b>	<b>Normal Range</b>	<b>Measured Output</b>	<b>Status</b>
Heart Rate	120-160 BPM	142 BPM	Normal
Body Temperature	36.537.50C	38.2 <sup>0</sup> c	High Fever
spO <sub>2</sub>	95-100%	93%	Slightly low monitor closel
IV Fluid Level	of Total volume	18%	Low-Refill Needed
Face Detection	Face Detected	Present	Normal

	camera feed		
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**Table 2.** Comparison of Our Innovative System with

Reference Pa er	Sensor Type	Accuracy	Sensitivity	Overcome
Daba Nemomssa2022	Oximeter, Temperature sensor: IOT Enabled	1-- 1R±2W T ±0.5 <sup>0</sup>	Abnormal vitals	Delay in NICU Response
Yang He2025	Dual Pole Capacitive	1 mm res.: 1.99% lim 0.53%	High	Rigid Sensor Error
Giulia Palladino2025	Fibre Optic mattress	Tested 20 infants	Motion & Posture	Intrusive Tracking
Current Paper	ESP32CAM: NLAX30100: LM35:	IV±2ml	Vitals, IV: Temp, Face Detection	Muluparameter Safety System

In conclusion, prior research conducted single-parameter monitoring such as vital signs monitoring, fluids, and motion monitoring that all had limitations such as latency, rigid sensor, or intrusive setup Table 2. In the current project, 10T and Python-based processing will be combined to develop multi-sensor (HR, SpO2, temperature, IV fluid, and motion) monitoring for real-time, accurate, and safer monitoring of infants in clinical environments.

## 7 Conclusion

The smart infant care system represents an effective and reliable method of continuous monitoring of infants in neonatal care units. The system is equipped with multiple sensors: MAX30100 - heart rate and SpO2, LM35 - body temperature, load cell with HX711 - IV fluid level, and ESP32-CAM - movement and posture. Each of these sensors track important physiological and environmental readings, in real time. All readings from the previously defined sensors were processed using Python algorithms

to filter noise in the signals, detect abnormal readings and compare sensor readings to defined thresholds. The system issues an alarm (buzzers and/or indication LED) based on the abnormal readings of heart rate or SpO<sub>2</sub> being below normal or defined thresholds (i.e., fever, running out of IV fluids, or being in an unsafe position), as well as being reported to the nurses' mobile device using the Blynk application. The system also has automatic temperature control in the smart infant care cargo to provide a stable environment for the infant, while keeping him/her comfortable. The system was designed to be small and portable on battery power, to allow easy movement while maintaining the process of monitoring using the sensors without any compromise; this project minimized the need for human involvement, while simultaneously provided safety.

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