
DEVELOPMENT OF SMART TEXTILE FOR INFANT HEALTH MONITORING BY INTEGRATING IoT AND MACHINE LEARNING**MOUNIKA C₁, CIRATHEEP P₂, DHARSHINI C₃, MUHAMMED ZAID₄, SHANMATHI P₅**

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Abstract

Smart fabrics are proving to be an exciting device in pediatric care by facilitating continuous, non-invasive physiological monitoring of infants. This paper is concerned with the fabrication of a cotton-based smart fabric wristband interfaced with digital temperature and PPG-based heart rate/SpO₂ sensors to establish practical, real-time monitoring. The selected cotton substrate provides softness, breathability, and biocompatibility for sensitive infant skin, while conductive embroidery with silver-coated yarn provides a robust electronic pathway without affecting fabric comfort or wear. A low-power microcontroller with Wi-Fi communication was utilized for data sampling and wireless uploading to a dedicated mobile app, which allows real-time visualization, threshold-based alarms, historical data analysis, and secure cloud storage. The integration of textile and sensor was tested using fabric elasticity, wash durability, skin compatibility, and pressure distribution tests to ensure its feasibility for extended use in infants. Sensor performance was compared against clinical reference devices to ensure measurement accuracy and consistency. In addition to real-time observation, the system also utilizes machine learning algorithms, such as logistic regression, random forest, long short-term memory (LSTM) neural networks, and anomaly detection algorithms, to facilitate predictive healthcare through the detection of early physiological shifts and emergent health threats. The research identifies the potential use of integrating smart biomedical fabrics with IoT-capable data transfer and predictive analytics for reversing infant health monitoring from passive measurement to active care.

Keywords: *Biomedical textiles, conductive embroidery, infant monitoring, temperature sensors, wearable electronics.*

1. INTRODUCTION

Physiological monitoring in infants is highly sensitive, with most of their parameters like temperature and heart rate fluctuating; detection of any abnormalities in health is delayed, and hence it leads to complications. This limitation can be overcome by the application of smart textiles. Smart textiles thus allow for continuous and real-time health tracking. This research is concerned with integrating a textile substrate with a sensor to monitor the body temperature of an infant. Cotton is the textile substrate selected for its superior quality of breathability and softness, and biocompatibility of delicate skin of infants. The smart wristband is embedded with a temperature sensor (DS18B20) and PPG-based heart rate and SpO₂ sensors. An ESP8266 microcontroller enables wireless data transmission to a mobile application. This sensor and the textile substrate are integrated through a conductive embroidery without compromising textile comfort.

2. MATERIALS AND METHODS

Fabric Selection

100% cotton fabric with a tight weave is the most suitable for this study, hence fulfilling the WHO recommendations for infant textiles. The taken cotton fabric is reinforced with a moderate elasticity that ensures stable skin contact. This selected fabric is good in its tensile strength, wash durability, softness, and breathability—all those properties so essential for wearer's comfort and sensor integration.

Sensor and Electronic Integration:

The wristband design is integrated with DS18B20 digital temperature sensor and ESP8266 microcontroller PCB. The digital temperature sensor will be inlaid inside the inner area of the wrist and the silver-coated embroidered yarn will work as a conducting path to the sensor and the microcontroller.

Communication Unit and Mobile Application:

In the presented system, an ESP8266 microcontroller undertakes the functions of data acquisition, processing, and transmission via Wi-Fi. Similarly, noise reduction is performed through a Kalman filter. Further, a deep sleep function is employed to increase battery life. A Flutter-based mobile app for Android and iOS endpoints has been designed that can provide real-time temperature display, historical trend graphs, threshold-based alerts, and secure cloud storage through ThingSpeak. Push notifications have been implemented for prompt alerting to caregivers.

The Smart Textile Architecture

- Sensor Layer: This layer includes embedded temperature and heart rate sensors, which are interconnected by using silver-coated conductive threads.
- Process Layer: Collect, filter (Kalman Filter), and prepare data packets using the ESP8266 MCU.
- Communication Layer: Sending data over Wi-Fi to a cloud server—ThingSpeak.
- Application Layer: The mobile application in Flutter allows for real-time display, historical analysis, and sending warning notifications.

Machine Learning for Predictive Analysis

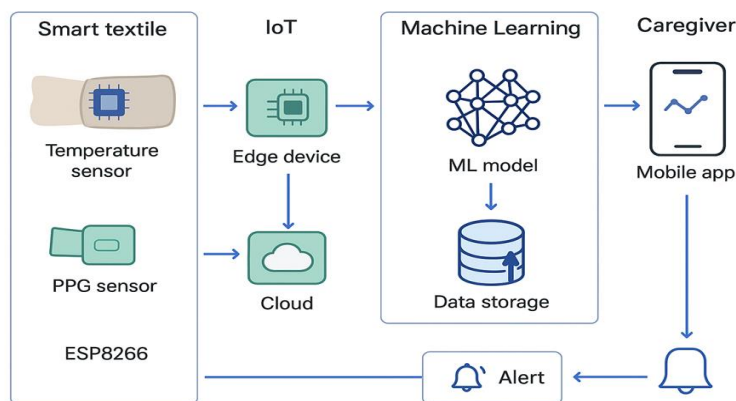


Fig. 1: Smart healthcare monitoring system

The current system allows for real-time monitoring, but implementing ML capabilities can make it truly predictive in health assessment. These variations are assisted by IoT and machine learning technologies, which help the caregiver in case of any fluctuation. Each technology has the following role:

IoT: Collected data by sensors is transmitted to an Edge Device—a local processor near the patient—for preliminary processing. Data is also sent to the Cloud for storage and further analysis.

Machine Learning

Sensor data is processed through the cloud by an ML model. It categorizes, processes, and identifies patterns or other abnormalities that can define health issues. Processing data is stored for future reference in Data Storage.

Working Model of Predictive Health Assessment Tool:

- 1. Data Collection:** Continuous streaming of temperature, heart rate, and SpO₂ readings from the smart band.
- 2. Preprocessing:** Noise removal via Kalman filter, normalization, and treatment of missing values.
- 3. Feature Engineering:**
 - Rolling averages and variances over time.
 - Temperature change rate (°C/min).
 - Heart rate variability metrics.
 - Day–night physiological patterns.

Predictive Models

- **Logistic Regression:** Classifies whether an infant's vitals indicate potential fever or hypothermia.
- **Random Forest Classifier:** This model detects anomalies by analyzing combined vital sign trends.
- **LSTM Neural Networks:** Predicts future temperature or heart rate values based on time-series data.
- **Isolation Forest:** Flags outlier patterns that could point to sensor displacement or sudden health changes.

3. TESTING

Textile and its Mechanical Properties

Any textile substrate testing is to ensure the effect of incorporated technology. Testing for the durability of conductive thread and its electrical performance was done after multiple washes following the ISO 6330 standard. The resistances were measured after every wash. Wicking test was also performed, and ensured uniform moisture spread without affecting the conductive paths. Evaluation of comfort of the fabric plays a vital role in infant wear. Biocompatibility should be ensured on variation in temperature and pressure. In addition to this, skin temperature stability and stretch recovery should be tested.

Testing on Smart Textile Equipment

Wireless communication either through Wi-Fi or BLE protocols enables real-time monitoring of parameters. Data is continuously transmitted over a cloud platform, namely ThingSpeak, through HTTP

for remote monitoring using the mobile application developed. Real-time readings are displayed on this app, and it sends push notifications in abnormal values and stores historical data for trend analysis.

4. RESULT AND DISCUSSION

This has been tested in all aspects to see whether the Smart Cotton-Based Infant Wristband will be effective, comfortable, and reliable for real-time infant health monitoring. Results are summarized hereafter:

Skin Temperature Variance

Under the band, temperature variation averaged $\pm 0.16^{\circ}\text{C}$ from baseline readings, showing that natural body thermoregulation is minimally affected by the wearing of a wristband. This would therefore mean that this design does not overheat and inhibit accurate temperature sensing.

Stretch Recovery

The cotton band demonstrated high elasticity retention, exceeding 91% stretch recovery across multiple cycles. This is well above the accepted limit of 85%, hence confirming the long-term durability and flexibility for active infants.

Pressure Distribution

This showed even pressure around the wrist, with an average measured pressure of 8.84 mmHg, below the safety threshold of 15 mmHg, ensuring comfort, preventing pressure sores, and allowing safe prolonged wear.

Vital Signs Accuracy

The device repeatedly measured body temperature and heart rate using simulated infant mannequins. Results were comparable to clinical reference devices, with less than a ± 5 bpm variation in heart rate and less than $\pm 2\%$ variation in SpO_2 measurements. Sensor responsiveness to physiological changes and motion was verified.

Battery and wireless performance

During continuous monitoring, the device gave stable performance for 7 to 8 hours and up to 18 hours in deep sleep mode. Wi-Fi connectivity was stable during the tests without any data dropouts or resets.

5. LIMITATION

- Continuous mode has shorter battery life and requires frequent charging.
- Wi-Fi dependency for data transfer.
- Sensor precision affected by movement; maintenance and cleaning required.
- Clinical testing restricted to mannequins, more human trials required for certification.

6. CONCLUSION

This study successfully demonstrates a cotton-based smart textile wristband integrating precise temperature monitoring with wireless transmission tailored for infants. By merging smart textile engineering with machine learning predictive models, infant monitoring systems can evolve from passive measurement tools into proactive health guardians. The observation found includes:

The wristband's heart rate (HR) measurements showed a mean deviation of less than ± 5 beats per minute (bpm) from clinical-grade reference devices. The photoplethysmography (PPG) sensor's heart rate readings exhibited a mean absolute error (MAE) under 5 bpm and root mean square error (RMSE) within clinically acceptable ranges compared to FDA-approved pulse oximeters across simulated infant heart rate ranges (100 to 180 bpm). SpO₂ (oxygen saturation) values deviated by less than $\pm 2\%$ compared to pulse oximeters. Temperature measurements using the DS18B20 sensor demonstrated a strong linear relationship with reference thermometer data over normal infant temperature ranges (35°C to 40°C). The average variance between skin temperature under the wristband and baseline skin temperature was $\pm 0.16^\circ\text{C}$, suggesting minimal bias. This approach ensures not only real-time alerts but also anticipatory care, providing caregivers with actionable insights well before emergencies occur.

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