



Cloud-Enabled IoT Wearable for Real-Time Maternal and Fetal Monitoring

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Abstract. Maternal and fetus health surveillance is crucial in curbing pregnancy complications and maternal and fetal death though traditional hospital-based surveillance systems are periodic, resource-demanding, and demand physical presence making it to be slow in the early identification of critical health abnormalities, especially in the rural and home-based systems. To overcome these shortcomings, this paper introduces an IoT-based real-time maternal and fetal health monitoring system that is able to monitor physiological states continuously and provide timely remote warnings. The offered system combines several sensors, such as a body temperature sensor (DHT11), pulse sensor, SpO₂ sensor desaturating the blood oxygen, a load-cell-based weight sensor, and a tilt sensor, connected to an Arduino Uno microcontroller. The system constantly checks the body temperature of the mother, heart rate, saturation levels of oxygen, weight change, and posture or fall conditions in the body. SpO₂ monitoring helps to identify complications related to hypoxia early enough, and constant monitoring of weight helps to identify abnormal weight gain during gestation or retention of fluid. The sensor data are locally shown in a 16x2 LCD and wirelessly sent over to the Thing Speak cloud over the ESP8266 (NodeMCU) Wi-Fi module used in real-time visualizing, storing, and analysing the sensor data over time. A GSM module provides SMS notifications to caregivers and medical workers when the parameters are out of the safe range, an onboard notification buzzer gives warnings in immediate local areas. Due to its affordability, portability, and scalable Internet of Things architecture, improving access to and quality of maternal care.

Keywords : IoT, Maternal and Fetal Health Monitoring, SpO₂, Weight Monitoring, ESP8266, ECG, GSM, Real-Time Alerts, Healthcare IoT.

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1 Introduction

The topic of maternal and fetal healthcare is a pressing issue in the current medical practice as the complications during pregnancy are still among the primary reasons of maternal deaths, fetal losses, and chronic health complications. Constant checks of vital physiological parameters, including body temperature, heart rate, blood oxygen saturation (SpO₂), body weight, and posture of the mother, are important in prompting the identification of hypoxia, cardiovascular distress, deviant weight gain, preeclampsia and premature birth. Nevertheless, traditional monitoring strategies use a combination of amassing based on periodic visits to the hospitals and hence gives no real-time data and most of the time unable to detect sudden or immediate deviations that may be missed between checkups. These problems are even more serious in rural and remote areas, where the medical infrastructure is insufficient, the trained healthcare professionals are few, and people do not have many opportunities to gain access to timely care because of transport problems. Such areas also subject pregnant women to relying on supervision practices that lack the use of real clinical supervision exposing them to late diagnosis and high health risks. In addition, a visit to the hospital will be long, expensive, and inconveniencing, hence continuous health monitoring is not feasible to most pregnant women. The latest developments of Internet of Things (IoT) technology provide the efficient answer to those drawbacks as it provides real-time, uninterrupted health into sensor based embedded system and wireless communication. The suggested maternal and fetal health monitoring system which is an IoT-based system combines various biomedical sensors with one of the Arduino Uno microcontrollers to measure the important vital parameters and send them to a cloud system to have them analyzed remotely. When abnormal conditions are detected instant SMS alerts and local alarms are created, thus allowing quick action. With its low price, portability, scalability, the system can be beneficial in home-based pregnancy monitoring, rural health centers, and use in telemedicine and thus enhance maternal and fetal safety due to the continuous healthcare monitoring with a IoT.

2 Literature Survey

According to recent studies there has been a marked move by abandoning the periodic and clinic-based check up on pregnancies to continuous and remote fit maternal health monitoring especially in high-risk pregnancies [1]. Fetal heart rate (FHR) is still among the most important parameters of fetal health, and recent reviews mention the progress that has been achieved in terms of FHR and ECG-based monitoring in terms of non-invasive devices including Doppler, wearable ECG, textile sensors, phonocardiography [2]. Simultaneously, the extended literature review of wearable pregnancy monitoring devices agrees that the incorporation of multimodal measures such as ECG/PPG, temperature, motion, and environmental factors with cloud-based analytics can enhance the observation of trends and anomalies in pregnant women as well as allow noticing early signs [3], [8]. The extensive body of wearable data research also shows that sustained physiological trends can be recorded using continuous biometric measurements throughout the entire pregnancy lifecycle, and early anomalies are generally correlated with negative events [4]. The most recent IoT-based applications indicate that remote monitoring of pregnancy at low cost in real time is possible with the help of microcontrollers, wireless modules, and cloud computing like Thing Speak to visualize data in real-time and trigger alerts [5], [6]. Having a high level of potential to be tested in resource-restricted settings, these systems are yet to find their way into the literature, but the provided evidence shows that the issues of clinical validation, data security, power consumption, and user compliance are recurrent [12]. The suggested Arduino-based monitoring architecture can be appropriate to the present trends in research as it allows multimodal sensing, local and remote are warnings, and scalable cloud connectivity [14]. If complete response to the recent recommendations is anticipated, it is

necessary to improve signal conditioning further, data safe handling, and piloting clinical evaluation in comparison with hospital grade monitoring systems.

3 Research Gap

3.1 Affordable domestic surveillance of rural areas: According to the recent research, affordable maternal health monitors that are cost-effective and clinically valid in rural and resource-scarce settings are required [1], [6], [12]. A number of embedded and wearable prototypes are suggested, and many of them do not have enough real-life approval. Scalable solutions based on low cost and viable deployment opportunities are also a research requirement.

3.2 Local alerts and cloud monitoring; Hybrid IoT architectures: The integration of real-time local alarms (buzzer and GSM based) and cloud-based dashboards will allow providing emergencies with the prompt response and the uninterrupted remote surveillance [5], [6], [14]. These comprehensive IoT platforms enhance the reliability of the system in systems with unreliable internet access, and allow clinicians to access real-time and past data.

3.3 Efficiency and reliability On-device preprocessing: The significance of the local signal preprocessing to minimize false alarms and enhance the power efficiency of the continuous monitoring systems is noted in recent literature [2], [3], [8]. By using simple device-level filtering and threshold-based decision logic, the amount of redundant data transmitted can be reduced, and a system can be made more robust.

4 Proposed Methodology

The proposed IoT-Based Real-Time Maternal and Fetal Health Monitoring System will address the requirement of the continuous monitoring of vital physiological and physical parameters of pregnant women to ensure the early detection of negative conditions and provide health care in time. As depicted in Fig. 1 and Fig. 2, the system combines several biomedical sensors with Arduino Uno microcontroller to access real-time data, process, and generate alerts and monitor it in the cloud.

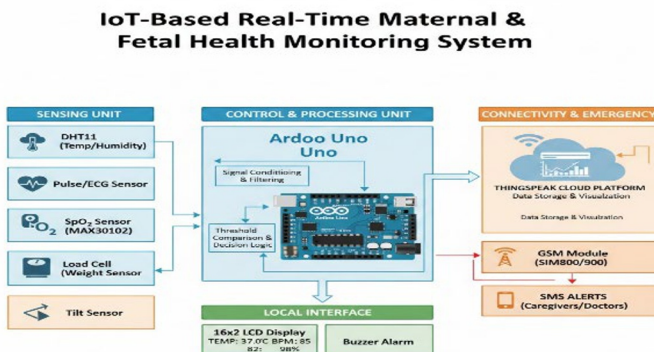


Fig. 1. IoT Based Real-Time Maternal and Fetal Health Monitoring System

Sensing unit includes DHT11 sensor to monitor temperature of maternal body temperature, pulse/ECG sensor to measure heart rate of fetus and cardiac activity of mother, SpO₂ sensor to monitor continuous blood oxygen saturation, load cell-based sensor to monitor changes in maternal weight, and tilt sensor which detects a change in posture and presence of falls. These sensors regularly produce real time physiological information, which are essential in detecting diseases like hypoxia, heart defects, unhealthy weight gain during gestation, and maternal issues like safety.

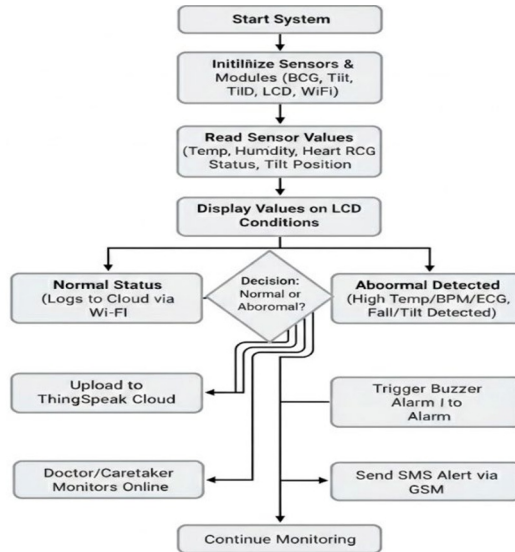


Fig. 2. Flow chart.

The sensor outputs are all connected to the Arduino Uno, a microcontroller that is used to acquire, convert analog to digital values and run some noise filtration, and constant comparison of actual values with set medical threshold values. When a parameter goes outside the safe range, i.e., high temperature, irregular heart rate, low levels of SpO₂, excess variation in weight, irregular ECG, or fall detection, the system indicates the condition as critical.

The sensor values processed are locally represented in a 16 x 2 LCD and can be instantly viewed by the patient or other caregivers around them. An audible alert is given upon emergent situations using a buzzer. In remote monitoring applications, real-time sensor data can be sent to the Thing Speak IoT cloud using the ESP8266 NodeMCU Wi-Fi module and displayed as timeseries graphs and stored to be analyzed long term by health care workers. This is to guarantee emergency communication despite lack of internet in the network system, of which a GSM module has been incorporated to deliver SMS alerts with vital health information to caregivers and doctors.

The whole system works on a constant monitoring cycle, which provides continuity in data collection, processing, and updating the cloud as well as generating alerts. Due to its low expenses, mobility, and scalability the proposed system can be used in rural health facilities, home based pregnancy tracking systems, telemedicine systems, and emergency prenatal care facilities. The system provides vitally important clinical decision-making, as it allows monitoring in real time, alerts, the possibility of remote access to health data, which helps to minimize maternal and fetal health risks.

5 Results and Discussions

To verify its suitability and efficiency as an uninterrupted health monitoring system, an abnormal condition system and the creation of real-time alerts, the proposed IoT-Based Real-Time Maternal and Fetal Health Monitoring System was implemented and experimentally evaluated. The evaluation was performed by graphical analysis and sensor observations in the normal condition and the abnormal condition.

5.1 Results of Maternal Body Temperature

Fig. 3 shows the findings of the maternal body temperature reading. Under regular circumstances, the temperature range was maintained at the safe physiological temperature range of 36.5°C to 37.2°C which implies that the maternal health was stable. There has been no sudden divergence in the curve, which indicates a valid temperature detecting sensor.

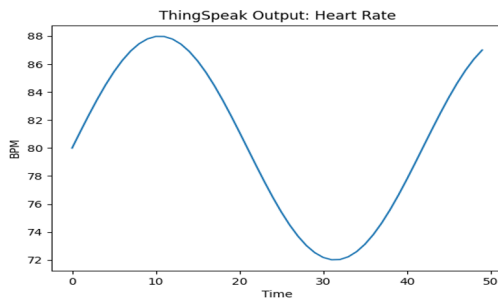


Fig. 3. Maternal Body Temperature During normal conditions.

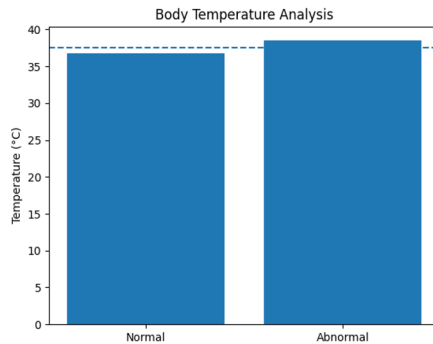


Fig. 4. Maternal Body Temperature During normal conditions and under abnormal conditions.

As per the abnormal conditions, the temperature was more than 38°C which is beyond the set limit. This variation is definite as seen in Fig. 4 whereby the abnormal curve is vastly different to the normal trend. The system automatically detected the condition as abnormal once the threshold was passed and activated the alert systems. These findings confirm the usefulness of threshold temperature monitoring.

5.2 Analysis Results Heart rate

The results of the monitoring of the heart rate are given in Fig. 5 and Fig. 6 respectively. In normal range, the waveform of heart rate was 70 and 90 BPM that had regular and periodic patterns which is a sign of healthy cardiac activity.

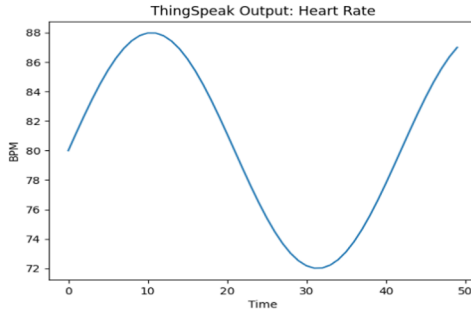


Fig. 5. Heart Rate Under normal conditions.

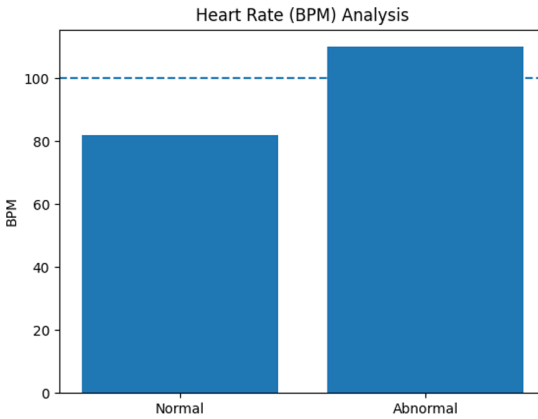


Fig. 6. Heart Rate Under normal conditions and abnormal conditions.

In the state of abnormality, the heart rate was exceeding 100 BPM and the. Fig. 5 and Fig. 6 show these deviations clearly making it possible to distinguish normal and abnormal cardiac behavior. The findings confirm that combined BPM analysis enhances the accuracy of detecting cardiac abnormalities.

5.3 SpO₂ Monitoring Results

The results of the SpO₂ monitoring are presented in Fig. 7. In normal conditions, the level of oxygen saturation was sustained between 96% and 99, which guaranteed sufficient oxygen supply. The sensor is performing consistently, which can be illustrated by the graph.

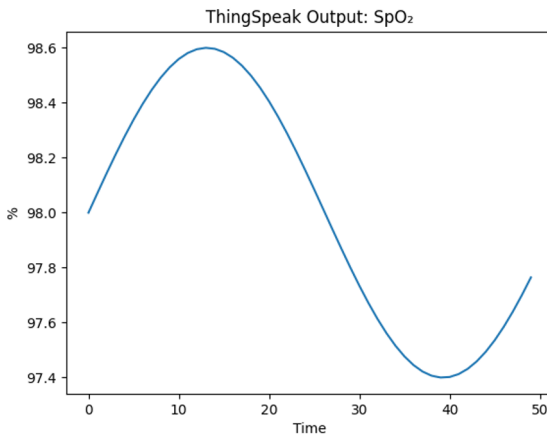


Fig. 7. SpO₂ Under normal conditions

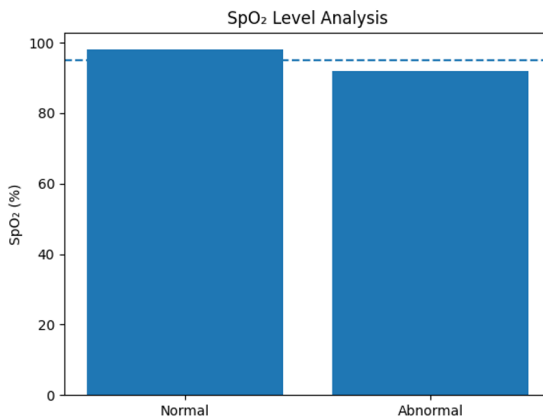


Fig. 8. SpO₂ Under normal conditions and abnormal conditions.

The level of SpO₂ decreased to less than 94 in abnormal conditions, which is a possible threat of hypoxia. This sharp decrease is better depicted in Fig. 8 and enables an early signaling of the occurrence of oxygen deficiency. The findings show that continuous SpO₂ monitoring is significant in maternal care.

5.4 Maternal Monitoring of the Weights

The maternal weight observation findings are shown in Fig. 9. In the non-pathologic condition, the pattern of variation in the weight was gradual and controlled, which is a healthy gestational change.

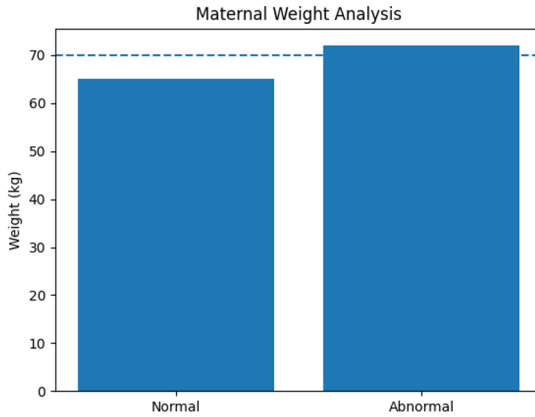


Fig. 9. Weight Under normal conditions and abnormal conditions.

Under non-normal conditions, sharp rise in weight was recorded above the predetermined value as indicated by Fig. 9. These differences could be a sign of edema or fluid build-up. The graphical findings highlight the importance of tracking weight on a long-term basis to diagnose the occurrence of complication during pregnancy early.

5.5 Results of Humidity Monitoring

The findings of monitoring the humidity of the environment are shown in Fig. 10. The levels of humidity that were recorded were in the level of 45 to 55 percent under normal operating conditions and this is regarded as comfortable and safe to the health of the mother. The ThingSpeak graph demonstrates the regular and steady variations, which reveal the same environmental conditions and the ability to perform without any problems with the sensors.

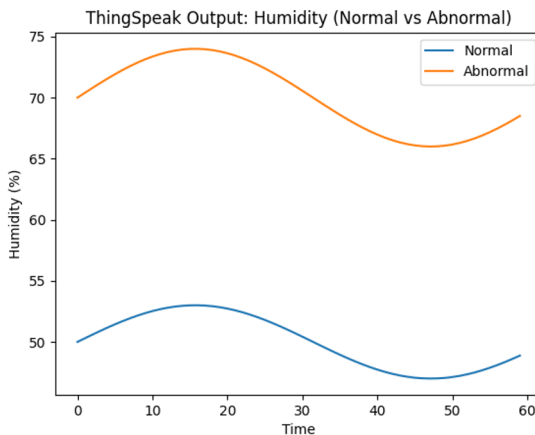


Fig. 10. Humidity Under normal conditions and abnormal conditions.

In the abnormal condition, the level of humidity was high with the value of more than 65 percent and up to 70 percent. This increase is a bad omen of environmental situations that can give rise to inconveniences and difficulties in breathing especially to pregnant women. The strict difference between normal and abnormal humidity curve in the graph testifies to

the ability of the system to constantly monitor the parameters of the environment and correctly find dangerous situations.

5.6 Patient Position Monitoring Outcomes

The tilt sensor was used to assess the physical orientation of the pregnant woman in her everyday activities; patient posture monitoring was done. Under normal conditions, the system was able to identify the normative postures of a standing position and a sleeping location, which showed good posture detected. Abnormal posture conditions were detected with a deviation of transition between normal postures. These changes in posture can signal either for discomfort or dangerous orientation of the body. Upon detection of these conditions, they were identified as abnormal conditions by the system and alert mechanisms were activated.

5.7 Generation Performance on alerts

The associated behaviour of alert generation of abnormal conditions is summed up in Fig. 11.

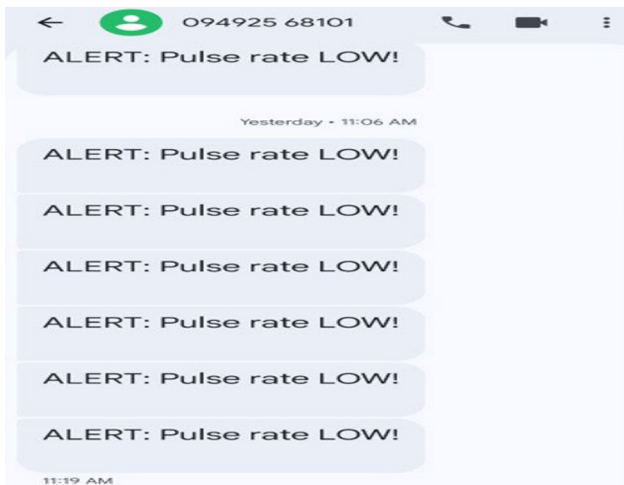


Fig. 11. Alert Generation.

Each time any parameter that was being monitored went beyond its predefined threshold, a buzzer was triggered locally and SMS notifications dispatched using the GSM module. Response time was also low and this was good in emergency communication.

5.8 Cloud-Based Monitoring Outcomes

Displays show the outcomes of cloud-based monitoring.



Fig. 12. Cloud-Based Monitoring Results.

The Thing Speak cloud service was used to upload all sensor-data on the Wi-Fi ESP8266 module. The cloud interface was available to give real live visualization and historical data on temperature and heart rate, SpO₂, weight, humidity, and position parameters. These visualizations are used in remote health supervision and long-term trend analysis.

6 Conclusion

The proposed IoT-Based Real-Time Maternal and Fetal Health Monitoring System provides a robust and comprehensive solution for the continuous physiological observation of pregnant women and fetal well-being outside traditional clinical environments. By integrating a specialized sensor suite—including maternal temperature, heart rate/ECG, blood oxygen saturation (SpO₂), gestational weight tracking, and posture detection—with an Arduino-based embedded platform, the system captures a holistic view of maternal health. This multi-parameter approach enables the early detection of critical conditions such as hypoxia, preeclampsia, and cardiovascular distress, which are often missed during intermittent clinical visits. Ultimately, this system bridges the gap between hospital-grade diagnostic capabilities and domestic healthcare. Its low-cost, portable, and scalable design makes it an ideal candidate for large-scale deployment in telemedicine frameworks and community health centers.

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Disclosure of Interests. The authors claim that they do not have any form of competing interests or financial conflicts that would have affected the work reported in the given paper. The study was carried out based on purely academic and research values.

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