IOT-BASED SMART WEARABLE DEVICE FOR CONTINUOUS FETUS WELL-BEING MONITORING

Project Reference No.: *49S_BE_2922*

College : CMR Institute of Technology, Bengaluru
Branch : Department of Electronics and Communication Engineering
Guide(s) : Dr. Abinash Panda
Dr. Meenakshi Patil
Student(s) : Mr. Lavdeep Kumar Tiwari
Mr. Rishi Dhar Mishra
Mr. Siddhant Singh

Keywords:

IoT-based Smart Wearable, Fetal Well-being, ESP32, Fetal monitoring, Force Sensitive Resistors (FSR).

Introduction:

Pregnancy is a physiologically sensitive period requiring continuous monitoring to ensure maternal and fetal safety. Traditional methods like ultrasound and cardiotocography (CTG) are reliable but restricted to clinical environments, creating gaps in monitoring between visits. Currently, mothers often rely on manual "kick counts" at home, a method that is highly subjective, error-prone, and easily influenced by maternal fatigue or stress. These limitations underscore the urgent need for a more objective, continuous, and accessible monitoring solution. This project proposes a low-cost, IoT-enabled wearable system designed for real-time fetal health tracking outside the hospital. By integrating multiple sensors, the system tracks fetal movements alongside maternal physiological parameters. This unified data stream offers a comprehensive assessment of prenatal health. The non-invasive and user-friendly nature of the belt makes it suitable for high-risk pregnancies. Furthermore, its remote monitoring capabilities allow healthcare providers to access vital patient data without requiring frequent, stressful hospital visits.

Objectives:

1. <u>Continuous Monitoring</u>: To perform uninterrupted measurement of physiological parameters, including fetal kicks, uterine pressure, maternal heart rate, SPO2, and body temperature.
2. <u>Remote Surveillance</u>: To reduce dependency on frequent hospital visits by enabling remote health tracking for women in rural or low-resource settings.
3. <u>Early Detection & Alerting</u>: To enhance the early diagnosis of fetal distress conditions and automatically trigger real-time alerts to caregivers when anomalies are detected.
4. <u>Data Analysis</u>: To utilize cloud analytics for storing and comparing health data with historical datasets to identify critical deviations.
5. <u>Accessibility</u>: To provide a portable, affordable, and comfortable wearable solution that acts as a reliable digital companion.

Methodology:

1. **Wearable Design & Sensor Integration**: A flexible abdominal belt is designed for comfort and accuracy. It utilizes Force Sensitive Resistor (FSR) sensors to measure uterine pressure and nine position-sensitive sensors to localize fetal movement intensity. Maternal vitals are monitored via the MAX30102 (SPO2 and heart rate) and DHT11 (body temperature).
2. **Data Processing**: An ESP32 microcontroller serves as the central unit for real-time data acquisition. It applies algorithms for noise filtering, signal normalization, and feature extraction to identify patterns like fetal movement frequency.
3. **Transmission & Cloud Analytics**: The ESP32 transmits timestamped data to cloud platforms (such as Blynk or Firebase) via Wi-Fi using MQTT or HTTP protocols. Cloud analytics identify trends and flag anomalies against historical data.
4. **User Interface**: A mobile application provides a dashboard for doctors and mothers to view live health metrics and receive automated alerts if critical thresholds are crossed.

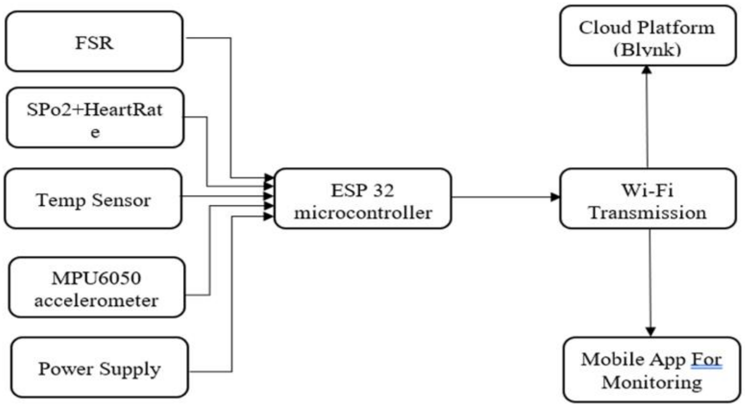

Figure 1: Block Diagram

Project Outcome & Industry Relevance:

The primary outcome is a functional, low-cost wearable prototype capable of simultaneous maternal-fetal monitoring. This project holds significant relevance for the burgeoning Telehealth and MedTech industries by bridging the gap between clinical visits and home-based care. For healthcare providers, it offers a data-driven tool for managing high-risk pregnancies remotely. In the insurance and public health sectors, such a device could reduce long-term costs by preventing complications through early intervention. The use of affordable components like the ESP32 and FSRs makes it a viable solution for rural or low-resource settings where expensive CTG machines are unavailable.

Working Model vs. Simulation/Study:
This project involved the development of a physical working model (Working Prototype).

Project Outcomes and Learnings:

1. Technical Proficiency: Gained hands-on experience in integrating diverse sensors (FSR, MAX30102, DHT11) with the ESP32 microcontroller.
2. Signal Processing: Learned to implement noise filtering and motion compensation algorithms to distinguish fetal activity from maternal artifacts.

3. IoT Architecture: Developed a full-stack IoT pipeline involving Wi-Fi transmission, cloud data storage, and mobile application interfacing.
4. Clinical Awareness: Understand the critical parameters of prenatal health and the stringent accuracy requirements for medical-grade wearable devices.

Result and Conclusion:

Experimental results have validated the system's ability to provide robust fetal kick detection and reliable maternal vital tracking. Testing confirmed that the FSR array is highly sensitive to impacts, while the IMU-based compensation significantly reduces false positives during maternal movement. Accuracy tests showed maternal SpO2 measurements remained within a +-2 error margin, and heart rate deviations were within +3 BPM compared to clinical standards. In conclusion, the proposed wearable system offers a scalable and user-friendly solution for remote prenatal care. By reducing the dependency on frequent hospital visits and providing objective, continuous data, the device enhances the early detection of fetal distress and improves overall health outcomes for both mother and child.

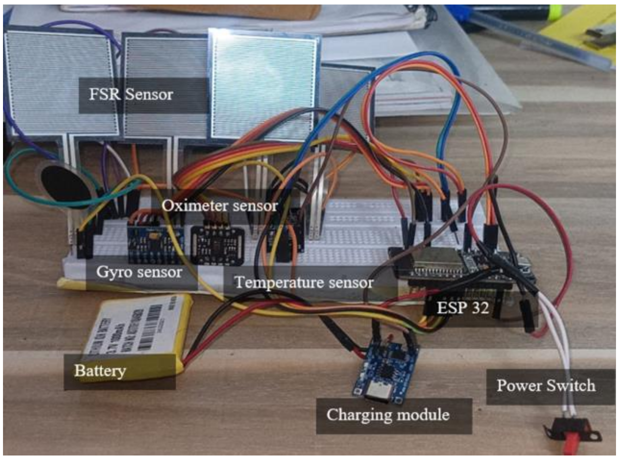

Figure 2: Working Prototype

References:

1. [1] E. Sadovsky and H. Yaffe, "Quantification of fetal movements: A method of identifying fetal distress," *American Journal of Obstetrics and Gynaecology*, vol. 115, no. 1, pp. 101-108, 1973.
2. [2] V. Smith, R. Begum, and D. Wood, "Wearable fetal monitoring technologies: A review of current trends in maternal-fetal health," *Journal of Medical Engineering and Technology*, vol. 44, no. 5, pp. 247-259, 2020.
3. [3] V. Subramaniam and P. Rajalakshmi, "IoT-based remote maternal health monitoring system using wearable sensors," *IEEE Internet of Things Journal*, vol. 5, no. 5, pp. 3810-3818, 2018.
4. [4] H. Lee, S. Park, J. Kim, and M. Seo, "Pressure-sensitive sensors for fetal movement detection: Design, performance, and clinical relevance," *Sensors and Actuators A: Physical*, vol. 295, pp. 124-134, 2019.
5. [5] B. Xu, L. Yi, and Z. Pang, "Real-time fetal movement detection using force-sensitive resistors and machine preprocessing filters," *Biomedical Signal Processing and Control*, vol. 62, pp. 102-118, 2020.

Future Scope:

1. **Advanced AI Integration**: Implementing machine learning algorithms at the cloud level to predict potential pregnancy complications based on long-term data trends.
2. **Enhanced Precision**: Integrating Doppler ultrasound modules for more granular fetal heart rate analysis during high-risk periods.
3. **Regulatory Compliance**: Further refining the device to meet stringent international medical standards for wider clinical deployment.