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Enhancing Maternal and Fetal Health: Wearable AI and IOT Innovations

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ABSTRACT

The World Health Organization (WHO) is concerned about the risks faced by mothers dur- ing pregnancy and childbirth in India, especially the high rate of emergency postpartum hys- terectomies. In low- and middle-income countries, around 21 million pregnancies occur among adolescents aged 15–19 annually, with half of them unintended, resulting in approximately 12 million births.

To address these issues, a groundbreaking solution has been proposed – a wearable belt integrated with AI and IoT technologies. This innovative system continuously monitors vital health parameters of expectant mothers, analyzes the data, and transmits it to ThingSpeak, an IOT-based cloud platform. The development includes machine learning models for fetal heart classification and identifying various risks during pregnancy, providing crucial insights into the well-being of both mother and child.

The proposed system uses sensors like accelerometers and pulse sensors to track the baby's movements and heart rate. This helps overcome accuracy issues of traditional monitors for fetal movement, challenges pregnant women face with in-person monitoring, and limitations in monitoring duration with devices like ultrasonic Doppler imaging.

This approach, focusing on the entire pregnancy journey, supports the goal of achieving Sustainable Development Goals (SDGs) for maternal and newborn health. The new technology not only addresses current problems but also lays the foundation for a comprehensive and data- driven strategy to improve the health of both mothers and newborns. This contributes to global efforts for a healthier and more sustainable future.

Keywords: Accelerometer Sensors, ThingSpeak, Heart rate Pulse Sensor, IoT cloud platform, Machine learning, SDGs.

1. Introduction

Maternal health, encompassing the well-being of women during pregnancy, childbirth, and the im- mediate postpartum period, is a critical aspect of global healthcare. Inadequate treatment and education, particularly in economically disadvantaged countries, contribute to maternal deaths. Hy- pertension in pregnant women is a prevalent issue worldwide, with conditions like preeclampsia posing significant risks. Routine prenatal appointments play a crucial role in monitoring and man- aging maternal health, involving aspects such as nutrition and exercise planning, as well as medical assessments like fetal heart rate monitoring, blood pressure checks, weight measurements, fundal height assessments, and urine testing. Regular medical checks and fetal kick count monitoring are essential for early detection of potential health issues in pregnant women.

A significant challenge, especially in rural areas, lies in the lack of awareness about the importance of proper medication and the financial constraints preventing access to necessary medical care. While ultrasonic scanning devices are available, their high costs pose a barrier to widespread use.

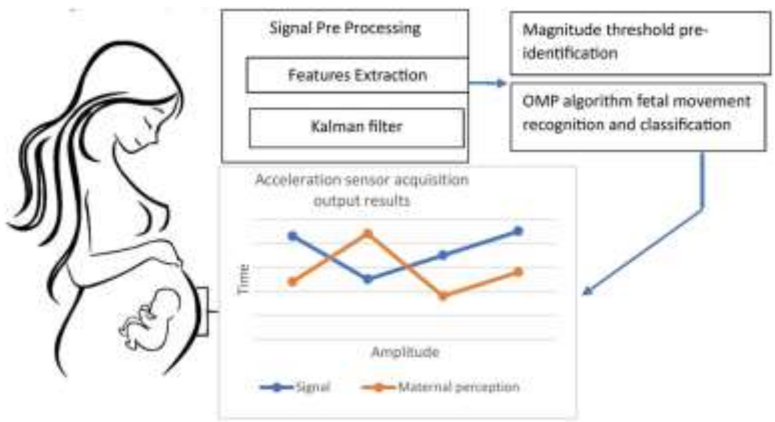

Figure 1: Measures of Fetal Data

The integration of Internet of Things (IoT) technology offers a promising solution to address these challenges. By leveraging embedded devices, communication protocols, sensor networks, internet protocols, and applications, IoT transforms conventional healthcare tools into intelligent, connected systems. This enables the seamless collection, management, and sharing of all healthcare-related information, encompassing diagnosis, treatment, recovery, inventory, and medication.

The proposed system employs various sensors, including a heart rate pulse sensor and an ac- celerometer sensor to monitor fetal kicks. The data collected from these sensors is communicated through an Arduino Uno and IoT technology to a software program.

This software can be loaded onto a mobile device or PC, allowing healthcare providers and expecting mothers to access graphical data through an LCD display. Importantly, the system includes alerts through a buzzer to promptly notify users of any abnormal values, enabling timely intervention and improving maternal health outcomes. This innovative approach not only addresses the challenges faced in maternal healthcare but also highlights the potential of technology, specifically IoT, in revolutionizing traditional healthcare practices for better accessibility and effectiveness[1].

Fetal monitoring is a crucial aspect of prenatal care, and ultrasound methods are pre- dominant in clinical practice. Among these, fetal echocardiography (fECHO) is commonly employed between the 20th and 23rd weeks of pregnancy for diagnosing congenital heart defects. Additionally, car- diotocography (CTG) is widely used to simultaneously measure the fetal heartbeat and maternal uterine contractions, contributing to a reduction in newborn mortality rates during delivery.

While CTG has proven effective, its drawback lies in high sensitivity to various types of noise caused by maternal movements. This sensitivity necessitates frequent repositioning of the ultrasound transducers, which can be inconvenient and impact the accuracy of the monitoring process.

Alternative methods for fetal heart rate monitoring include fetal electrocardiography (fECG), fetal phonocardiography (fPCG), and fetal magnetocardiography (fMCG). Fetal electrocardiography provides insight into the electrical activity of the fetal heart, while fetal phonocardiography captures its mechanical (acoustic) activity. Fetal magnetocardiography involves recording the magnetic field produced by the fetal heart.

Each of these methods offers distinct advantages and insights into fetal well-being. However, it’s crucial to acknowledge the limitations of each technique and consider factors such as sensitivity to noise and the need for repositioning in the overall assessment of their effectiveness in monitoring fetal health. As technology continues to advance, there may be opportunities to address these limitations and further refine fetal monitoring methods for enhanced accuracy and convenience in clinical settings.[2]

2. Motivation:

The pandemic lockdown provided a unique opportunity to study the movement patterns of healthy fetuses. We compared the activity levels of fetuses during the Covid-19 lockdown in the UK (specif- ically, the third national lockdown between January and March 2021) [3]. This analysis aimed to understand any potential impact on fetal well-being during this period. Additionally, feeling the baby’s movements during pregnancy is a longstanding and widely practiced method for ensuring the baby’s health. Nowadays, most pregnant women follow this informal method, where they pay attention to their baby’s movements regularly. Over 99% of women who have given birth to a live baby believe it’s crucial to feel the baby move every day[4].

Checking on the baby’s well-being regularly during pregnancy helps identify any potential issues early on. This early detection allows for timely intervention and improves the likelihood of a healthy baby being born. The overall health of both the mother and the baby provides important clues about potential or the well-being of the fetus in the future [5]. The fusion of heterogeneous sensors to design wearables for human activity recognition has been explored by numerous researchers in recent years. For example, Talitckii et al [6]. While most published research has concentrated on the direct effects of Covid-19 infections in pregnant women and postnatal outcomes in their offspring [e.g., 1], the potential consequences of lockdown measures on fetal well-being remain underexplored. For example, postnatal studies such as Aldrete-Cortez et al [3].

3. Project Objectives:

This study looks into the connection between decreased fetal movements (DFM) and the likelihood of early induction, emergency cesarean delivery, and having smallfor-gestational-age babies. It found that around 50% of women feel worried about their baby's movements at some point during preg- nancy, and 22% seek assessment for DFM. Experiencing DFM is only slightly linked to a higher risk of stillbirth, and most women who go through this condition end up having a healthy baby. [6, 7].

The system's software design follows the structure of the overall system, which is based on a symmetric sensor. It involves designing the application circuit for the three-axis acceleration sensor MC3672 and its corresponding data collection program. Additionally, the application circuit of the main control chip NRF52840 with a Cortex-M4 core is analyzed [8]. The goal of this research is to introduce a new way of monitoring the fetal body, considering maternal characteristics like movement (kicks) and heart rate. This is achieved by using an accelerometer sensor and a heart rate pulse sensor[1].

3.1 Clarity and Precision:

In Electronic Fetal Monitoring (EFM), a critical parameter is the fetal heart rate (fHR). This in- formation can be obtained either invasively, by using a scalp electrode inserted transvaginally and secured to the fetal fontanel, or non-invasively. The invasive method yields a higher-quality signal (greater Signal-to-Noise Ratio—SNR) since it directly measures the heart rate from the fetus's head. This invasive approach enhances the diagnostic quality of traditional Cardiotocography (CTG) and validates noninvasive Electrocardiogram (ECG) methods. However, the invasive method comes with several drawbacks [2].

In the current methods for managing gastroschisis, medical professionals use nonstress tests and biophysical profiles to evaluate a reassuring status. As part of the biophysical profile, counting gross fetal movements is considered. However, there hasn't been any report thus far on whether a fetus with gastroschisis exhibits the same amount of movement as a healthy fetus[8].

3.2 Measurability:

3.2.1 PULSE SENSOR WITH ARDUINO

The proposed Ubiquitous Sensor Network (USN) Healthcare Monitoring Applica- tion employs a comprehensive system architecture involving sensor nodes, Arduino technology, Wi-Fi for wireless communication, and medical professionals' wireless devices for patient data monitoring. Key com- ponents include sensor nodes for vital sign sensing, Arduino interface for data processing, wireless communication using an RN-XV module, a medical center as a base station, and a monitoring application for data analysis.

The hardware setup begins with the pulse sensor and Arduino to the computer, extending to include a wireless sensor node for Wi-Fi data transmission. The medical center serves as the base station, receiving and analyzing patient data, while medical professionals access the data through a Java-based Web Interface Application.

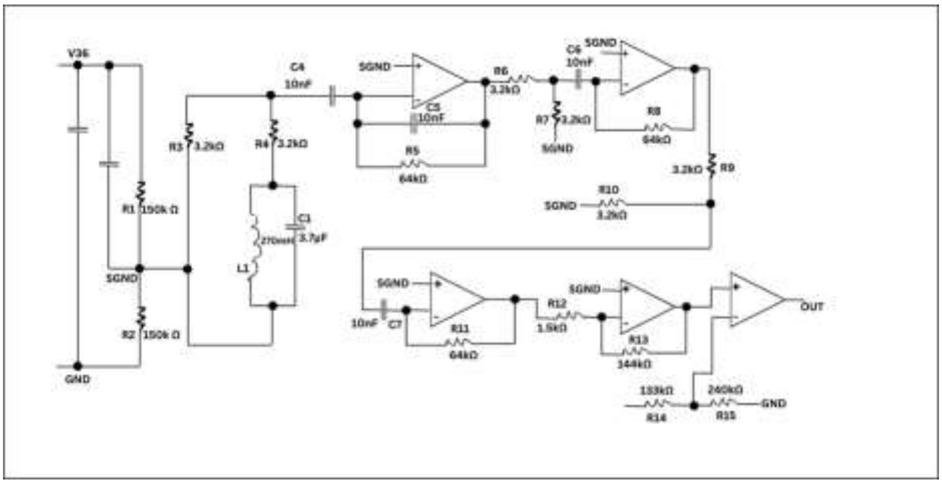

Figure 2: Circuit diagram of Pulse Sensor & Heart rate Sensor

The software development focuses on raw data interpretation, heart rate algorithms for activ- ity monitoring, and a web user interface for easy accessibility. The HR algorithm classifies normal and abnormal conditions based on heart rate parameters, and the web interface allows secure ac- cess to patient data. Implementation results highlight the development of wireless devices for heart rate measurement, emphasizing the integration of a pulse sensor with Arduino and wireless com- munication through a dedicated module. The monitoring application demonstrates effective data accessibility and HR algorithm translation, ensuring seamless communication between the sensor and the medical center through Wi-Fi. Overall, the USN Healthcare Monitoring Application provides a robust framework for continuous patient monitoring and timely intervention in abnormal situations [9].

3.2.2 ACCELEROMETER SENSOR

This comprehensive project involves utilizing accelerometer sensors for diverse applications. In au- tomobiles, they trigger airbags during accidents based on acceleration thresholds, emphasizing dura- bility and cost-effectiveness. High-precision accelerometers, often paired with gyroscopes, assist in guiding rockets and aircraft. In Earth's gravitational field, accelerometers help measure tilt and orientation,proving valuable in navigation. Ultra-high precision accelerometers find applications in seismology, aiding earthquake detection and geophysical mapping, with NASA's Jet Propulsion Laboratory developing extremely sensitive versions.

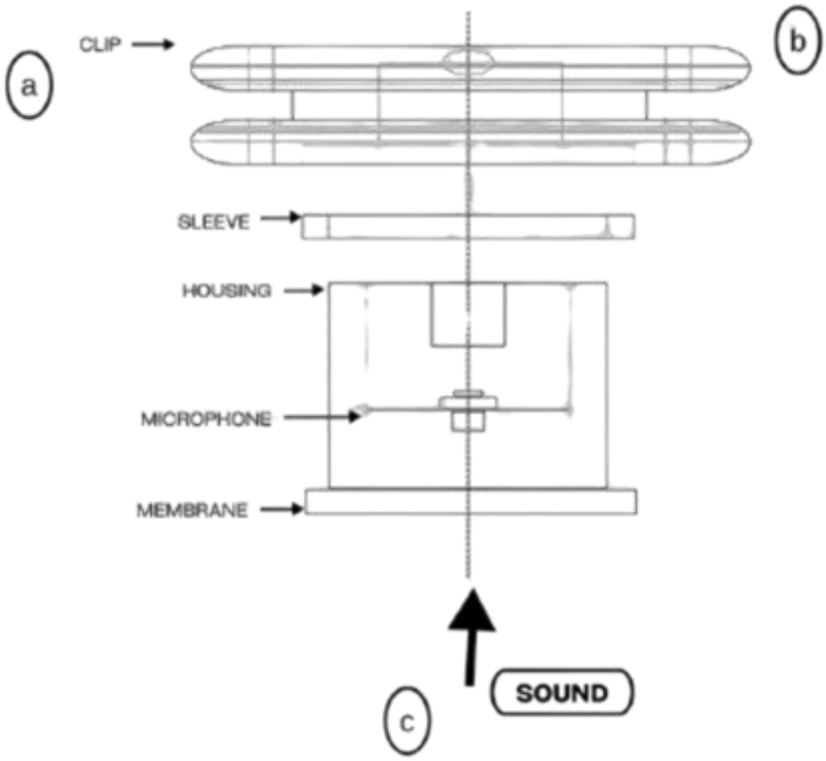

Figure 3: Circuit diagram of Pulse Sensor & Heart rate Sensor

Shifting focus, the project aims to measure involuntary hand motion in individuals with signif- icant hand tremors. Distinguishing between voluntary and involuntary hand motions, it explores characteristic frequency ranges associated with different tremors. This has potential clinical ap- plications, especially in diagnosing the origin of unknown hand tremors, such as those related to neurological conditions like Parkinson's and essential tremor[10].

3.3 Relevance:

This study explores the idea of monitoring data using IoT technology and emphasizes how the risk of missing data can impact doctors' diagnoses. The researchers concluded that losing data in remote monitoring can be highly dangerous because it affects the decisions that doctors need to make. While previous research has discussed the importance of Fetal Heart Rate (FHR) values and the consequences of data loss in healthcare decision-making, there hasn't been much focus on lost data during transmission and reception.

Building on prior research, the author plans to conduct a study titled "The Effect of Lost Data on the IoT Platform on the Formation of FHR Graphs for Remote Diagnostic Purposes." This study aims to investigate the lost data on the IoT platform to understand how it influences the displayed data. The primary goal is to analyze how the loss of data affects the formation of the Fetal Heart Rate graph on the IoT platform, which serves as a tool for remote diagnosis [12].

4. Literature Review

In this project, we suggest ways to detect fetal movement. Here's a brief description of what this thesis contributes:

The Effects of Lockdown during the Covid Pandemic on Fetal Movement:

Author : N. Reissland [Durham University], Beyza Ustun[Wageningen University & Research], J. Einbeck[Durham University]

DOI: https://www.researchsquare.com/article/rs-3342492/v1

Purpose:

This study focused on understanding how the Covid-19 lockdown directly affected fetal move- ments, addressing an important gap in existing research. While previous studies mainly looked at the impact of lockdowns on maternal health and outcomes after childbirth, there has been limited attention given to the direct effects on the well-being of the fetus.

Fetal movements: A framework for antenatal conversations

Author : Billie F. [Bradford], Robin S. [Cronin], Jane Warland, Anna [Akselsson], Ingela [R˚adestad], Alexander EP Heazell, Christopher J.D. [McKinlay], Tomasina Stacey, John M.D. Thompson, Lesley

M.E. McCowan

DOI: 10.1016/j.wombi.2022.09.003

Purpose:

A considerable number of antenatal assessments involve presentations related to decreased fetal movements, which is linked to a higher chance of adverse pregnancy outcomes, including stillbirth. Although guidelines suggest that pregnant women should regularly receive information about fetal movements, the actual practice varies, and the information shared is often not based on evidence. Additionally, there are gaps in knowledge regarding how to assess and manage concerns about fetal movements.

Fetal Movement Assessment:

Author : J. Frederik Frøen, MD, PhD, Alexander E.P. Heazell, MBChB(Hons), Julie Victoria Holm Tveit, MD, Eli Saastad, RN, Rm, MSc, Ruth C. Fretts, MD, MPH, and Vicki Flenady, RN, Rm, MMedSc

Doi: 10.1053/j.semperi.2008.04.004

Purpose:

Feeling the baby's movements is the oldest and widely practiced way to check the baby's well- being during pregnancy. Almost all pregnant women follow this method, but organized screening by fetal movements has not been consistently popular among health professionals.

Multi-modal detection of fetal movements using a wearable monitor:

Author: Abhishek K. Ghosh, Danilo S. Catelli, Samuel Wilson, Niamh C. Nowlan ,Ravi Vaidyanathan Doi: https://www.sciencedirect.com/science/article/pii/S1566253523004402?via%3Dihub Purpose:

The significance of Fetal Movement (FM) patterns as a marker for fetal health has been widely discussed in obstetrics. However, the limitations of current FM monitoring methods, like ultrasonog- raphy, being usable only in clinical settings, make it difficult to fully comprehend the nature and changes in FM. To fill this gap, a limited amount of research has introduced wearable sensor-based FM monitors.

5. Methodology

In this study involving one participant, fetal movement (FM) in the uterus serves as an indicator of fetal well-being, dependent on placental vascular health. Maternal perception of these movements, commonly known as ”kicking,” begins around the fourth month of pregnancy and is discussed based on one respondent's experience. Sampling is random, and results are obtained once. The study notes a growing preference for internet-synced devices and smartphone applications. These devices typically employ both active and passive sensors, primarily for monitoring fetal movement, heart rate, uterine activity, ECG, FECG, and EMG [11, 12].

5.1 System overview

The block diagram for the proposed device is divided into three units. It consists of accelerometer sensors as the input, ARDUINO microcontroller as aprocessing unit and MATLAB Interface as the output unit. The hardware used for this work was constructed and the results were benchmarked with maternal perception and ultrasound in order to validate the hardware developed. A block diagram of the proposed FMs recording is shown in Figure-3. Details of each of the unit making up the FMs recording system described in the subsequent paragraphs.[13]

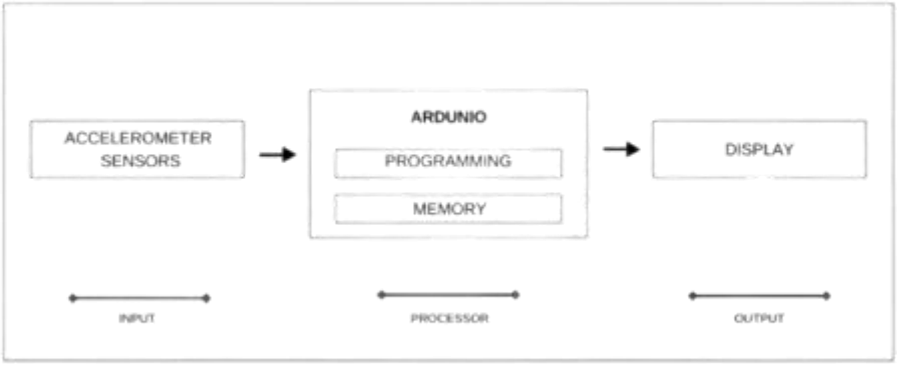

Figure 4: How our project works

5.2 Acceleration sensor data collection unit

The study employs the MC3672 acceleration sensor from MEMSIC Semiconductor, packaged in WLCSP-8, for fetal movement signal collection. This sensor, measuring 1.29 mm × 1.09 mm ×

0.74 mm, is a compact three-axis accelerometer with features like 32 sampling buffers, low power

usage, high sensitivity, and integrated digital output. The sensor communicates with the NRF52840 master chip through the IIC protocol, transmitting collected acceleration values on X, Y, and Z axes at a rate of up to 1 MHz. The data communication mode involves one host and two slave modes, facilitating communication between the master controller and two acceleration sensors. The host controller initializes, sets sensitivity and range, and reads accelerometer data cyclically with a 100 Hz sampling frequency. The accelerometer has three axes, each corresponding to a register group, with high and low 8-bit data registers in sequential addresses [14, 15].

5.3 Flowchart

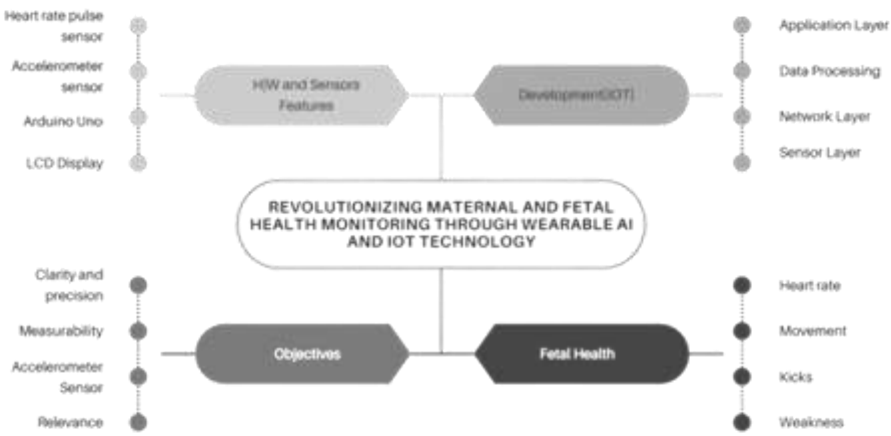

Figure 5: Overview Of Project

6. Conclusion

All over the world, specially in rural areas, various problems of pregnancy become very difficult at times. It is hoped that this paper, prepared for the good health and longevity of the expectant mother and her child, will be of benefit to all, irrespective of caste and religion. The baby's movements along with heart rate will be recorded through the pulse sensor and we can receive it through the Accelerometer. The market we are using will sound if the baby's movement or heart rate is not sensed at the appropriate rate or if the movement is not required. As a result, we can understand it very easily and it will be possible to take necessary measures, in that case, we can serve the mother and the baby for that moment with good advice and adequate medicine. That way they will be healthy.

7. Future Work

If we can detect in advance the possibility of all the terrible dangers that exist while the child is in the mother's womb, then this huge amount of maternal and child deaths can be prevented. Because accurate information is not always available about the position of the baby in the fetal stage. Even if available, it is very expensive. If this machine reaches the homes of villages and homes, the necessary information will be known at home without going to the hospital or nursing home. By doing this, along with our time and money, the tendency of mother and child to stay healthy will increase a lot. Another advantage of this is that if the child and mother or one of the two are sick, it will be reported immediately, and necessary measures can be taken. It is hoped that this effort will be a good cause for people of every level of society.

8. Declarations:

Our study follows ethical guidelines set by Durgapur Institute Of Advanced Technology & Manage- ment, prioritizing the safety and privacy of participants, particularly expectant mothers and their unborn children. We emphasize transparency, respect participants' autonomy, and ensure informed consent. Our commitment to ethical practices extends to advancing maternal and newborn health in alignment with global goals. The project adheres to international standards for both human and animal studies, promoting the well-being of mothers and newborns through innovative healthcare solutions.

- Ethical Approval : This Declaration is not applicable.
- Funding : This Declaration is not applicable.
- Availability of data and materials: This Declaration is not applicable.

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