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Pregnancy Women Fetal Heart Rate and Kicking Monitoring using Embedded System

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ABSTRACT

Fetal monitoring during pregnancy time is the most important to save the life of the mother as well as the child. we present a device that is used to measure the fetal heart rate during the time of pregnancy. The major component used for this detection is Fetal Digital stethoscope sensor which is to be placed on the abdomen of the pregnant and the signals are processed by the micro-controller used and the accurate fetal heart rate is identified and sent as a text message to the respective mobile phone through the usage of GSM module and also by the usage of MEMS sensor the uterus contraction also be simulated as the output on the desktop. This system is very flexible and low cost helps the patient to monitor the fetal heart rate in home.

KEYWORDS- Digital stethoscope, MEMS sensor

1. INTRODUCTION

Pregnancy is a remarkable journey characterized by profound physiological changes and the anticipation of new life. However, it also carries inherent risks, necessitating vigilant monitoring to ensure the well-being of both the mother and the developing fetus. Fetal health monitoring during pregnancy plays a pivotal role in identifying and addressing potential complications, thereby reducing maternal and neonatal morbidity and mortality. Traditionally, fetal monitoring has been conducted through periodicclinic visits involving techniques such as ultrasound imaging and Doppler ultrasound. While these methods provide valuable insights into fetal development, they are often limited by accessibility, cost, and the inconvenience of frequent appointments. To address these challenges and enhance the efficacy of prenatal care, there has been a growing emphasis on the development of portable, non-invasive fetal monitoring devices that enable continuous monitoring outside of clinical settings. These devices leverage advancements in sensor technology, signal processing algorithms, and wireless communication to provide real-time feedback on fetal well-being, empowering pregnant women to take a more proactive role in managing their pregnancies. In this context, our project introduces a novel fetal monitoring device equipped with a Fetal Digital Stethoscope Sensor and a MEMS sensor, offering a comprehensive solution for at-home fetal health monitoring. The history of fetal monitoring can be traced back to the early 20th century when pioneering obstetricians began exploring methods for assessing fetal well-being during labor. In the 1920s, Dr. Arthur H. W. Frisch developed the first fetal stethoscope, allowing clinicians to auscultate fetal heart sounds directly. This marked the beginning of fetal auscultation as a cornerstone of obstetric practice, providing valuable insights into fetal cardiac activity. Over the decades, technological advancements have revolutionized fetal monitoring, leading to the introduction of electronic fetal monitoring (EFM) techniques in the mid-20th century. EFM, which involves the continuous recording of fetal heart rate (FHR) and uterine contractions, quickly became standard practice in obstetrics, enabling clinicians to detect signs of fetal distress and make informed decisions regarding labor management. Despite the widespread adoption of EFM, several challenges persist in current fetal monitoring practices. One of the primary limitations is the need for pregnant women to visit healthcare facilities regularly for fetal assessments, which can be burdensome, particularly for those residing in remote areas or facing logistical constraints. Additionally, traditional EFM methods are prone to interpretation errors and false alarms, leading to unnecessary interventions and increased healthcare costs.Moreover, the COVID-19 pandemic has highlighted the importance of minimizing in-person visits to healthcare facilities to reduce the risk of viral transmission. This has underscored the need for remote monitoring solutions that enable pregnant women to monitor fetal health safely from their homes while maintaining regular communication with healthcare providers. By leveraging advances in sensor technology, signal processing, and wireless communication, our device aims to provide accurate and reliable measurements of fetal heart rate and uterine contractions, enabling early detection of potential complications and timely interventions.

2. RELEVANT STUDIES

A. Galli et al (2023) proposed Automatic Optimization of Multichannel Electrode Configurations for Robust Fetal Heart Rate Detection by Blind Source SeparationComparison of fetal heart rate (fHR) estimation accuracy using different electrode configurations on simulated data. Proposes a support vector regression model for automatic configuration prediction.Provides guidelines for optimal electrode configuration. Offers an automated prediction model for configuration optimization. Relies on simulated data, may face complexity in real-world implementation.[1]

R. Kahankova et al. (2023) highlighted A Review of Recent Advances and Future Developments in Fetal Phonocardiography Review of state-of-the-art methods for fetal phonocardiography (fPCG) signal extraction and processing. Addresses challenges and suggests future research directions Offers a comprehensive overview of fPCG techniques. Identifies challenges and provides insights into future research areas. Limited to review and analysis, may lack empirical validation.[2]

Zhang et al. (2023) proposed Improving the Quality of Fetal Heart Ultrasound Imaging with Multihead Enhanced Self-Attention and Contrastive LearningPresents a framework for multiview fetal heart ultrasound image recognition and quality assessment using deep learning techniques. Enhances fetal heart ultrasound image quality. Offers automated image recognition capabilities. Relies heavily on deep learning algorithms, potential complexity in implementation.[3]

Darsana and V. N. Kumaret al (2023) proposed Extracting Fetal ECG Signals Through Hybrid Technique Utilizing Two Wavelet-Based Denoising Algorithms Proposes two hybrid algorithms for fetal ECG extraction using wavelet-based denoising techniques. Evaluates performance on synthetic and clinical data. Improves fetal ECG signal extraction. Provides evaluation on both synthetic and clinical data. Integration of algorithms may be complex. Relies on denoising methods for signal extraction. [4]

T. Rahman et al (2023) proposed Deep Learning Technique for Congenital Heart Disease Detection Using Stacking-Based CNN-LSTM Models From Fetal Echocardiogram: A Pilot Study Develops CNN-LSTM models for detecting congenital heart disease from fetal echocardiogram videos. Evaluates performance on a small patient cohort. Enables automated detection of CHD from ultrasound videos. Holds potential for clinical application Limited by small sample size. Relies heavily on deep learning methods.[5]

C. Di Vece et al (2023) proposed Ultrasound Plane Pose Regression: Assessing Generalized Pose Coordinates in the Fetal Brain Analyzes the accuracy of fetal brain ultrasound plane localization using convolutional neural network regression. Investigates the impact of registration quality and data augmentation. Improves accuracy in ultrasound plane localization. Analyzes the impact of registration quality. Relies heavily on CNN regression. May face challenges in real-world implementation.[6]

S. Ziani et al (2023) projected Extraction of Fetal Electrocardiogram by Combining Deep Learning and SVD-ICA-NMF Methods Combines CNN with mathematical methods for fetal ECG signal extraction from abdominal leads. Emphasizes time-frequency analysis for distinguishing fetal and maternal signals. Efficient fetal ECG extraction. Innovative approach combining deep learning and signal processing. Integrating algorithms may be complex. Potential computational burden. [7]

S. Prabakaran et al. (2019) proposed the An Ultrasound Fetus Phantom Dataset with Deep Neural Network Evaluations for Fetus Orientations, Fetal Planes, and Anatomical Features Introduces a dataset for training DNN models to detect fetal orientations, planes, and anatomical features from ultrasound images. Evaluates on real-world datasets. Provides a novel dataset for fetal ultrasound research. Includes pre-trained models for accurate detection. Dataset limited to phantom images. May face challenges in generalization.[8]

Cordero-Grande et al (2020) Fetal MRI by Robust Deep Generative Prior Reconstruction and Diffeomorphic Registration Proposes a deep generative prior for robust fetal MRI reconstruction integrated with diffeomorphic registration. Evaluates on a cohort of fetal datasets. Improves image resolution and quality Offers competitive gestational age prediction.Relies on MRI data. May face computational complexity.[9]

S. Öztürk et al (2020) proposed A Novel Approach for Cardiotocography Paper Digitization and Classification for Abnormality Detection Introduces a novel approach for digitizing and classifying abnormality in CTG signals using image processing, feature extraction, and SVM classification. Evaluates on a novel dataset. Efficient abnormality detection in CTG signals. Offers a novel approach for digitization and classification. Relies on image processing and feature extraction. May have limitations in generalization.[10]

C. Di Vece et al(2024) Ultrasound Plane Pose Regression: Assessing Generalized Pose Coordinates in the Fetal Brain Analyzing the accuracy of fetal brain ultrasound plane ocalization using convolutional neural network regression, investigating the impact of registration quality and data augmentation Improved accuracy in ultrasound plane localization, analysis of registration quality impact.Reliance on CNN regression, potential challenges in real-world implementation.[11]

S. Ziani et al (2023) analyzed Extraction of Fetal Electrocardiogram by Combining Deep Learning and SVD-ICA-NMF Methods presented Combining CNN with mathematical methods for fetal ECG signal extraction from abdominal leads, emphasizing time-frequency analysis for distinguishing fetal and maternal signals Efficient fetal ECG extraction, innovative approach combining deep learning and signal processing Complexity in algorithm integration, potential computational burden.[12]

B. S. Prabakaran et al (2023) presented FPUS23: An Ultrasound Fetus Phantom Dataset with Deep Neural Network Evaluations for Fetus Orientations, Fetal Planes, and Anatomical Features Introducing a dataset for training DNN models to detect fetal orientations, planes, and anatomical features from ultrasound images, evaluating on real-world datasets. Novel dataset for fetal ultrasound research, pre-trained models for accurate detection. Dataset limited to phantom images, potential challenges in generalization.[13]

L. Cordero-Grand et al (2023) analyzed Fetal MRI by Robust Deep Generative Prior Reconstruction and Diffeomorphic Registration Pructioro posing a deep generative prior for robust fetal MRI reconstn integrated with diffeomorphic registration, evaluating on a cohort of fetal datasets improved image resolution and quality, competitive gestational age prediction. Reliance on MRI data, potential computational complexity.[14]

S. Öztürk et al (2023) analyzed A Novel Approach for Cardiotocography Paper Digitization and Classification for Abnormality Detection Inducing a novel approach trofor digitizing and classifying abnormality in CTG signals using image processing, feature extraction, and SVM classification, evaluating on a novel dataset Efficient abnormality detection in CTG signals, novel approach for digitization and classification Reliance on image processing and feature extraction, potential limitations in generalization.[15].

3. SYSTEM DESIGN

3.1 PROPOSED METHODOLY

Enhancing Fetal Monitoring Through Innovative Technology Our proposed system aims to revolutionize fetal monitoring during pregnancy by introducing a comprehensive, user-friendly device equipped with advanced sensor technology and wireless communication capabilities. By leveraging the synergies between the Fetal Digital Stethoscope Sensor, MEMS sensor, microcontroller, and GSM module, our system enables real-time monitoring of fetal heart rate and uterine contractions, empowering pregnant women to take proactive measures to safeguard their health and the health of their unborn child.

3.2 ARDUINO MICROCONTROLLER

An Arduino is actually a microcontroller based kit which can be either used directly by purchasing from the vendor or can be made at home using the components, owing to its open source hardware feature. It is basically used in communications and in controlling or operating many devices. It was founded by Massimo Banzi and David Cuartielles in 2005.The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. "Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions.

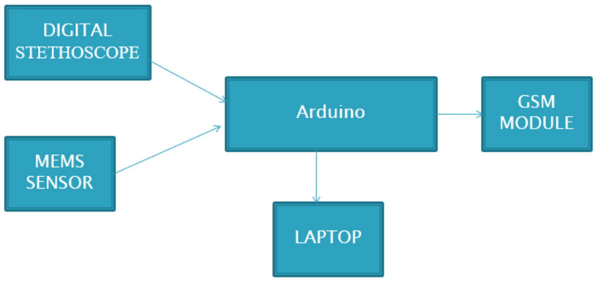


Figure 1.1: BLOCK DIAGRAM

3.3 MEMS SENSOR:

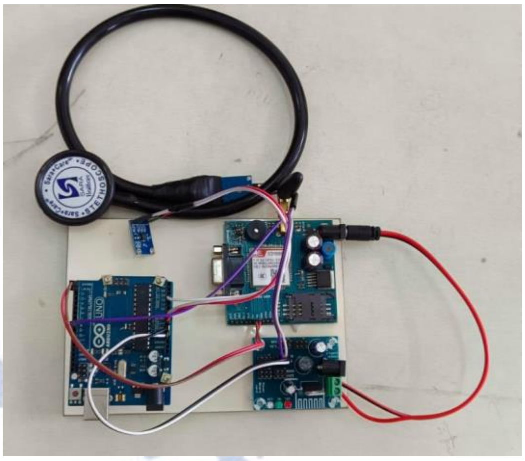
We are using MEMS SENSOR (MMA7600FC) is used for fall detection. This may arise due to low or high Blood Pressure (BP).With the help of this MMA7600FC, whether fall detection occurred or not is known. Micro electro mechanical systems (MEMS, also written as microelectromechanical, Micro Electro Mechanical or microelectronic and micro electro mechanical systems and the related micro mechatronics) are the technology of microscopic devices, particularly those with moving parts. MEMS are also referred as micro machines in Japan, or micro systems technology (MST) in Europe. MEMS are made up of components between 1 and 100 micro meters in size (i.e., 0.001 to 0.1 mm), and MEMS devices generally range in size from 20 micro meters to a millimeter (i.e., 0.02 to 1.0 mm), although components arranged in arrays (e.g., digital micro mirror devices) can be more than 1000 mm2. They usually consist of a central unit that processes data (the microprocessor) and several components that interact with the surroundings such as micro sensors. Because of the large surface area, forces produced by ambient electromagnetism (e.g., electrostatic charges and magnetic moments), and fluid dynamics (e.g., surface tension and viscosity) are more important design considerations than with larger scale mechanical devices.

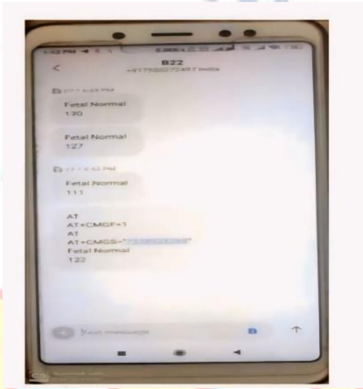
3.4 GSM MODEM:

GSM is a mobile communication modem; it is stands for global system for mobile communication (GSM). The idea of GSM was developed at Bell Laboratories in 1970. It is widely used mobile communication system in the world. GSM is an open and digital cellular technology used for transmitting mobile voice and data services operates at the 850MHz, 900MHz, 1800MHz and 1900MHz frequency bands.GSM system was developed as a digital system using time division multiple access (TDMA) technique for communication purpose. A GSM digitizes and reduces the data, then sends it down through a channel with two different streams of client data, each in its own particular time slot. The digital system has an ability to carry 64 kbps to 120 Mbps of data rates.There are various cell sizes in a GSM system such as macro, micro, pico and umbrella cells. Each cell varies as per the implementation domain. There are five different cell sizes in a GSM network macro, micro, pico and umbrella cells. The coverage area of each cell varies according to the implementation environment.

4. EXPERIMENTAL RESULTS

We conducted a series of experiments using a prototype of our fetal monitoring device, consisting of the Fetal Digital Stethoscope Sensor, MEMS sensor, microcontroller, and GSM module. Pregnant volunteers participated in the experiments, with their consent obtained prior to the commencement of the study. The sensors were positioned on the abdomen of the pregnant women, and data collection was initiated using the monitoring device.





A GSM modem is a device which can be either a mobile phone or a modem device which can be used to make a computer or any other processor communicate over a network. A GSM modem requires a SIM card to be operated and operates over a network range subscribed by the network operator. It can be connected to a computer through serial, USB or Bluetooth connection.

5. CONCLUSION

In conclusion, our project has introduced a novel fetal monitoring system that addresses the critical need for accurate, reliable, and accessible prenatal care. Through the integration of advanced sensor technology, signal processing algorithms, and wireless communication capabilities, our system empowers pregnant women to monitor fetal health from the comfort of their homes while facilitating real-time communication with healthcare providers. One of the key strengths of our system lies in its ability to provide continuous monitoring of fetal health throughout pregnancy, reducing the need for frequent clinic visits and minimizing the burden on healthcare systems. By enabling pregnant women to take a more proactive role in managing their pregnancies and facilitating timely interventions, when necessary, our system has the potential to improve maternal and fetal outcomes while enhancing the overall prenatal care experience.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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