(1)

(A)Title: A Comprehensive Framework for Wearable Module for Prenatal Health Monitoring and Risk Detection

(B)Problem Attempted To Be Solved: Lack of a prenatal health monitoring system which has led to high maternal mortality ratio in Bangladesh.

(C)Method Used: The problem is tackled by designing a costeffective, non-invasive device that connects with smartphones for consistent monitoring.

- The wearable device is placed in a pouch around the user’s waist, and the sensors that

need to be placed on the fingers or underarms are connected to the main processing unit using wires.

- The wearable device monitors temperature, oxygen saturation, heart rate, blood

pressure, and blood glucose.

- Fetal movement and detect unwanted falls is also monitored in this project.

- The designed user interface of the mobile application for maternal health

monitoring. The system can also store the data in the database, and if the doctor wants to analyze the

historical data, he/she can do it using the designated portal designed for the doctors.

-The system has a feature that sends SMS when it detects

any anomaly

- A central processing unit OF the ESP-32s microcontroller is chosen for it's ability to collect and send data over the cloud through Wi-Fi.

TECHNICALITIES

-An NIR 940mm led and a photodetector were used to detect the blood glucose level.

Light absorbed by the high level of glucose in blood is different from light absorbed by the low level of glucose in blood.

Some of the light is absorbed by components like glucose whereas some of the light is scattered due to interactions with cells and tissue structures.

The remaining light either passes through the tissue or is reflected back toward the photodetector.

-Photodetector measures the intensity of light by converting the incoming light into an electrical signal.

However, in order to mitigate the noises, we have enclosed the

glucose measurement system in a black box so that it cannot

be affected by the external lights. This method allows

continuous monitoring without the pain associated with

traditional techniques which involves poking a needle every

time we want to measure.

-To measure blood pressure,

We have used an off the shelf blood pressure monitoring device equipped with an EEPROM which stores the reading of the measurements. The way the Blood pressure machine and the EEPROM chip communicates is by utilizing the I2C(Inter-Integrated Circuit) protocol.

When the blood pressure machine and the EEPROM chip communicate via I²C, it means they use a shared two-wire bus to transmit data.

\*Blood Pressure Machine as Master: It sends commands to or requests data from the EEPROM.

\*EEPROM as Slave: It stores from the master.

-For temperature readings, DS18b20 sensor is used. For monitoring oxygen saturation and heart

rate, the MAX30100 sensor is used.

-In order to get the fetal movement, we have used another IMU(Inertial Measurement Unit) named ADXL335 which is an acceleration sensor.

IMUs are widely used in motion tracking.

- The fall detection algorithm works with the use of acceleration parameters of MPU6050(acceleration sensor). If a sudden change is

seen in the acceleration, then it is considered as the person has fallen.

- If it is seen that after subtracting the MPU6050’s acceleration value from the ADXL335’s there is still a noticeable increase in the acceleration value, then the system flags it as a fetal movement.

(E)Results

MSE measures the average squared difference between predicted (or measured) values and actual (true) values. A smaller MSE indicates better accuracy of the system.

1. Temperature measurement system has a Mean Squared Error of only 0.0035.

The reference device that has been used is a commercially available thermometer.

2.The implemented oxygen saturation and heart rate measurement system has a

Mean Squared Error of only 1.1 and 2.45 respectively.

NB: Normal Blood oxygen level is 95% to 100%.

Normal Heart rate level is 60 and 100 bpm.

The reference device used is a commercially available pulse oximeter.

3.

The Mean Absolute Percentage Error (MAPE) measures the accuracy of a system's predictions compared to actual values, expressed as a percentage.

-The MAPE for systolic blood pressure is 4.54%.

This means that, on average, the measured systolic blood pressure values differ from the actual values by 4.54%. For example, if the actual systolic blood pressure is 120 mmHg, the error would typically be around

-The MAPE for diastolic blood pressure is 5.43%.

Similarly, the diastolic readings differ from the actual values by about 5.43% on average. If the actual diastolic blood pressure is 80 mmHg, the error would be

The data taken is already from a commercially available blood pressure machine.

4. MAPE of only 4.77%, and it can be utilized as an early indicator of any anomaly in the blood glucose trend.

A commercial blood glucose monitoring device is used.

5.For the fall detection, we have used the MPU6050. When a fall occurs, abrupt change happens in the values of the accelerometer in a very short time.

6.To detect the fetal kick, we have used the ADXL335 as the sensor responsible for detection, and it is placed on the abdomen of a pregnant woman based on the fetal orientation.

(F)Conclusion:

A vitals sign monitoring with innovative features like fall detection and fetal movement tracking is designed.

(G)Performance of the system : As per the results obtained, this system is a highly effective one.

(H)Strength: The values obtained from the wearable device compared to commercial devices goes to show the high level of accuracy of the system.

(I)Gap: No integration of AI for predictive analysis of patients vitals to forewarn a risk of complication.

(3)

(A)Title: Fetal Heart Rate and Kicking Monitoring System for Pregnant Woman

(B)Problem: According to a report by WHO, the mortality rate of pregnant women was about 800 per day and to be very precise death occurred almost every two minutes. These deaths are mostly because of the premature fetus and improper diagnosis of the fetus in the last trimester of pregnancy.

(C)Method Used:

-The stethoscope diaphragm detects fetal heart rate by causing a membrane within the stethoscope diaphragm to vibrate in response to the sound from the fetal heart.

It is strategically placed on the abdomen of the pregnant woman.

-A microphone of MAX4466 is used to detect acoustic signals from the stethoscope.

-EMG (electromyography) muscle sensor is augmented by ECG electrodes to capture electrical signals associated with muscle contractions, hence detecting a fetal kick.

-An Arduino microcontroller takes input from the sensors of EMG muscle sensor and MAX4466 and processes it to give output signal to the GSM module in the event that abnormalities are detected.

-GSM Module sends an SMS to a healthcare provider or an expectant mother in event of high or low fetal heart rate, no heartbeat detected or hypoxia detection.

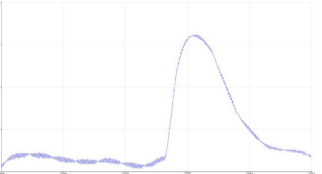
(D)Results

-Heartbeat of Fetus



Heartbeat is measured in terms of milli volts. Whenever the peak crosses the threshold, which is set to a particular level, we sense that there is a heartbeat. This heartbeat is detected on an average per minute or 60,000ms. In this graph, **the peak represents the heartbeat detected and the timescale is shown on the x-axis.**

-Kick Monitoring



Usually, when there is **no sense of movement from the baby, the graph will remain constant at a particular rate** and when the mother senses the kicking, the EMG sensors will be placed on the abdomen of a pregnant belly. **When the baby kicks the belly, a large peak will be detected** as shown in the graph. Whenever we see a peak that crosses a particular threshold, it is sensed that the baby is kicking.

- Fetal Hypoxia:

Hypoxia is a condition where the baby is devoid of oxygen. We have generated a fake fetal hypoxia situation to detect the case. Usually, a zig-zag pattern is observed in the graph. Whenever the heartbeat of the baby falls within the range of – 2 or +2, it detects a hypoxia situation which is very dangerous for the baby.

(E)Conclusion

The fetal heart rate and kicking monitor is designed to provide accurate and reliable monitoring of fetal health, with the ability to alert healthcare providers or expectant mothers in case of any potential issues

(F)Strengths:

-Highly ergonomic and alarm system for timely intervention in event of emergency

(G)Gap:

- Data Security

-Signal Interference and Noise when sensors are measuring the parameters.

LITERATURE 5

(A)Title: A Wearable Device for Evaluation of Relative Position, Force, and Duration of Fetal Movement for Pregnant Woman Care

(B)Authors : Tsai et al

(C)Problem Statement :

- The doctor usually asks the pregnant woman to spend 15 minutes to one hour per day on perceiving and recording the FM at home and to keep written records for the doctor to read .

(D)Method Used :

- In order to validate the sensitivity and clinical feasibility of the device, this study performed phantom simulation tests and clinical tests on 13 pregnant women.

- The phantom test results showed that the device had high accuracy (>90.3%) in recognizing 12 FM positions, the relative force had high correlation (R2 > 0.98), and the duration of FM had a low error percentage .

- In 2017, Heazell et al. indicated that before fetal death in utero due to chronic causes (such as toxemia), there was a definite decrease in fetal movements or cessation of movements, although heartbeats might still audible. This usually requires immediate delivery of the fetus. FM result is often used as an important index of fetal abnormality

- Additionally, according to related studies, the immunologic function degrades due to pregnancy;

- At present, clinical home monitoring of FM depends on the pregnant women’s self-perception.

After the 20th week of pregnancy, most pregnant women can perceive obvious FM.

- FM(Fetal Movement), the vibration resulted from touching the uterine wall is quite appropriate

\*fetal movement acceleration measurement (FMAM)

- Pregnant women are a group prone to infection, the clinical demand for home measurement is growing steadily. Therefore, this study proposed a multi-IMU sensing method that used multichannel sensing to calculate the basis of analysis, in which FM signals could be extensively and accurately measured from the pregnant woman’s abdomen, and the relative FM position, force and time parameters can be demodulated.

- **The FM measuring method proposed in this study used a multi-point IMU to detect FM signals on the pregnant woman’s abdomen**. The FM signals were detected instantly by the energy evaluation, and the signal interval was extracted as the basis of analysis. **All the signals received by the IMU passed through an Inter-Integrated Circuit (I2C), the hardware filter filters the 60 Hz noise, and the data were sent to the MCU**. The signals from various channels were processed by a Kalman filter to reduce noise, and then **the position, duration and relative force (RF) of the fetal movement were worked out from the signal interval generated by the energy evaluation.**

- A triangular measurement shape was extended from a circle as the center point, and there was an IMU sensor at each of the three corners.

MCU……….MicroController Unit

- Related data could be collected in the SD card inside the device and sent to the PC through wire transmission for analysis,

- This study designed an FM simulation system as the basis of a phantom test

- . The phantom test included: (a) an RF of FM test; (b) a position of FM test; (c) a duration of FM test; and (d) a number of IMUs test. The clinical trial compared the measurement result of the device with the pregnant woman’s subjective FM counting, to analyze the clinical feasibility, and used questionnaires to analyze the pregnant women’s acceptance

- The pregnant women clicked the FM counter of the fetal monitor whenever FM was perceived according to their self-perception, to count the number of FMs. At the same time, the device proposed in this study was worn to monitor the FM condition, as shown in Fig. 13. Each subject was measured at least once, and the measurement time was longer than one hour

RESULTS:

* This study invited 13 voluntary subjects, who were recruited from the College of Medicine’s Department of Obstetrics and Gynecology at National Cheng Kung University, Tainan.
* The subjects had to conform with the following conditions: pregnant women over 28 weeks of pregnancy, aged 24 to 37 years, and willing to sign the informed consent
* In order to know the subjects’ subjective thoughts before and after using this device, a simple questionnaire survey on the subjects’ satisfaction was designed. The questionnaire included the subject’s psychological aspect (two items) to know how the pregnant woman felt while wearing the device and the pregnant woman’s satisfaction after use (three items)
* In order to know the subjects’ subjective thoughts before and after using this device, a simple questionnaire survey on the subjects’ satisfaction was designed. The questionnaire included the subject’s psychological aspect (two items) to know how the pregnant woman felt while wearing the device and the pregnant woman’s satisfaction after use (three items)
* The clinical medical care personnel who participated in this clinical trial were satisfied with the design and the wearing method of this device.

CONCLUSION:

-A method for measuring FM was proposed and a wearable device for long-term home measurement was designed, to effectively obtain the position, duration and relative force of FM. The feasibility of this device was validated by a self-made FM simulation system. The test results proved that this device had decent performance in distinguishing the FM position, FM duration accuracy and relative FM force.

GAP : Also, related AI methods might be applied to improve the specificity of this device.

(4)

SIDE NOTES

- Photoplethysmography (PPG) data refers to signals collected through a **non-invasive optical technique** used to measure changes in blood volume in the microvascular tissue.

IMPORTANCE OF CONTINUOUS PATIENT MONITORING

- Records small, subtle changes in health parameters that might be missed with periodic checkups. Examples include fluctuations in heart rate, blood pressure, oxygen levels, or uterine activity.

-We’ll use big data analytics and AI in the project.

-Recent studies show that such remote health monitoring systems can improve health outcomes for both mother and baby during pregnancy and the postpartum.

-Such monitoring provides a holistic view of mothers’ health, promoting healthy lifestyles in pregnancy and reducing the risk factors for health in pregnancy.

NON-FUNCTIONAL REQUIREMENTS

(1) Feasibility and usability

(2) Energy consumption and efficiency

(3) Reliability and Accuracy.

-Most monitored are:

\*Sleep

\*Heart Rate

\*Step count

-A **healthy circadian rhythm** is a natural, internal process that regulates the sleep-wake cycle and repeats approximately every 24 hours.

-A **PPG (Photoplethysmography) sensor** is a non-invasive device used to measure changes in blood volume in the microvascular tissue, which occurs as a result of blood flow.

NB: For the portable device, it is a blood pressure device whose values are manually input into the mobile application.

\*The participants were also asked to measure their blood pressure once a week.

\*We carried out the full system implementation and conducted a real human subject study on pregnant women in Southwestern Finland.

\*We also integrated various AI-based and machine learning methods into the system in a holistic way, providing a data analysis pipeline. This pipeline contains deep learning-based quality assessment of data [30], personalized modeling, missing data imputation and anomaly detection. What does this mean?

Answer :

* The statement describes an advanced system that incorporates artificial intelligence (AI) and machine learning (ML) techniques into its functionality to process and analyze data effectively. Here's a breakdown of what it means:

1. Holistic Integration: The system is designed to work as a unified whole, where different AI and ML methods are combined seamlessly. This ensures that all components work together to enhance data analysis.

2. Data Analysis Pipeline: This refers to a structured process or workflow for analyzing data. It typically involves multiple steps, each focusing on a specific task, to transform raw data into actionable insights.

3. Deep Learning-Based Quality Assessment: Deep learning models are used to evaluate the quality of the data. For instance, they might detect noise, inconsistencies, or other issues in the data, ensuring that only high-quality data is used for analysis.

4. Personalized Modeling: The system creates models tailored to specific users, datasets, or scenarios. For example, in a healthcare setting, it could customize predictions or recommendations based on an individual's unique health data.

5. Missing Data Imputation: When there are gaps in the data (e.g., missing measurements or records), the system uses machine learning algorithms to predict and fill in the missing values. This ensures that the analysis remains robust even with incomplete data.

6. Anomaly Detection: This involves identifying unusual or unexpected patterns in the data that may indicate errors, fraud, or significant events. For instance, in a medical context, it could detect irregular vital signs that might signal a health issue.

In summary, the described pipeline uses advanced AI and ML methods to enhance the quality, completeness, and reliability of data, allowing for more accurate and personalized analysis and decision-making.

STRENGTHS:

- The data are stored anonymously in the server to ensure the user’s privacy(Data Security Point)

- Machine learning algorithms are exploited to train patients’ models, by which trends and changes are evaluated throughout the pregnancy and postpartum.

GAP

- Data uploading will be automatic and real-time to improve user experience

LITERATURE 6

Notes:

- Monitoring is often the first step in early detection of pregnancy abnormalities, providing an opportunity for prompt, effective intervention to prevent maternal and neonatal morbidity and mortality.

-The system consists of

1. Sensors (3 total)

- Wireless sensors that capture physiological data

- Likely measuring different parameters simultaneously

- Capable of Bluetooth Low Energy (BLE) wireless transmission

2. Mobile Tablet

- Acts as a "base station" or central hub

- Receives data from all three sensors simultaneously

- Uses Bluetooth Low Energy for communication

- BLE is energy-efficient wireless protocol

- Low power consumption

- Allows continuous data transmission

- Shorter range (typically ~10 meters)

3. Real-Time Data Display

- Immediate visualization of sensor data

- No delay between measurement and display

- Allows continuous monitoring

- Likely includes:

- Live graphing

- Numerical readouts

- Potential alerts/notifications

- Historical data tracking

\* **Electrohysterography (EHG)** is a non-invasive method used to monitor the electrical activity of the uterine muscles. It involves recording and analyzing the bioelectrical signals generated by uterine contractions.

\* Central Temperature:

* Core body temperature
* More accurate than peripheral measurements
* Normal range: ~37°C (98.6°F)
* Monitors for:
  + Fever
  + Infection
  + Thermoregulation

\*Peripheral Temperature:

* Measures temperature at body extremities
* Different from core/central temperature
* Normal range varies by location:
* Fingers: ~32-35°C (89.6-95°F)
* Toes: slightly lower

\* Real-time comparison of maternal HR and FHR is also displayed on the software interface

Literature (2)

-First, a wearable device obtains patient health parameters, this data gets sent to a mobile device through an application, the data gets stored in a database in the cloud and finally the data is processed and analyzed through a data analytics application offered by the cloud provider

- The wearable device is connected via Bluetooth with the mobile application all the data captured by the wearable will pass immediately to the cell phone and the memory of the wearable will be cleaned to obtain new data. This case occurs when the cell phone is not connected to the wearable, otherwise the data will be stored directly in the cell phone memory.

- The patient will be able to monitor his health anytime through the statistics shown in the application, besides this, he will be able to visualize the medicines that s/he must take, appointments and her/his treatment. The application is also developed to alert the health organization and the patient when an incident of high blood pressure is present, this alert also shows the location on google maps in which the patient is located.

- The device captures her blood pressure, heart rate and patient steps

- Another interesting finding was to observe and confirm health guidelines. For example, we found that in their thirtieth month, pregnant patients had a greater number of alerts for high blood pressure and high heart rate compared during their twentieth month of gestation. **Although, this finding was not surprising, it helped healthcare providers develop preventive and corrective actions starting from week 28th of pregnancy.**

**-** **We showed the healthcare providers how the data could be potentially analyzed and displayed. For example, one graphs showed all patients who had their blood pressure and heart rate controlled. A second graph indicated the analysis of the patients based on the healthcare parameters, and a third graph showed the month of gestation where higher alerts by pressure or high heart rate occurred. This preliminary information helped the healthcare providers to start developing new strategies to control and monitor these patients more efficiently and effectively.**

**\*Controlled means patients being actively monitored, with blood pressure within target range.**

**\*** **110-160 beats per minute (bpm)……A constant deviation of +2 or -2 every minute could indicate a warning**

Literature 3

1. Stethoscope diaphragm: The stethoscope diaphragm is used to detect the fetal heart rate. It contains a membrane that vibrates in response to the sound of the fetal heart, allowing the monitor to detect the heart rate.

2. Microphone (MAX4466): The microphone is used to detect acoustic signals from the stethoscope. The MAX4466 microphone is a high-sensitivity, lownoise microphone that can accurately pick up the sound of the fetal heart.

3. EMG Muscle sensors: EMG muscle sensors are used to **detect and record the electrical activity produced by muscles**. They are commonly used in medical applications to assess muscle function and diagnose neuromuscular disorders.

4. Arduino Uno: The Arduino Uno is a microcontroller **that processes the inputs from the sensors,** **such as the EMG muscle sensor and the MAX4466 microphone**. It is programmed to analyze these **inputs and send a signal to the GSM module if any abnormalities are detected.**

5. GSM 7670C: The GSM module is used to communicate with a recipient, such as a healthcare provider or the expectant mother, in case of an emergency. **It can send SMS alerts about conditions such as high or low fetal heart rate, hypoxia detection, no heartbeat detected, and kicking monitoring**.

6. SMS alert: **Once the Arduino Uno detects an abnormality, it sends a signal to the GSM module, which then sends an SMS alert to the recipient**. The SMS alert provides information about the detected condition, allowing the recipient to take appropriate action.

Literature 4

**1.Stress, sleep, and physical activity were the vitals monitored.**

**2.** **It enables performing big data analytic and machine learning algorithms to find trends and anomalies in the collected data. It provides personalized health monitoring and alarm notifications by analyzing individuals data**

**3.** **An SSL API (Secure Sockets Layer Application Programming Interface) was also utilized to provide secure communication.**

**\*** **Provides encrypted communication**