IoT Enabled Prenatal Health Monitoring System for Pregnant Women

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Abstract. Maternal and new-born well-being is a concern for underdeveloped as well as developing countries. Pregnancy problems, such as miscarriage, stillbirth and premature birth, increase the risk of maternal and new-born death. Pregnancy problems can be reduced by making lifestyle changes and focused health monitoring under supervision of trained, well equipped health care professionals during and after pregnancy. Approximately more than 40% population reside in rural areas, where medical systems are not integrated to facilitate information exchange. In the first trimester of pregnancy, most pregnant women in these countries are unable to get their normal checks, which results in a greater death rate for both the new-born and mothers in these areas. Also, it is not possible to monitor health vitals of pregnant women in the absence of physicians all the time during pregnancy due to several reasons like global availability of physicians, labs etc. The women's health is at jeopardy as a result of this predicament.

Although, practitioners recommend ultrasound scans to see the growth of fetus. In underdeveloped and developing countries, access to such scanning facilities is not very common as well as expensive. To address these issues, the authors propose a solution in the form of a device which consists of various sensors like Temperature sensor, Heartbeat rate sensor, Blood Pressure sensor, Sweat sensor to measure sugar levels, oximeter to measure oxygen level, weight machine to measure weight, Accelerometer sensor and other devices like Arduino, GSM module etc. which can be further converted into compact device for accessing vital statistics of pregnant women to integrate it and to transfer the captured readings to the Thingspeak cloud so that the analytics can be monitored by physicians with the help of mobile or web application etc. The availability of IoT sensors and devices make this solution affordable with high accessibility for personalized care.

Keywords: Oximetry, Temperature sensor, Heart rate sensor, Accelerometer sensor, Blood pressure sensor, Arduino, Internet of Things, Thingspeak cloud, GSM.

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1 Introduction

When a mother dies during pregnancy or childbirth, or when the infant dies, the excitement and anticipation of such couple, family, or community is suddenly replaced by sorrow and loss.[1]As per data published by WHO, nearly 810 women died from pregnancy-related causes every day in 2017 and approximately 94% maternal mortalityoccurred in developing countries. Teenagers between the age of 10 to 14 were facing various complications and deaths as a result of pregnancy related issues.[2] According to UNICEF estimates, over 6,700 neonatal fatalities occur daily, with one-third occur-ring on the first day of life and nearly three-quarters within the first week, with 2.4 million children dying in 2019.[3] Nearly 2 million stillborn births are reported each year, most of these can be prevented. It is possible that even in developed nations, the frequency of miscarriages and stillbirths is underestimated.[4]

Among the most common causes of neonatal deaths, experts think that prematurity-related complications account for 21% of cases, birth asphyxia and injury (23%), neonatal tetanus (7%), congenital malformations (7%), and diarrhoea (3%). Mothers, family members, and traditional delivery attendants are the primary caregivers for the vast majority of these newborns who pass away at home.

Anxiety and stress during the course of pregnancy are also substantial risk factors for a variety of pregnancy problems, including miscarriage, stillbirth, and neonatal death. There are many factors that can interfere with the adaptations that are necessary for a successful pregnancy: maternal challenges, environmental stresses, and more.

Most of these disorders can be diagnosed with the aid of ultrasound scanning, whichis a non-invasive diagnostic tool that can help prevent the negative effects of pregnancycomplications as well as assist in treatment and monitoring of progress of the baby inside the womb. However, this obstetric method of using ultrasound scanning is not widely used, and even doctors, professional obstetricians, and sonologists in developing countries are not completely trained in its advance interpretation. There are also concerns about the long-term implications of prolong ultrasonic exposure on the fetus, its affordability and accessibility. Ultrasound scans can detect some issues, but they can also expose the baby to heat, which can cause birth defects.

High mortality rates in rural areas due to lack of knowledge and awareness are a problem. People skipped their regular check-ups not only because of a lack of hospitalsin the vicinity and approaching hospitals and medical practitioners is tough due to distance, time and affordability as well as earning livelihood for survival is the priority.

In order to ensure the birth of healthy children, timely qualitative medical attention is required. It is very important to monitor various vital statistics during pregnancy like blood pressure, blood sugar, weight, vaginal bleeding, body temperature, blood oxygen saturation levels, heartbeat of fetus, fetal kick count etc. and even behaviour to track stress and anxiety.

We all know that if skilled and smart care is made affordable during the pregnancy then more and more lives during and after childbirth can be saved. The Internet of Things (IoT) has made it possible to implement real-time remote health monitoring systems. The cloud server enables data storage and a wide range of health data analytics.

2 Proposed Work

A system that includes a heartbeat sensor, temperature sensor, blood pressure sensor, pulse oximeter, and an accelerometer sensor to count the kicking of the fetus. We can collect data from these sensors and transfer it to the mobile app using IoT infrastructure with the help of ARDUINO UNO. The information captured through the sensors is be visualised and analysed using Thingspeak cloud and be displayed on a web or mobile application.

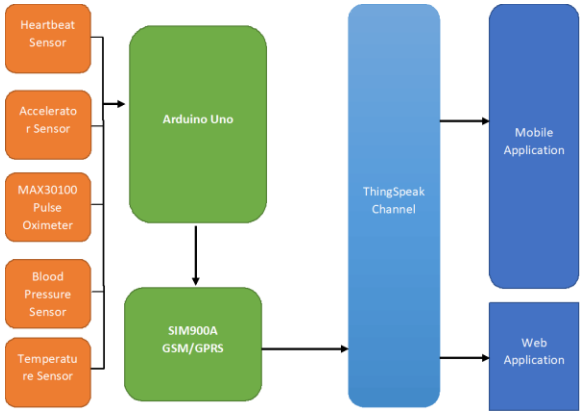

Fig. 1. Block Diagram of IoT Enabled Prenatal Health Monitoring System

3 Hardware Parts

3.1 Use of Body worn Accelerometer for measuring Fetal Kicks

Fetal kicking in the uterus is a sign of fetal health that is mostly determined by the vascular status of placental insufficiency. The maternal sense of movement known as "kicking," begins in the fourth month of pregnancy.[5] The fetal demonstrates more clearly longer duration of fetal movements gradually over time. At various times of the day, the fetus becomes more active, and it begins to adjust to a more regular sleep-wake pattern.[6] When it comes to fetal movements, fetal has a unique style. Monitoring fetal movements entails not only measuring the number of movements, but also learning about what goes on within the uterus and the typical pattern of their fetal movements.[7] Fetal movements must be monitored by mothers because fetal spontaneous movements are the most basic signs of early neuronal activity. These movements help determine whether the fetal is in good health or requires additional monitoring or assistance.[8]– [10]

The accelerometer is an electromechanical device that measures dynamic forces. Dynamic force is caused by the accelerometer's movement or vibration. That is why in this study

accelerometer sensor is used to detect the dynamic movement of the fe- tus.[8]Accelerometer-based systems are safe, cheaper, and can be used in home envi- ronment.

In this study, a typical 3-Axis accelerometer sensor with an analogue output was used. The sensor needs to be attached to the maternal abdominal wall of pregnant lady. An Arduino microcontroller was used to process the analogue output signal captured by the accelerometer. The sensors involved are completely safe for both the mother andthe fetus. As it is essential for long-term monitoring, it does not emit any signal that could impair fetal development.

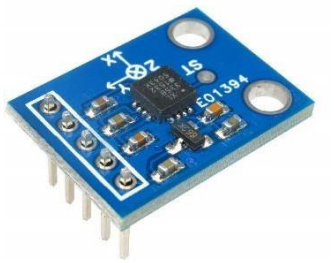

Fig. 2. ADXL335 Triple Axis Analog Output Accelerometer Tilt Angular Transducer Module

3.2 Use of Temperature Sensor

A woman's body undergoes many changes during pregnancy. Bodily temperature tendsto rise along with other pregnancy symptoms like a growing belly, changing skin and morning sickness. This is one of the most unpleasant aspects of pregnancy for most women. The discomfort that comes with weight gain is exacerbated by the rising temperature. There is nothing wrong with a slight increase in temperature, but overexposure to heat can be dangerous. Keeping core body temperature below 102.2 degrees F is essential. Pregnancy glow is a real phenomenon that is a combination of joy and a heat flush. It is a mixture of both. The body's temperature rises with each stage of pregnancy. It's common for pregnant women to notice a noticeable increase intheir body temperature and perspiration, even in their sleep. New hormones are releasedduring pregnancy to ensure that everything goes according to plan. The body's temperature may rise slightly as a result of the hormonal changes. As the body gets ready to welcome a new life, it uses more blood to transport oxygen and nutrients to the baby. When blood volume increases, the heart must work harder to keep up. Body temperature rises as a result of an increase in heart rate. When a pregnant woman is exposed to excessive heat, it can have negative effects on both the mother and the unborn child.

Backbone and spinal cord development may be affected by heat stress, according to medical studies. Problems such as neural tube defects can arise depending on the stage of pregnancy and the level of heat exposure. Your baby's growth can be harmed by theheat. Miscarriage or birth defects can be caused by excessive heat in the first trimester.[11]

So, it is very important to monitor temperature of the pregnant lady time to time to avoid problems. The LM35 is a temperature sensor with precision whose output volt-age changes with temperature. Temperature ranges from -55°C to 150°C can be measured using this inexpensive IC. An ADC-capable microcontroller or development plat-form like Arduino can easily be attached to it.[12]

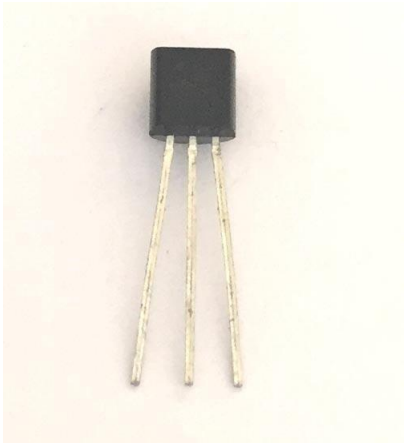

Fig. 3. LM35 Temperature Sensor

3.3 Heartbeat Sensor

Pregnant women should closely monitor their heart rate because it indicates the healthof their heart (just heart rate). Electrocardiography is the most accurate method for measuring heart rate. A Heartbeat Sensor, on the other hand, is a more convenient method of monitoring the heart rate. A variety of sizes and shapes are available, makingit possible to take a quick reading of a person's heartbeat. Heartbeat Sensor is used to measure the heart rate, which is referred to as "the speed of the heartbeat." Photo-plethysmograph is the underlying technology of the Heartbeat Sensor. An organ's volume change is measured by the intensity of light passing through it. Beats per minute, is a way to measure the number of times the heart contracts or expands in a given period oftime.[13]

Fig. 4. Heartbeat Sensor Module with Probe (finger based)

3.4 Blood Pressure Monitoring

One in every twenty pregnant women, or 5%, will experience an increase in their blood pressure. Gestational hypertension is a condition in which their blood pressure rises slightly and their urine contains no protein. Pre-eclampsia is a condition in which their blood pressure rises significantly and their urine contains protein. This milder form of pre-eclampsia, gestational hypertension, requires careful monitoring, according to new research.

Pre-eclampsia is brought on by a problem with the placenta, which connects the mother and the child and feeds them both nutrients and oxygen taken from the mother's bloodstream. If it goes unnoticed, it could pose a serious threat to both mother and child. A rise in blood pressure and the presence of protein in the urine are two of the most common symptoms. Having regular prenatal checks by a midwife is critical to catching any problems early and getting them taken care of. If pre-eclampsia is discovered, the pregnant woman and her unborn child will have to be closely monitored. Pre-eclampsia can only be treated by having the baby delivered, which may necessitate a premature birth.[14],[15]

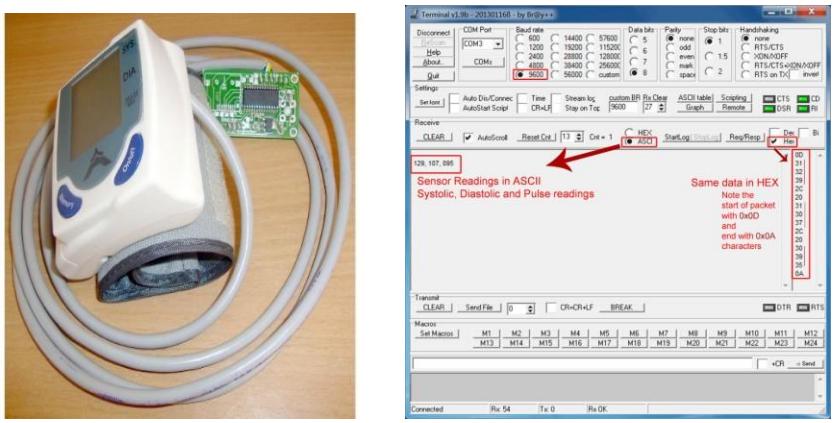

Fig. 5. Blood Pressure Sensor - Serial output

3.5 Oximeter

Oxygen deprivation increases the risk of a stillbirth, Intrauterine growth restriction, or diabetes in the womb. Pregnancy and sleep apnea share a few symptoms, making it difficult to tell the difference between healthy and unhealthy changes in the body. When a mother is able to tell the difference between the two, she will be better equipped to understand her body and, if necessary, take action to find a cure. In order to make this happen, she needs a sleep study. Oxygen treatment options are available once the issues have been identified.

The lungs take in oxygen and then distribute it throughout the body. Oxygen is carried by the blood to various parts of the body. Hemoglobin is the primary oxygen carrier in our blood. The

oxygen saturation level of a patient's blood is measured with this instrument, which is applied to the finger, earlobe, or toe of the patient. The amount of oxygen in the blood in the finger is measured by passing small beams of light through the blood. Oxygenated and deoxygenated blood are measured by comparing light absorption changes in blood.[16]

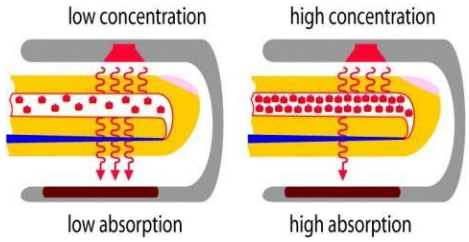

Fig. 6. Light absorption in oxygenated or deoxygenated blood

Fig. 7. MAX30100 Pulse Oximeter

MAX30100 has two lights: one emitting red and the other infrared. Pulse rate measurement necessitates the use of infrared light. Oxygen levels in the blood can be measured using both red light and infrared light. A rise in oxygenated blood occurs as a result of an increase in blood volume. Relaxing the heart causes a decrease in oxygen-ated blood volume. The pulse rate can be calculated by timing the rise and fall of oxygenated blood.[17]

Infrared light is more readily absorbed by oxygenated blood, but deoxygenated blood emits more red light. Since both light sources have their absorption levels measured, this is the MAX30100's primary job. It stores those readings in an I2C buffer for later use.

3.6 Internet of Things in Healthcare

IoT, is a term that's been around since the early '90s, but it has become a lot more popular recently. It wasn't until 1999 that the term "Internet of Things" was coined to describe these functions. IoT is all around us. Because of its prevalence in nearly every environment, it has a stranglehold on our daily lives, whether we are aware of it or not. There are many components

that work together to collect and share information, as well as to process data, in order to produce actionable results that can be used for a variety of purposes.[18] Electronic devices, digital and mechanical appliances, and similar "things" are all included in this umbrella term. Everything that goes on when internet- connected devices, such as everyday objects or special gadgets, are used for a specificpurpose is referred to as the IoT.[19][20]

General and sensing devices are the two types of devices that make up the process. When it comes to data hubs and information exchange, general devices are the gadgets or appliances that serve as the primary component. When it comes to sensing devices, they are made up of sensors and actuators that are used to perform in-device functionssuch as measuring humidity, temperature and light intensity. A processing node or gate- way receives the actual data extracted from sensors and appliances. Once the data is processed in the node, it will be sent to a back-end network known as the cloud. All general devices can communicate and interact with each other through the cloud, whichis the IoT's network. Data can now be securely stored and passed on to the next step forfurther analysis. Data from general and sensing devices is analysed in this phase to produce a solution that will be of great benefit to companies who are using this technology.[21][22]

There is already a lot of value and innovation in the Internet of Things. This smart process, however, is life-changing when applied to critical sectors like healthcare The Internet of Things has improved the daily routines of everyone in the ecosystem, from patients to providers and everyone in between:

It's a great source of information for researchers who are looking for ways to improve healthcare and other industries, thanks to the massive amounts of data that come from IoT devices. Researchers' ability to conduct large-scale studies is broadened by the easewith which they can collect data from all over the world.[20]

Using the Internet of Things, the healthcare industry has been able to come up with concrete and functional solutions. Medical facilities and other businesses now have the opportunity to actively improve their performances and services through IoT-connected devices as a result of the network's expansion. People all over the world are managing and responding to illnesses in profoundly new ways as a result of the IoT in action.

3.7 SIM900A GSM/GPRS Module

SIM900A GSM module is capable of operating at 900 and 1800 MHz. We can connect a PC and a microcontroller equipped with an RS232 chip to the modem via the included RS232 interface (MAX232). AT command can be used to change the baud rate from 9600 to 115200. An internal TCP/IP stack allows end users to connect to the internet via GPRS with the GSM/GPRS Modem.[23] This module help the Arduino controller to communicate sensors information to the IoT cloud. To send data to Thingspeak, ATcommands for the GSM Module will be used to provide information about heartbeats, temperature, and blood pressure, as well as fetal kick count.

Fig. 8. GSM SIM800/900 GPRS Module

3.8 Thingspeak Cloud

Thingspeak is an IoT analytics solution that allows users to gather, visualise and analyse real-time data streams in the cloud via a web browser. As soon as a device posts information to Thingspeak, it is immediately visualised by Thingspeak. Online analysis and processing of data can now be done using MATLAB code in Thingspeak.[22] A Rest API or MQTT can be used to submit data from any internet-connected device to Thingspeak. [24]

In the proposed solution, Thingspeak is used for real-time monitoring of all the data provided by sensors for health monitoring of pregnant women. Thingspeak provides a digital dashboard as mobile application or web application that displays real-time prenatal health statistics of pregnant women.

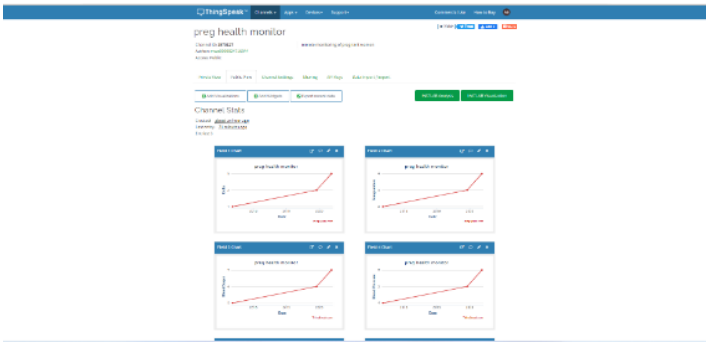

Fig. 9. Thingspeak Channel for prenatal health monitoring

4 Conclusion

Traditional healthcare institutions can no longer meet the needs of a constantly evolving and expanding population. As the population of pregnant women continues togrow, the globe must face the necessity of providing assisted-living facilities. Women in rural communities are pursuing the same goals. It's because of this that there are many serious and fatal complications in pregnancy. The solution is smart healthcare. This research proposes a state-of-the-art and unique IoT paradigm for smart maternal healthcare. Sensors can be used to monitor a variety of health metrics, including the number of kicks a fetus makes, heartbeats, blood pressure, temperature, and oxygen levels. In addition, practitioners will be able to use mobile or online applications to view and analyse patient data in the cloud so that they can provide prompt treatment. The proposed solution will be able to provide health experts with information with least delay.

Future research will focus on how the underlying system may be used to a wide range of situations, including those where there are a lot of sensors. Healthcare organisations looking for low-cost and low-risk solutions, this could be a great resource. For this purpose, an omnichannel approach will be developed, which implies that patient information will be made available across various media, including web apps, online forums, and electronic communications. As a result, a data and information platform might be established.

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