

Smart Cervix Monitoring of Pregnant Women

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Health monitoring can be achieved by using different sensors for measuring the health parameters like heart rate, blood pressure, baby's position, sleeping posture, number of steps, pulse, body temperature change. The problems such as preterm birth, cesarean deliveries, infections, sudden infant death syndrome, false alarms can be avoided using this system. The changes during pregnancy are position shifts, density changes, cervical mucus changes & cervical length becomes measurable and during labor, cervix changes include stages such as effacement, dilation, the baby moves through the birth canal, after birth and recovery. The cervix monitoring can be done by using dilation sensors where the fetal movements and uterine contractions can be measured which is useful for avoiding the risk of cesarean deliveries, preterm birth, or preterm labor. During labor, it is also very important to check the position of fetal head for birth, so deep neural networks are used for measuring the fetal head biometric parameters such as head circumference and biparietal diameter. Health monitoring sensors can be fitted in the wearable devices, so it becomes easy for pregnant women, her family and doctors to continuously track the report of her for avoiding any unnecessary complications.

Keywords: Cervix Dilation sensors, Deep Neural Networks, Cloud Computing, Internet of Things, Wireless Sensor Networks.

1. INTRODUCTION

Nowadays, it is very important to monitor the pregnant women's life as she gives birth to a new life. So, it is the need of continuous monitoring of their health. In the science, today though there are many techniques and devices used for monitoring of pregnant women. But side by side it's also necessary to have the devices or technologies with safety, efficiency, not expensive and it should give more accuracy in any kind of complications or problems occurred in pregnant women's life.

Pregnancy, on top of referred to as gestation, is the time during which several siblings develop within a woman. A couple of being pregnant includes multiple offspring, reminiscent of with twins, being pregnant can happen by sexual activity or assisted reproductive technology. A being pregnant may lead to a reside birth, a miscarriage, a precipitated abortion, or a stillbirth. Childbirth usually happens round 40 weeks from the beginning of the continue menstrual length. This is barely over 9 months, the place every in around 28 days averages 31 days. Lijue Liu [2020], When measured from fertilization it is set 38 weeks. An embryo is the constructing descendant all through the primary eight weeks in line with fertilization, wards which, the time fetus is used till birth signs of early being pregnant may encompass overlooked periods, smooth breasts, nausea and vomiting, hunger and often urination being pregnant might be confirmed with a being pregnant test.

Pregnancy is split into three trimesters, every lasting for about 3 months; the primary trimester consists of conception, which is when the sperm fertilizes an egg. Also, the fertilized egg, then travels down the fallopian tubes, falling and clinging to the inside of the uterus, the place where it begins to appear to the embryo and placenta for the duration of the primary trimester, the potential for miscarriage (natural loss of life of the Embryo or fetus) is highest in the middle of the moment trimester, the flow of the fetus is likely to be felt. At 28 weeks, greater than 90% of infants can continue to exist outdoor of the uterus if supplied with excellent quality clinical care,

Lijue Liu [2020]

As pregnancy is the most important phase in every woman's life, there are many complications and risks factors available in this phase as well. The risk of miscarriage is highest cases for this phase. The other risks or complications in pregnant women's life are: - infant death of mother or child, caesarean deliveries, heart diseases, high blood pressure and preeclampsia, preterm delivery, risks of infections, life threatening events, pulmonary embolism. These above risks or complications are involved with the five things which gives a high-risk factor for pregnant women and those are: age, socioeconomic status, gender inequality, available resources, and parity. Sometimes, one of the huge problems can occur and that is giving the false alarms in pregnancy conditions. This can lead to above complications or risk factors for women and her family. The pregnancy conditions that can cause some false alarms to be like- mild vaginal bleeding, fever, headaches, contractions (false labor), pain, Fluid discharge.

There are various technologies and algorithms used for reducing the above complications, risks and false alarm in pregnant women's life. In this model, this above risks factors and false alarms conditions are considered as parameters and have been implemented by using the deep Convolutional neural networks and other machine learning algorithms. The cervix dilation sensors or devices can be used to reduce the problem of caesarean deliveries, preterm delivery, risks of infections, etc. The dilation device can be inserted in the vagina of the pregnant women and continuous monitoring can be occurred to stop the complications of pregnant women and to deliver the correct information about the pregnancy and her delivery on time.

2. LITERATURE REVIEW

The Paper, "System for real time cervix analysis and monitoring of pregnant woman", Patil [2016] Author describes that this system is utilized to constantly screen the strength of enceinte ladies. It is withal used to diminish the danger of preterm conveyance, the danger of diseases, hazardous occasions. It is utilized to give ongoing cervix analysis.

The Paper, "A Study of E-Healthcare System for Pregnant Women", Rydhm Beri and Singh [2019] describes about this model gives social insurance answers for enceinte ladies by using perspicacious gadgets. This model can profit the medico to a more profound break down the enceinte ladies if there should be an occurrence of any high-hazard pregnancies has occurred.

The Paper, "Wearable Patch Device for Uterine EMG and Preterm Birth Monitoring Applications", Young Chang Jo [2018], to remove the EMG signal from the ECG+EMG complex, the differential mode circuit arrangement is planned, and test results show great extraction execution. The quantity of envelope top purposes of EHG signals is required to be valuable in anticipating preterm conveyance chance.

An IoT-based wearable system using accelerometers and machine learning for fetal movement monitoring, Xin Zhao [2019], an IoT-based wearable framework is utilized for fetal development observing. By joining signal pre-handling, limit identification, cross-relationship, and AI, computational unpredictability could be decreased while keeping up high grouping precision and power. A superior microcontroller makes the neighborhood execution of these calculations possible.

A Hospital Healthcare Monitoring System Using Wireless Sensor Networks, Aminian and Naji [2013], this versatile physiological checking framework is utilized to consistently screen all the parameters in the medical clinic. This framework can do long haul checking of the patient's condition and is furnished with a crisis salvage system utilizing SMS/Email. The proposed framework gives better execution is regarding inclusion, vitality utilization, and postpone time.

Neural networks prediction of preterm delivery with first trimester bleeding, U. Elaveyini [2011], Artificial neural networks serve a decent device to foresee the occurrence of preterm work, which will empower the specialists to remember the hazard factors related to seeping during the primary trimester when choosing antenatal observation and the executives of such pregnancies. This model can be utilized to recognize ladies at the danger of untimely conveyance for arranging antenatal consideration and clinical intercessions in pregnancy.

Application of machine-learning to predict early spontaneous preterm birth among nulliparous non-Hispanic black and white women, Ann Weber and Shaw [2018], Contrasted with different examinations, cross-approval is acquainted with lessen the danger of over-fitting the information and missing information ascription to limit predisposition from barring cases with deficient data. Three punished relapse calculations offering change inclination tradeoffs utilized for investigating better expectations. AI calculations improved the exhibition of all the data.

In Vivo Measurement of Cervical Elasticity on Pregnant Women by TorsionalWave Technique: A Preliminary Study, Paloma Massó and Rus [2019], TW strategy is a possible way to deal with equitably evaluates the diminishing of cervical solidness identified with gestational age. TW strategy may give clinically pertinent information on the cervical aging notwithstanding that acquired from advanced investigation and standard sonography.

3. MATERIALS AND METHODS

From the above survey and prior art, some technologies are used in this model for the implementation. Using these technologies, the different parameters are analyzed for the continuous monitoring of data. The technologies used in this model are IOT (Sensors, WSN, Communication, Embedded Systems, Health App), Wearable devices. The analysis is done based on these technologies which will help in implementing the model for continuous monitoring of data and reducing all the complications and risks in pregnant women's life and her family.

a) **IOT (Internet of Things): -**

The Internet of Things (IoT) is a process of interrelated computing devices, mechanical and digital machines supplied with unique identifiers (UIDs) and the power to switch information over a community because there is no requiring human-to-human or human-to-computer interaction.

The definition of the Internet of Things has advanced resulting from the convergence of more than one technologies, real-time analytics, machine learning, commodity sensors, and embedded systems. Conventional fields of embedded systems, Wi-Fi sensor networks, regulate systems, automation (including dwelling and constructing automation), and others all make contributions to enabling the web of things. In the shopper market, IoT know-how is more importantly synonymous with merchandise bearing on the idea that of the "smart home", masking units and home equipment (such as lights fixtures, thermostats, dwelling safety programs and cameras, and different house appliances) that beef up a number of standard ecosystems, and shall be managed via gadgets related to that ecosystem, reminiscent of smart phones and brilliant speakers.

Using the IOT sensors, one smart solution can be built for the pregnant women by taking the health into consideration. So, this can be called as health care preg model, where different health parameters of pregnant women and child are measured. The different health parameters such as blood pressure, pulse rate, varies in body temperature, no. steps taken, baby squirt, sleeping posture, baby posture, swelling relationship with the woman's physique When measuring these health parameters, the response will analyze the diversifications of women's well-being and will categorize women's well-being from according to the proportion of problems, such as no complications, minor complications, or significant complications. To measure the different parameters, various IoT sensors like temperature sensor, pulse oximetry sensor, LDR module, gyroscope sensor, accelerometer sensor, Flexi sensor, nodeMCU microcontroller are used.[6] In this model, by using these sensors, the wearable devices are designed.

b) **Health App: -**

The Health Care Preg Model has been designed with wearable devices and these wearable devices data is to be stored on cloud and can be used with the help of Smart Health Preg App. Nowadays, Android platform has very trending effect on every human and it is easily

useable. So, this app will track the details of pregnant women with all the distinctive features available in the wearable devices. These wearable devices will be connected to the android app and becomes easily accessible with all pregnant women's information. Firstly, wearable devices will measure all the details accurately and will send it to the app and the app will also store the data on cloud for backup purpose. This app will also send the data to the doctors, family members and any important person.

c) **WSN and Communication: -**

A wireless sensor system for the continuous monitoring of cervical dilation of a feminine drawing close labor and delivery. The designed and developed sensor that may continually degree the dilation and transmit this info wirelessly to a transponder worn like a cell phone or PDA. This transponder can robotically transmit the info on dilation to a faraway data-processing company in get in touch with the pregnant lady and her physician and hospital [19]. This sensor contains an electromechanical instrument encased in a non-reactive plastic tube. The sensor is stretched due to the expansion of the cervix. The health care provider can easily retract the entire unit when monitoring is finished, and projection begins. Each circuit or small "active" tag containing its own sensor battery is attached. This circle determines the diameter of the widened cervix and transmits the diameter value in centimeters by means of radio frequencies to a small radio unit carried by the pregnant woman, a "mobile phone" as proven. This wireless unit is worn on a belt or attached to the female's clothing, Pramode Verma and Shanshan Chen [2009]

d) **Embedded Systems: -**

Embedded devices are the objects that meet the authentic computing system. These programs may or will not hook up with the Internet. An embedded tool scheme normally runs as a single application. However, these units can yoke during the cyber web connection, and ready keep in touch by means of different community devices. Nowadays, embedded systems have taken a significant impact on developing trending technologies for removing the expensive technologies or unknowledgeable methods. As embedded systems consist of hardware and software parts where IOT (Internet of Things) plays the most significant role in which different sensors are used for developing the system for pregnant women and to track the activities of her for reducing or eliminating the risk factors during labor, delivery and pregnancy.

e) **Analytics: -**

In this model, the continuous monitoring is the main part of the system. The monitoring of the cervix and health of the pregnant women to protect her from many complications or any infant death. Following are the objectives that need to be designed and developed with the basis of various technologies: -

1. This model provides real-time monitoring of the cervix and health of pregnant women with the help of a smart e-health care system using IoT and Cloud Computing for storing the larger amount of data on the cloud.
2. To continuously monitor the cervix of pregnant women for avoiding complications, risk factors, or any death with the help of the dilation sensors or devices which is achieved by wireless sensors.
3. Also monitoring the health of pregnant women using IoT by inserting the sensors into wearable devices such as a watch, belt, and shoes.
4. To stop the preterm birth or caesarean deliveries, the help of cervix dilators or MEMS-based sensors invent the non-invasive embedded devices.

5. Measuring the biometric parameters of the fetal head using the deep neural networks for knowing the position during the labor from the signals of wireless cervix sensors.
6. Different datasets are used during the labor of pregnant women using machine learning libraries available in python.
7. To send the alarm or email or SMS to the pregnant women, her family, doctors, or hospital in case of any emergency or report of the daily tracking/monitoring to avoid any complications.
8. The wearable devices can also provide the status of pregnant women to the doctors and family members of the patient.
9. To provide a system with minimum energy consumption, cost-effective, safety, efficiency the use of wireless sensor networks-based algorithms has been produced.
10. All the reports, alarms, or statuses can be stored on the cloud for many patients for future reference.

All the above objectives are helpful for the development of the smart monitoring of the cervix and health of pregnant women to avoid all the complications, risk of infections, death, preterm birth or caesarean deliveries during pregnancy and labor.

From the above objectives and analysis done, the parameters that analyzed are accuracy, false alarms, energy and time consumption, safety, efficiency, inexpensive. These parameters will help in developing the great model for every pregnant woman and her family and to the society to remove the risk factors and to provide a health care system.

4. SYSTEM ARCHITECTURE

The system architecture is divided into four main modules which is shown in the figure below: -

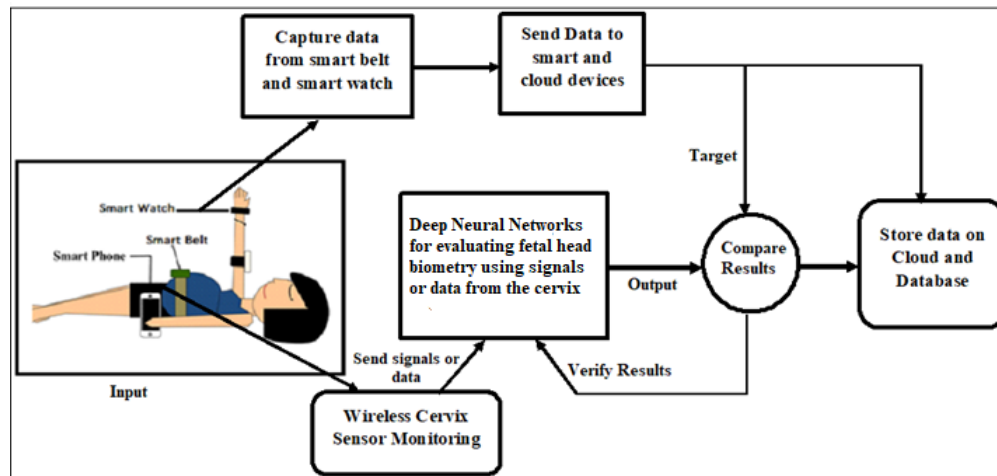


Figure 1. System Architecture

The four modules are: -

1. Wireless Cervix Monitoring
2. Measuring fetal head parameters
3. Health Monitoring
4. Storing data on cloud

The first module is the main module where after analyzing numerous methods for monitoring the cervical dilation, this module is determined on an electronic instrument because of such gadgets will likely be made in all the tiny size, will likely be inexpensive, can be packaged for implantable assembly contained in the body, and such units can wirelessly transmit the information to the surface sphere. This module designed and developed wireless sensor technology to continuously monitor the cervical dilation of a female drawing near birth and delivery.

1. The module has designed a sensor that can continuously measure expansion and transmit this information wirelessly to a carried transponder such as a cell phone or PDA. This transponder can robotically transmit dilation information to a remote IT company to help pregnant women and her doctor and hospital.
2. A schematic diagram of this process is proven in the figure above.
3. This sensor must be connected to the cervix of the pregnant woman by her doctor. This sensor consists of an electromechanical instrument enclosed in a non-reactive plastic tube. The sensor stretches because the cervix dilates.
4. A doctor can remove the whole unit easily when monitoring is complete, and delivery begins.
5. A tiny detail “active” circuit or tag with its own battery is connected to the sensor. This circuit determines the diameter of the dilated cervix and transmits the diameter value in centimeters by RF to a small wireless unit worn by the pregnant woman as a “cell phone” as shown in the figure.
6. This wireless unit is in most cases worn on a belt or hung on a woman’s clothing.
7. The main fraction of the electromechanical sensor is a solenoid coil.

The next module is the measurement of biometric parameters of fetal head. This module is very important as this reduces the complications like preterm birth, caesarean deliveries, infant death. Without this module, the complete system won’t be able to develop. In this module, the data i.e. the ultrasound images from the previous module is been captured to measure the biometric parameters of the fetal head. Fetal biometric parameters such as head circumference (HC) and biparietal diameter (BPD) are measured using the images (captured images while cervix monitoring) from cervical dilation data. This model guarantees for the true and false cases in the pregnancy and delivery situation. So deep neural network is the method where the performance of these true and false cases in any situation can be handled easily. From this module, we can able to know the delivery date and by that delivery date we can avoid the miscarriage, and all the safety measures can be taken. DNN is used to train the ultrasound images firstly from 3rd trimester, then 2nd trimester and then 1st trimester. The 3rd trimester ultrasound images are very important because from that trimester we can able to predict the exact delivery date. It is very important to capture the images accurately and visible so that the data from these images can be processed to measure the parameters and handle the complications of pregnant women during labor and delivery.

The next module is the health monitoring which is also the most important module for taking care of pregnant women and her child and to save her life from any kind of complications coming in the way.

1. The Smart Watch begins by exercising and detects the heartbeat to perform its required functions, and smart sports shoes or shoes will start to carry when the shoes catch the appropriate toes of the shoes, and the smart application will automatically link them.
2. After starting, each device will monitor the sanitary parameters and may perform its required functions.
3. Since the records accumulated entirely by documents in the affected person visualization unit can be used in a deeper way, along with the welfare messages that will be sent to her family members, this will be better implemented using cloud storage.

4. Moreover, the device will generate a large amount of information as it can collect information every second, so there is a desire to filter the information so that the huge information challenge does not appear in the cloud storage.
5. A subsequent series of information about cloud storage, doctors and relatives will obtain information about women's well-being and procedures through the intense intellectual application that desk computers, laptops, smartphones or tablets provide them.
6. Medical officials will receive an analytical report for each operation from the women, which may benefit from medicine to analyze women in depth even with high-risk pregnancy conditions.
7. Moreover, the family members will get the welfare information related to the woman, or the non-compulsory procedures that you take on the specified time or not, and they will also get to know the wellness adaptations such as starting from labor pains etc.

In the above third model, the data storage on cloud is processed to gather all the required information and analyze the information for the future.

5. RESULTS AND DISCUSSION

The analysis of various information and methods from various approaches and strategies are gathered for developing and designing our system for the sake of pregnant women, her family and doctors and hospital. Following is the comparison of the parameters like accuracy, False alarms, precision, recall and other with our current system for removing any kind of complications and handling the complications.

Accuracy may not be a good measure if the dataset is not balanced (both negative and positive classes have different number of data instances). In the paper [35], a prediction model of embryonic pattern using machine learning algorithms in response to historic case data, in this fashion docs could make extra correct recommendations on the selection of affected person follow-ups, and supply choice fortify for medical who're comparatively inexperienced in medical practice.

From the above analysis of parameters, our system is being designed and developed for handling the complications of pregnant women.

Study	Findings
Adolescent pregnancy, in qs [2004]	This ponder incorporates the sundry angles of gravidity in young, such as hazard issues, care, post impacts on ladies of youthful gravidity
What are the factors that put a pregnancy at risk, in Shriver [2018]	This article depicts distinctive components that make a salubrious gravidity in risk. Creators withal states that the risk components depend upon subsisting wellbeing (tall BP, Polycystic Ovary Disorder, Diabetes, Kidney Illness, Thyroid, Fruitlessness, Excessive corpulence, HIV), Age (High schooler Age, to begin with Gravidity at age 35) Way of life variables (Drink, Smoke) or gestational variables (Preeclampsia, Eclampsia, Multi gestational, gestational Diabetes)
Maternal mortality, in oq [2018]	<p>The article talked about the maternal passing proportions that happened over the world. Key actualities incorporate within the article are as follows: -</p> <ul style="list-style-type: none"> —Each day, around 830 ladies kick the bucket from preventable causes cognate to gravidity and childbirth. —99% of all maternal passing's happen in creating countries. —Maternal mortality is higher in ladies living in rustic regions and among more devastated communities. —Childish youths confront the next hazard of complications and passing since of gravidity than other women. —Dexterous care afore, amid, and after childbirth can protect the lives of ladies and beginning born babies. —Between 1990 and 2015, maternal mortality ecumenical dropped by almost 44%.

Pregnancy care network, in Khanum S. [2017]	The creators proposed a Gravidity Care Arrange that interfaces ladies with adjacent healing centers utilizing GPS. In their think about, the arrange is caused around gravid ladies utilizing smartphones to supply wellbeing housing to ladies. They offer as it were the communication arrange between ladies and wellbeing officials.
Remote E-Health care system, in Spaander-man M. [2011]	The creator proposed a system in which wellbeing housing are given agreeing to the wellbeing conditions of the ladies. It just guides the ladies, not measure the action of the ladies.

Table I: Comparative Analysis of Different Studies of Papers with their Findings

The above table is compared with various technologies and from that we will be designing and developing one better system that gives accurate results and works efficiently.

Comparative Results: -

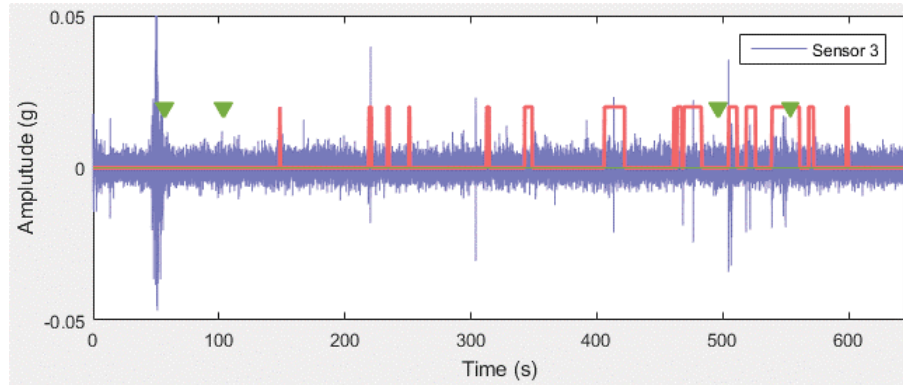
Figure 2 Ganeshwari D [2018], gives the report of the affected person especially includes details of the heart rate, Blood stress, Temperature and Muscular pastime. The coronary heart price levels from 60 to 100 beats per minute and Blood pressure is expressed in numbers, along with 120/80. A normal body temperature is 98.60F (370C). If Heartbeat, BP, Muscular contraction and Temperature is greater or much less than the given parameter, then it is going to be indicated with the LED and alarm, and that file will be sent to the doctor as well as to guardian (husband). The health practitioner will examine the document and send the required prescription through transceiver IoT to be affected person. at the identical time, the modern location of the affected person will also be sent to the ambulance provider via the GPS machine, Ganeshwari D [2018].



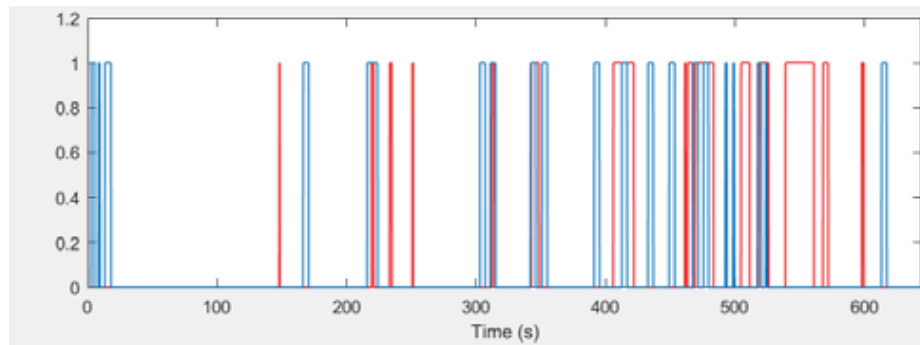
Figure 2. Sample Output of Temperature Sensor

The experimental result of the subsisting system in this offline statistics is proven in Fig. 3b, Xin Zhao [2019]. it's far discovered that the system has as it should be identified fetal moves placed from around 150s to 600s with reference to maternal markers. However, the classifier brought some efficacious outputs at the commencement of the signal without maternal annotations. this can be because of the concern become now extemporary for recording when just subsided. It is proved that the proposed tracking contrivance has true sensitivity, but since there

is no genuinely trustworthy reference for fetal kineticism, and the mother may not have the faculty to feel a few fetal actions which surely detected by designates of the monitoring system, it is hard to assess contrivance specificity, Xin Zhao [2019].



(a)



(b)

Figure 3. (a) Acceleration data from sensor 3 (purple) together with maternal perception (red) and artifact markers (green). (b) Output of the proposed monitoring system (blue) together with maternal perception (red).

From the above graphs of existing system, the following table gives comparative study of various parameters with various papers referred which tells that our system will give better results. Not only our system gives the accuracy but also this will work on parameters like precision, recall, false alarms, prediction of accurate delivery date.

Parameters	In Rydhm Beri and Singh [2019]	In Lijue Liu [2020]	Our Study
Accuracy on pregnancy delivery	Accuracy rate is up to 90%	Accuracy rate is up to 99%	100% Accuracy
Health Parameters	20-25 health parameters are evaluated using wrist band, shoes and smart app.	-	More than 25 parameters will be evaluated using smart devices.
False Alarms	-	-	More than 93% false alarms rate is to be reduced.
Precision-Recall	-	Precision and Recall rate is 97%	Precision and Recall will be up to 100%

Table II: Comparative Analysis for Various Parameters of Pregnant Women with our System

6. CHALLENGES

This paper is in consideration with the study of limitations, various hardware, and software challenges from the above literature survey. The limitations with its challenges of the survey are as follows:

1. Cervix monitoring with harmless dilators or sensors is difficult because of its electrical or mechanical signals transmitting into the device.
2. For the prediction of preterm birth, it is very difficult for the neural networks to provide the inputs for n number of patients for one value.
3. Some sensors are expensive, and some sensors give false positive outcomes and share a negative response to the pregnant women and her family members.
4. The continuous tracking of pregnant women sometimes becomes difficult due to restricted or limited devices.
5. To manage the complications, continuous monitoring of the cervix, and health of pregnant women in a single system.
6. Reliability, accuracy, safety, efficiency, flexibility, cost, energy consumption, time consumption are the parameters that cannot be achieved in one application or system.

Considering all the pros and cons of the above limitation and its challenges, some objectives are set to produce a single continuous monitoring system.

7. CONCLUSION AND FUTURE WORK

The Cervix and Health monitoring of pregnant women helps to measure all the complications like preterm birth, risks of infections, infant sudden death, caesarean delivery, and preventive measure tracking and smart monitoring. Tracking and monitoring the symptoms of pregnant women are done using wearable devices like wrist-watches, belts, shoes with the help of various technologies like IoT and Cloud computing. Deep Neural Networks are used to measure the foetal head biometrics parameters. With the help of wireless cervix dilation sensors used to monitor cervix changes during pregnancy and labor.

In the future scope, the actual implementation of this model can be proposed to avoid the complications and risks occurring during pregnancy and the labor of pregnant women.

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