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[ijirset@gmail.com](mailto:ijirset@gmail.com)

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# Wearable Device using AI and IoT for Assessment of Fetal & Maternal Well-being During Pregnancy

<sup>1</sup>Fozail Ahmed, <sup>2</sup>Ananya Bhombore, <sup>3</sup>Charan Simha D, <sup>4</sup>Mrudula S Prasad,  
<sup>5</sup>Dr. Sowmya Naik

<sup>1-4</sup>UG Students, Department of CSE, City Engineering College, Bengaluru, Karnataka, India

<sup>5</sup>Professor and HOD, Department of CSE, City Engineering College, Bengaluru, Karnataka, India

**ABSTRACT:** The maintenance of good health for both the fetus and mother proves to be essential in pregnancy for preventing as well as identifying potential complications. To achieve this goal, effective monitoring needs to be implemented that takes into account these concerns. Pre-eclampsia, a serious complication occurring typically after 20 weeks gestation, involves increased blood pressure alongside proteinuria. When untreated untoward effects on both the mother as well as further fetal development may ensue. Effective monitoring of maternal and fetal health is vital during pregnancy. This includes regular monitoring for parameters such as fetal heartrate and gestational diabetes. Therefore, constant innovation is necessary for developing seamless technological solutions capable of facilitating accurate tracking continuously. This research paper signifies the importance of monitoring maternal and fetal health during pregnancy, with a focus on pre-eclampsia, fetal heart classification, and gestational diabetes. The system we propose is a wearable belt equipped with AI and IoT technologies to continuously monitor the mother's health vitals, analyze them, and send the data to ThingSpeak, an IoT-based cloud platform. We have developed ML models for fetal heart classification and various risks during pregnancy to provide insights into the health of both mother and child. The data is integrated into our web application, Growing Together, which has two dashboards for mothers and doctors. The mother's dashboard displays the health vitals from the IoT device, along with recommendations for well-being such as exercise and diet. The doctor's dashboard includes the ML models to classify fetal heart rate and predict the risk of pre-eclampsia and gestational diabetes. Our solution aims to reduce the need for hospital visits while improving early detection of potential health issues, aiming to provide easy to access, cost-effective and user-friendly solution mainly to women with restricted access to healthcare facilities. Our research demonstrates the potential benefits of wearable technology in promoting early detection of complications, providing recommendations for healthier pregnancies, and improving overall health outcomes for expecting mothers and their fetuses.

**KEYWORDS:** Sensors, IoT, Machine Learning, Decision Tree Classifier, Health monitoring system, Fetal Heartrate, Pre-eclampsia, Gestational diabetes.

## I. INTRODUCTION

Regular monitoring throughout the pregnancy allows early detection of well-being problems that might arise and will aid their treatment, improving the chance for the birth of a healthy baby. The health and condition of both the mother and the baby is a clear indication of future complications or the well-being of the fetus [1]. Routine check-ups are advised by doctors during pregnancy for monitoring of health vitals like blood pressure, heart rate, body temperature etc., frequently in order to ensure the well-being of both mother and her fetus. An abrupt and sudden increase in blood pressure levels during pregnancy can result in a medical condition known as Preeclampsia and unhealthy eating habits along with mood swings and other external conditions may cause the BP level of pregnant women to increase due to certain changes occurring in their bodies. The presence of preeclampsia increases the risk for proteinuria and seizures which may end up causing maternal death or even fetal loss [2]. To identify fetal distress during labour or delivery period; it's necessary to monitor Fetal Heart Rate (FHR) using a Doppler device, however, when it comes to documenting FHRs in practice today there's no more common method than Cardiotocography (CTG). Neglecting to

correctly interpret the CTG graph may result in significant business loss [3] As women capable of bearing children experience a considerable surge in overweight and obesity rates, the prevalence of gestational diabetes mellitus (GDM) also increases and women who are able to bear children have seen a significant increase in both obesity and GDM rates. In this paper, we discuss the effectiveness of existing systems for monitoring maternal and fetal during pregnancy, their strengths as well as their limitations. The proposed system uses a belt around the mother's belly to analyse various pregnancy-related biological factors, such as heart rate of pregnant women, changes in blood pressure, oxygen level, and temperature. By transferring high-speed medical data to the ML models, the proposed system will help doctors make quick decisions and administer treatments tailored to the mother's health.

### II. RELATED WORK

In [5], The authors propose a system consists of a sensor belt worn by the mother, which measures fetal movements and uterine contractions, and a sensor placed on the mother's thigh, which measures maternal activity. The system also has the capability of identifying early indicators of difficulties, such as preterm labour and fetal distress, but it has certain drawbacks like the requirement for further validation studies to guarantee its accuracy and dependability. The paper [6] proposes an IoT system to monitor preeclampsia risk in pregnant women and uses machine learning to predict the risk and alert healthcare providers. However, the accuracy of the ML model depends on data quality and patient variability, and the system may be costly and require a stable internet connection. The study [7] assesses how well machine learning models predict GDM using various characteristics and methods. After reviewing 25 earlier studies, the study comes to the conclusion that machine learning models, with the random forest algorithm being the most successful, can predict GDM with a high degree of accuracy, sensitivity, and specificity. This study has some drawbacks despite offering a thorough overview of the existing literature. The included studies' quality could vary, which could have an impact on the reliability of the findings. Additionally, the original studies' potential biases and confounding variables weren't examined, which might have had an impact on how generalizable the results were. In the paper [8], an approach for counting fetal movements with optical fiber sensors is presented. Non-intrusiveness, simplicity of usage, and ongoing monitoring are all benefits. However, fetal position or maternal movement can influence the method's sensitivity and accuracy, leading to false positives or negatives. The study's small sample size and controlled environment further hinder the method's applicability in actual settings, necessitating additional study. In [9], the paper proposes a recommendation system for monitoring pregnant women's health using IoT and an Android application, allowing for quick access to prenatal care and real-time monitoring. The system's benefits—accessibility, early health issue identification, and convenience—are outweighed by its drawbacks, which include expense, the requirement for a reliable internet connection, and the technical proficiency of the user. Overall, the method offers promise, but to solve these drawbacks, further work may be required.

### III. PROPOSED SYSTEM

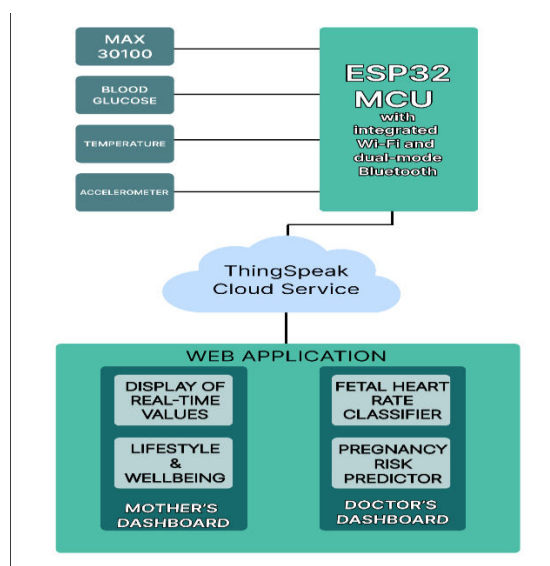


Fig 1: Overall System Architecture

The above figure 1 demonstrated the overall system architecture for our proposed system. The system consists of a wearable device, equipped with AI and IoT technologies, which is made into a belt that can be worn around the mother’s belly. The non-invasive and convenient wearable device is embedded with high-end sensors consists of MAX 30100 integrated pulse oximetry sensor, Blood Glucose sensor, Temperature sensor and an accelerometer. Certification ensures the necessary components and sensors are safe to be used by expectant mothers, and with the use of an ESP32 MCU that offers integrated Wi-Fi and dual-mode Bluetooth functions at a reasonable price point along with energy efficiency helps connect these sensors efficaciously. All the health vitals that are collected from the wearable device are being sent to the cloud service called ThingSpeak which is an IoT analytics platform service that allows you to analyse live data streams from your device into the cloud. The system will make use of the API service provided by ThingSpeak cloud. The Write API key will be used to write the readings from the device to the cloud. The Read API key will be used to read the health vitals stored in the ThingSpeak Cloud and load it into our web application. Our web application, Growing Together, is a user-friendly interface that is fully responsive on all devices to access the health monitoring system and machine learning models to help the mothers have healthier pregnancies. The web application will start with the home page, from where the user can access two dashboards, one for the mother and another for her doctor. The mother and doctor can access their respective dashboards by authenticating themselves through the login feature which has been provided. Once the mother is logged in, she will have access to the mother’s dashboard. The mother dashboard displays the health vitals from the IoT device in a user-friendly interface and recommendations regarding her lifestyle and well-being, like exercise and diet, are given to her during pregnancy. The mother can also enter her emergency contact information, which will send alerts if her health vitals are out of the normal levels. Once the doctor is logged in, they will have access to the doctor’s dashboard. The doctor’s dashboard consists of 4 ML models. The ML models are overall pregnancy risk prediction, pre-eclampsia risk prediction, gestational diabetes risk prediction whose values will be loaded directly from the patient’s IoT device. The last ML model is the fetal heartrate classification where the doctor will input the ultrasound values of the mother in order to classify the fetal heartrate into suspicious, pathological and normal. All the results of the ML models will be displayed on the doctor’s screen. Overall, our approach is to improve the early detection of potential health issues like preeclampsia, gestational diabetes, fetal heartrate determination and reduce the number of hospital visits required for monitoring.

IV. METHODOLOGY

A. IOT SYSTEM DESIGN

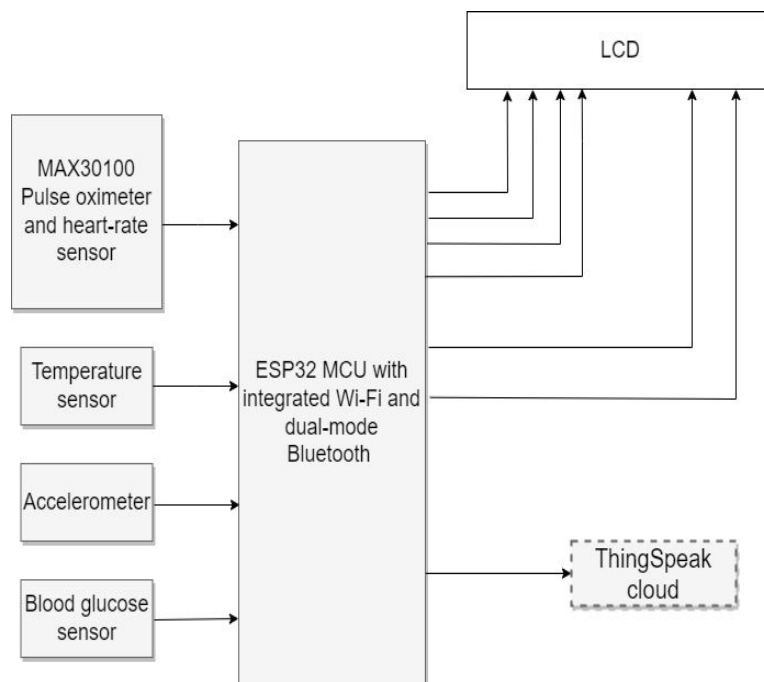


Fig 2: Circuit Diagram of IoT device

The above circuit diagram illustrates the proposed IoT device and its necessary connections. The IoT device consists of a temperature sensor, an accelerometer, a blood glucose sensor and MAX-30100 pulse oximeter and heartrate sensor. These sensors are mounted on top of a belt made of cotton-polyester material which makes it lightweight and convenient. The sensors themselves are non-invasive and fit into the life of the mother perfectly.

The accelerometer captures the fetal movement records the same for further analysis. The blood glucose sensor works by emitting light at a specific frequency, which gets reflected by the blood cells. The blood glucose of the user is then calculated by capturing the reflected light.

The MAX-30100 pulse oximeter and heartrate sensor has a similar working to the blood glucose sensor to determine the SP02 level and heartrate. The temperature sensor detects the temperature of the mother. The connection between the sensors is established by an ESP32 microcontroller that has integrated Wi-Fi dual-mode Bluetooth for communication in either mode and the microcontroller is linked to an LCD screen that displays real-time values obtained from our top-of-the-line sensors. These real-time values are then sent to a cloud service called ThingSpeak. This process of transmission uses the API service provided by ThingSpeak service. The data provided by the sensor is stored in the ThingSpeak cloud and then retrieved by the web server to be shown live on the mother's dashboard. The IoT device collects and transmits the data every thirty seconds as long as it can access any network.

## B. DATA PROCESSING AND MODELLING

Machine learning models are transforming the healthcare industry by enabling physicians to resourcefully analyse potential risks in pregnancy by integrating these models into a doctor's dashboard, we made it possible to predict and identify risks to help improve maternal and fetal health outcomes. The machine learning models that are used in our proposed system are: overall risk predictor, pre-eclampsia risk predictor, gestational diabetes risk predictor and fetal heart rate classifier. Each model is trained by highly accurate and very well pre-processed datasets to achieve high accuracy. This section will describe each of the four models in detail including their accuracy and application cases:

The Overall Risk Predictor is a random forest classifier model that predicts the risk of all pregnancy complications based on various factors of mother such as Age, Systolic BP, Diastolic BP, Blood Sugar, Body Temperature, Heart Rate out of which some of the values are in real time sent to the web application through the ThingSpeak cloud service from the IoT device. This model is designed to help identify potential pregnancy risks that might otherwise be ignored. It provides a risk probability indicating the likelihood of complications in pregnancy with an average accuracy of 72%. These predictions are utilized by the doctors to determine appropriate care and treatment that are required for the mother.

Pre-eclampsia is a serious complication that can occur during pregnancy, which might lead to maternal and fetal mortality. Hence, we have proposed a machine learning model called the Pre-eclampsia Risk Predictor. Our model helps the doctors predict the likelihood of pregnant woman developing preeclampsia. This model has an accuracy of 91%, through which the doctors can identify which women are at high risk for pre-eclampsia and take steps to keep them and their babies safe. The model provides doctors with a risk probability that can be used to guide appropriate management strategies such as frequent monitoring, medication, and in some cases early delivery.

Gestational diabetes is a common complication of pregnancy that can lead to adverse maternal and fetal outcomes. The Gestational Diabetes Risk Predictor is a Random Forest Classifier model that predicts the likelihood of developing gestational diabetes based on various factors. This model has an accuracy of 97% and is designed to help doctors identify patients at high risk of gestational diabetes. The doctors can guide the mother with appropriate management strategies such as frequent monitoring, dietary changes, and insulin therapy.

Fetal heart rate monitoring is an essential aspect of prenatal care that helps doctors identify potential fetal distress. The Fetal Heart Rate Classifier is a Support Vector Classifier model that classifies fetal heart rate patterns as normal, suspicious, or pathological. This model has an accuracy of 99.5% and is designed to help doctors interpret fetal heart rate patterns accurately. The model provides doctors with a classification of fetal heart rate patterns that can be used to guide appropriate management strategies such as fetal monitoring, delivery, and resuscitation.

Machine learning models that are integrated into the doctor's dashboard are transforming the way doctors analyse potential risks that might occur during pregnancy using the vitals of the mother. The project described in this paper has four models: Overall Risk predictor, Pre-eclampsia risk predictor, Gestational diabetes risk predictor, and Fetal heart rate classifier, each with its own accuracy and use case. These models enable doctors to identify high-risk pregnancies early and guide appropriate management strategies, thus improving maternal and fetal health outcomes. Further research is needed to optimize these models and integrate them into clinical practice seamlessly.

C. WEB APPLICATION DESIGN

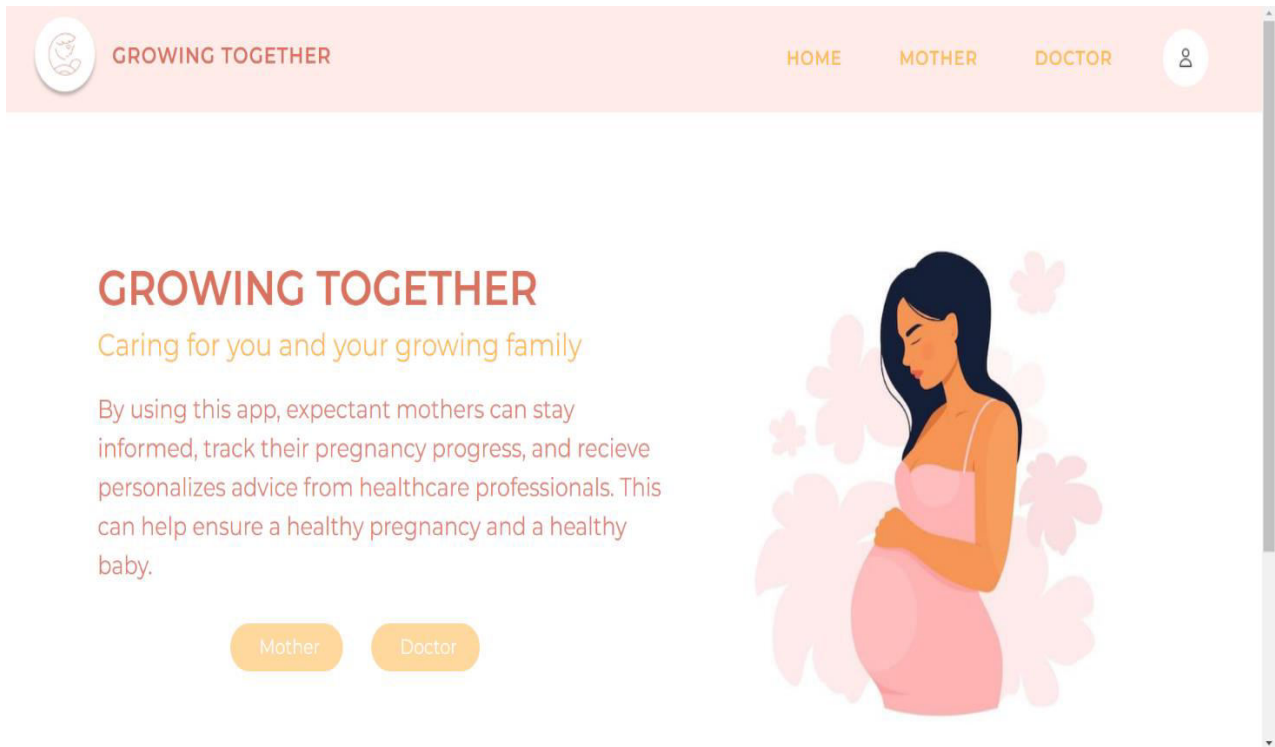


Fig 3: Homepage of the web application

Our web application's goal is to make health monitoring easier for both moms and doctors by offering a dependable and practical platform for the effective management of prenatal healthcare. The name and logo of our service, Growing Together, are presented to users as soon as the app has loaded. The homepage provides an intuitive interface featuring options for logging in and signing up, providing authorization for both mothers and doctors.

The app is designed with two separate dashboards, each serving specific purposes. The mother's dashboard enables real-time tracking of vitals, such as heart rate, blood pressure, oxygen levels, temperature, and accelerometer readings, which are updated every 30 seconds via an IoT device. These readings are pushed to the ThingSpeak cloud, allowing for easy display on the mother's dashboard. Additionally, our platform offers mental wellbeing suggestions, diet and nutrition recommendations, and exercise advice, all provided by qualified professionals. Emergency contact numbers are also readily accessible, ensuring the safety and wellbeing of the mother.

On the doctor's dashboard, physicians are provided with crucial patient information, including mother's name, age, blood group, weight, and height. Furthermore, our app features four predictive models to assist doctors in making informed decisions. The first is the overall pregnancy risk prediction model, which analyses real-time values to determine the level of risk, categorizing it as low, medium, or high. The fetal heart rate prediction model incorporates values from both the IoT device and manually-entered data by doctors, utilizing 21 key input values to make accurate predictions. Our preeclampsia prediction model is particularly useful starting from the second trimester, assessing blood pressure values to determine whether the mother is at risk of developing the condition. Lastly, our gestational diabetes prediction model analyses blood sugar readings which helps make sufficient predictions.

In summary, our proposed system provides a comprehensive solution to the many challenges faced by pregnant women throughout their pregnancy journey. Our platform takes into account a range of factors, from real-time monitoring of vital signs to cost efficiency for mothers. Our web app acts as a supportive system, helping mothers to monitor and maintain their own health all under the guidance of a trained professional, as well as that of their growing baby. Our app will be a valuable tool for both mothers and doctors alike, providing an intuitive, reliable, and human-centred approach to pregnancy healthcare management.

V. RESULTS AND DISCUSSIONS

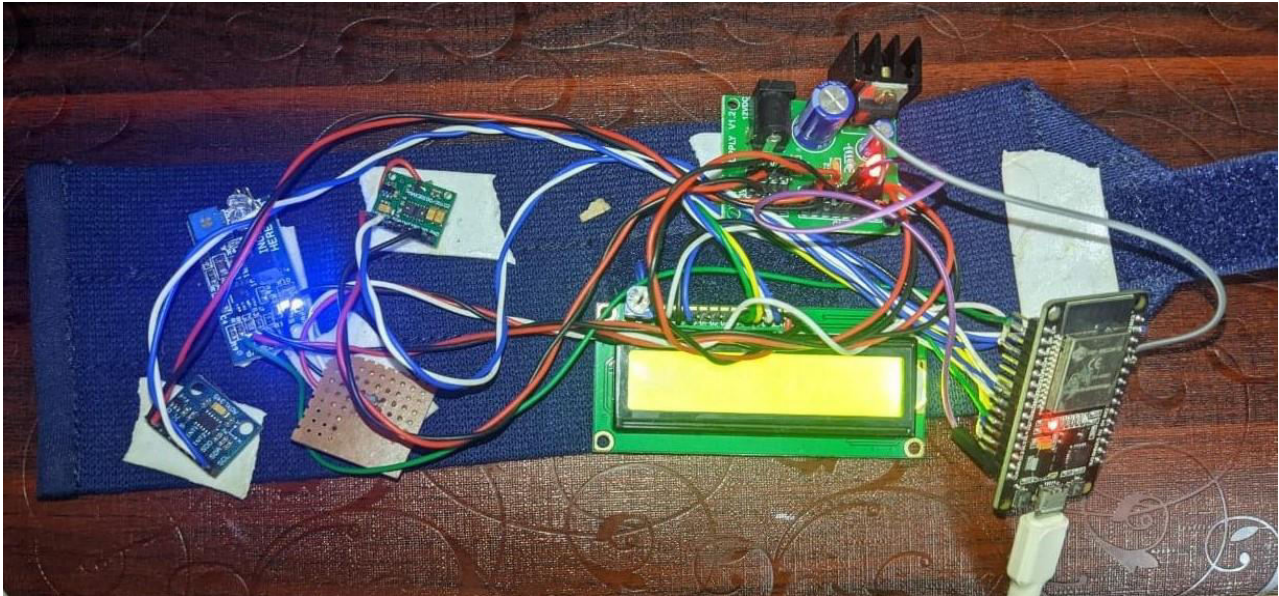


Fig 4: IoT device embedded with sensors, LCD and MCU



## Welcome to Growing Together

Here we help you prioritize your health and empower you to make positive changes for you and your growing family.

This page is designed to prioritize the health of mothers. Track your health parameters like blood pressure, heart rate, and blood sugar levels, set goals, and monitor progress. The wellness section offers exercise plans and healthy recipes to maintain a healthy lifestyle.

### Health Monitoring System Readings

BLOOD PRESSURE

88

OXYGEN LEVEL

94

BODY TEMPERATURE

35.55555555555556

HEART RATE

81

Fig 5: Health vital readings from the IoT device



Fig 6: Health predictions for the overall risk, risk of pre-eclampsia and gestational diabetes

**Fetal Health Prediction**

Suspicious



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Fig 7: Health prediction made to classify the fetal heartrate

The three modules of the proposed system – IoT device, Machine Learning Models and the Web Application – have been integrated together seamlessly to provide an end-to-end product solution for regular health monitoring of the mother and fetus and early detection of pregnancy health-related issues like pre-eclampsia, gestational diabetes, overall pregnancy risk and fetal heartrate determination. The non-invasive and convenient IoT device around the mother’s belly accurately detects the vitals like her Body Temperature, Heartbeat, Blood Pressure and SPO2 level. Also, the accelerometer readings through which can determine the fetal positioning is mainly utilized in the third trimester of the pregnancy. The health vitals that are collected from the IoT device were fairly accurate, we found that the device was giving us more than 90% accuracy on running numerous testing and validation sessions. The same health vitals are being sent to the ThingSpeak Cloud, where we can store, retrieval and analyze the same. In the mother’s dashboard, the health readings from the device are efficiently being retrieved and display on the screen through which the mother can regular monitoring her health during pregnancy. Also, she will receive various recommendation on lifestyle and well-being, like exercise and diet, which will help her to a healthier and safe pregnancy. In the doctor’s dashboard, we have all the machine learning models for deeper analysis of the mother’s health. Utilizing the values such as Systolic BP, Diastolic BP, Body Temperature, Heartrate, Blood Sugar and Age which are obtained through the mother’s IoT device, we are able to predict the likelihood/risk of pre-eclampsia, gestational diabetes and overall pregnancy risk. The model for pre-eclampsia made using the decision tree classifier yields 91% accuracy, the random forest classifier for gestational diabetes achieved an accuracy score of 97% and the overall pregnancy risk delivered an average accuracy of 72%. The last machine learning model for fetal heartrate classification utilizes the ultrasound values which the doctor will input. After running through comparative tests on different ML models to accurate classify the fetal heart rate, we



utilize the SVM classifier which give us a high accuracy level of 99.5%. To culminate, the result of development and testing of the integrated system comprising of the IoT device, ML models and web app, demonstrated incredible performance with expectational results and coherence during real-time data testing yielding quantifiable results.

#### VI. CONCLUSION AND FUTURE WORK

This wearable device which embedded with AI and IoT technologies, has the potential to have significant benefits for pregnant women living in both rural and urban areas. The proposed system aims to provide a lightweight, cost-effective and convenient monitoring device especially to those women who have restricted healthcare facilities. By continuous monitoring the physical health of the mother and the fetus, the device along with the machine learning models can detect any possible complications early on, through which the doctor can provide immediate medical intervention and treatment. In addition to monitoring, the device can also provide personalized recommendations for healthier pregnancies based on the data collected from the wearer. This can include advice on nutrition, exercise, and other lifestyle factors that can impact the health of the mother and baby.

Future enhancements that we would like to implement is a machine learning model for stress detection and other handling techniques. After we get permissions from hospitals, doctors, and the Indian Medical Association (IMA) to ensure compliance with relevant regulations and standards for conducting human trails, we can introduce an additional paid subscription model for personalized recommendations for the mother based on her IoT device health vitals.

The use of this wearable device has the possibility to change entirely how we take care of pregnant women particularly those who are living in isolated places, ensuring that all women receive top-notch medical care during this crucial time in their lives irrespective of where they reside or what financial background, they come from can be achieved through providing uninterrupted monitoring and customized tips.

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