TECH PREG: ANALYSIS AND DEVELOPMENT OF PREGNANCY E-HEALTHCARE SYSTEM USING FOG COMPUTING

Thesis Submitted For the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Computer Applications

By

Rydhm Beri

41500176

Supervised By

Dr. Mithilesh Kumar Dubey

Professor

Co-Supervised by

Dr. Anita Gehlot

Professor & Head(R&D)

LOVELY PROFESSIONAL UNIVERSITY

PUNJAB

2023

DECLARATION

The presented thesis entitled “Tech Preg: Analysis and Development of Pregnancy E-Healthcare System using Fog Computing”, was undertaken during the period from March 2016 to February,2023 at the School of Computer Applications and School of Electronics and Communication Engineering, Lovely Professional University, Phagwara, India. I acknowledged that the material presented in this thesis is my original work and has not been submitted in whole or part of the degree in any university.

Rydhm Beri

School of Computer Applications

Lovely Professional University, Phagwara

CERTIFICATE

This is to confirm that the student's declaration statement is accurate to the best of our knowledge and belief. Under our direction and supervision, she has completed the Ph.D. thesis "Tech Preg: Analysis and Development of Pregnancy E-Healthcare System using Fog Computing". The present work is the result of her original investigation, effort, and study. No other university has ever used any of the work for another degree. Accordingly, the doctoral thesis is suitable for the submission and fulfillment of the requirements of the Lovely Professional University Phagwara, a Ph.D. degree in Computer Applications

Dr Mithilesh Kr. Dubey
Professor
School of Computer Applications
Lovely Professional University,
Phagwara, Punjab, India

Dr Anita Gehlot
Professor & Head
Research & Development
Uttaranchal University,
Dehradun, India

ABSTRACT

"Pregnancy is the phase of a woman's life in which she gives birth to new life and that new life gives birth to mother". Pregnancy comes with full of excitement and happiness for the lady and the family members. However, with full joy and excitement, pregnancy also comes with some health-related issues for the woman and the infant. The major issues that arise in a woman's body include, pre-eclampsia, heart disease, depression, gestational diabetes, gestational thyroid, etc. The issues related to infant health include thalassemia, chronic liver, kidney disease, and some hereditary issues, etc. If these issues can be predicted on time, one can save the woman's or infant's life and reduce the chances of future health-related issues for both.

This work presents a novel E-healthcare system for a pregnant woman to monitor health-related problems that occur due to hypertension and offers real-time suggestions to the pregnant woman for saving her life from any further predicted risk. This minimizes the chances of health loose or mortality ratio of mother and infant due to the unawareness of the health conditions.

The presented system monitors the health parameters including heartbeat, blood pressure, and ECG level of pregnant women in a real-time environment with biomedical sensors. Based on these parameters system predicts the health-related issues such as the stage of hypertension or cesarean chances. The system works in different stages to perform the task as a whole. At the very first step, when a woman wants to capture the health parameters, she needs to wear biomedical sensors attached to the microcontroller unit which is responsible to collect data from the sensors and send it to the further processing node. The data is captured by the system only after the authentication process which helps to offer the security of the system and reduction of data overwhelming at the cloud servers. The authentication process is done through facial recognition of the pregnant woman by the involvement of fog and cloud nodes. Initially, the details about the pregnant woman are stored in the database which further is used for comparing the real-time image of the pregnant woman captured through the fog node. The task of authentication is performed by a trained deep-learning model written in a Python programming tool.

In the second step, the processing of health parameters is done which classifies the health condition of the pregnant lady into healthy, or non-healthy classes using the Bayesian classification technique. Based on the resultant class the recommendation is generated using a designed recommendation system created in Django web-based application framework. This web application is connected to a cloud server using which the family members of the lady and health providers can directly get her health-related data remotely.

At last, the ensembled machine learning-based multi-layered model created in the current system predicts the chances of a cesarean based on the collected health parameters. The result of the prediction was found highly efficient and accurate when tested on the existing dataset and actual patients.

ACKNOWLEDGEMENT

Let me start by expressing my thankfulness to God for giving me the chance to use my knowledge and experience in this research endeavor. The grace and endurance that God has poured upon me in the midst of all of these terrible situations are incomparable. Thanks to my supervisors, Dr. Mithilesh Kr. Dubey and Dr. Anita Gehlot, for their unwavering support, direction, and supervision during this research. I feel fortunate and grateful to work with someone of this caliber. In addition, I want to express my gratitude to Dr. Rajesh Singh for all of his help and advice. He was always there to inspire me and provide me with wonderful ideas for my Ph.D.

A special thanks to my father, Mr. Rajesh Beri, for his blessings and encouragement, which have given me the strength to persevere in the most challenging circumstances of my life. When I go back to the doctoral dream that my mother Mrs. Suman Beri, planted within me, I am grateful for her inspiration. Actually, my mother is pursuing a Ph.D., not me. I am also very thankful to my brother for his support in every matter, and without his support, I could not even pursued this degree. Besides, I would like to thank all my fellow friends and colleagues who always motivated me with their valuable suggestions.

I also indebted to the whole family of BBK DAV College for Women, Amritsar, particularly the computer science department. Without their teaching, I would never have attempted to think about or work on my ambition. Finally, I'd want to use this occasion to express my gratitude to the entire Lovely Professional University family, particularly the School of Computer Applications and the School of Electronics and Communication Engineering, for their encouragement and support.

Last, but not least I extend thanks to my critics as without their criticism, I would not be able to get motivated to work on my research work.

Date: Rydhm Beri

Table of Contents

List of Figures

List of Tables

List of Abbreviations

Abbreviation	Description
PA	Physical Activity
RPHM	Regular Pregnancy Health Monitoring
ACOG	The American College of Obstetricians and Gynaecologists
TEH	Technology Enabled Healthcare
E-Healthcare	Electronic Healthcare
IoT	Internet of Things
MIT	Massachusetts Institute of Technology
CISCO	Commercial & Industrial Security Corporation
SL	Sensory Layer
GL	Gateway Layer
FL	Fog Layer
ComL	Communication Layer
UMTS	Universal Mobile Telecommunications System
WiFi	Wireless Fidelity
3G	Third Generation
4G	Fourth Generation
CL	Cloud Layer
CoAP	Constrained Application Protocol
CC	Cloud Computing
5G	Fifth Generation
AI	Artificial Intelligence
FC	Fog Computing
CC	Cloud Computing
BP	Blood Pressure
ECG	Electrocardiogram
ICT	Information and Communication Technology

IT	Information Technology
FC	Fog Computing
SOA	Service Oriented Architecture
RFID	Radio Frequency Identification
US	United States
WSAN	Wireless Sensor and Actuator Network
WISP	Wireless Identification and Sensing Platforms
UN	United Nation
IP	Internet Protocol
SOA	Service Oriented Architecture
WSN	Wireless Sensor Network
API	Application Programming Interface
QoS	Quality of Services
ABC	Artificial Bee Colony
MATLAB	Matrix Laboratory
BC	Blockchain
TSCH	Time Synchronized Channel Hop-Ping
PAN	Personal Area Network
TEET SRAM	Tunnel Field-Effect Transistor Static Random Access Memory

Chapter 1

Introduction

"Pregnancy is a phase in a women's life where the women give birth to the new life, and that new life gives birth to the mother."

When a woman is pregnant, she is in a state of ecstasy and anticipation for the arrival of a new addition to her family. But, aside from all the joy that comes with pregnancy, hormonal changes in women's bodies significantly influence women's daily lives.

It is common for pregnant women to have various health difficulties due to hormonal changes [1] which may also affect the health or body of the unborn kid. Every day, 830 women die due to pregnancy problems [2]. In addition, Preeclampsia, Eclampsia, Gestational diabetes, Premature birth, congenital impairment, such as heart problems, miscarriage, and other disorders can be caused by changes in a woman's hormones. Furthermore, in today's society, when almost 80% of women work and have busy lives, they may be missing out on important preventative measures like getting regular exercise, which might raise the chances of illness in their bodies. As a result, she needs the gadget to look after her health and her pregnancy period requirements every place and every time. Therefore, to protect women against certain health problems, it is vital to assess their health status regularly.

1.1 Pregnancy Healthcare System

From conception until delivery, the phrase "pregnancy" encompasses the whole span of time that occurs. In typical circumstances, it takes around 40 weeks to complete [3]. One of the most common risks associated with pregnancy is the risk of miscarriage, which makes it difficult to estimate future pregnancy rates and health-related statistics. To ensure the health of both the mother and the unborn child, women must take extra precautions and adopt a different way of life during pregnancy. Pregnant women need Physical Activity(PA), Regular Pregnancy Health Monitoring(RPHM), and precautionary action is taken to have a healthy infant. PA reduces the heartbeat of the fetus [4]. Comparing pregnant women to non-pregnant women, pregnant women engage in PA at the lowest rates (15.8% vs 26.1%) [5]. According to research, pregnant women are more active during the first six months of pregnancy. However, the American College of Obstetricians and Gynecologists(ACOG) recommends that pregnant women must engage in 150 minutes of moderate-intensity physical exercise every week[6].

The RPHM empowers communities to avoid sickness. Maintaining good health for both the mother and her fetus becomes more critical throughout pregnancy[7]. RPHM includes monitoring of health vitals like body temperature, pulse rate, respiration rate, blood pressure, etc.), and body weight, [8][9] which leads to the risk of gestational diabetes, hypertension, and early birth[10].

Identification and monitoring of health parameters during pregnancy are most required. For monitoring health conditions, the pregnant woman needs to rush to the doctor whenever she got some health variations, which might be normal during pregnancy, or the woman needs to suffer in case of the doctor's unavailability during an emergency, which can cause treatment delay. The process of RPHM if performed in a real-time environment can be proven as a life and time saver during pregnancy. This could help health professionals remotely examine their patients and deliver health treatments to them. Therefore, real-time health monitoring task automation is highly required by patients and recommended by doctors.

In the last decade, mobile technology has revolutionized the way people engage with one another. The healthcare industry has benefited greatly from recent advances in mobile technology. With the development and application of mobile health technologies, the world is moving toward a future of secure healthcare. Technology-Enabled Healthcare (TEH) is an umbrella word encompassing telecare, telehealth, telemedicine, mobile health, digital health, and e-Health. TEH is the convergence of health technology, digital media, and mobile devices. It is increasingly viewed as a critical solution component to many of the challenges confronting the health, social care, and wellness sectors, particularly facilitating more effective care integration. TEH enables the delivery of high-quality healthcare through the use of linked medical devices. TEH encompasses both software, such as health apps, and hardware, such as mobile diagnostics, remote monitoring devices, or wearables [11]. Monitoring the health conditions of the pregnant woman can be performed effectively and efficiently with the utilization of TEH. Pregnancy healthcare is a result of the confluence of many TEH domains. Examples of these technologies may be seen in Figure 1-1.

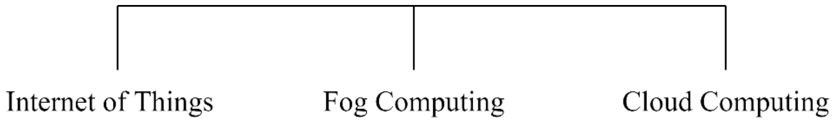


Figure 1-1 Technology-Enabled Healthcare domains

1.1.1 TEH domains' contribution to the Pregnancy healthcare system

In this section, we have discussed several aspects of Technology Enabled healthcare domains mentioned in Figure 1-1 contributing to the real-time pregnancy healthcare and health monitoring system.

1.1.1.1 Pregnancy Health Monitoring with IoT

The Internet of Things (IoT) is a network of physical objects, home appliances, vehicles, and devices, as well as numerous embedded electronics items, actuators, sensors, software, hardware, and connections that enables data communication between these objects and enables a high degree of integration of the physical world into digital systems. It resulted in financial gains, increased productivity, and lessened human effort [12]. Health care monitoring, building automation, logistics, linked automobiles, smart city development, smart grid, and smart homes are examples of how IoT improves people's lives [13].

For pregnant women in an emergency circumstance, distance and time are essential concerns. There is a lesser number of health facilities including healthcare centers, and gynecologists, available in rural areas[14][15]. Several technologies are used by researchers to reduce complications during pregnancy and maternal or infant deaths. One of these technologies used by health professionals nowadays is the Internet of Things to monitor the health conditions of pregnant women remotely. The IoT-based smart healthcare system reduces the workload of health professionals and improves work efficiency by offering quality treatment remotely[16].

IoT can be utilized in several ways before, during, or after pregnancy such as health monitoring of the pregnant woman by self-management apps[17], wearable sensors[18], childcare devices[19], etc. Some of these may be required to send data manually to the health professionals by the user or some may automate this task. IoT-based pregnancy healthcare system improves the health condition of the pregnant woman even in the case of a doctor's unavailability by offering some remote recommendations.

1.1.1.2 IoT-based pregnancy healthcare system architecture

The IoT-based pregnancy healthcare system usually works in different layers as shown in Figure 1-2. The reason for having different layers in such type of system is that every layer is responsible to perform a dedicated task which ranges from data collection to remote health recommendations. Each layer in the presented architecture performs services to the above layer.

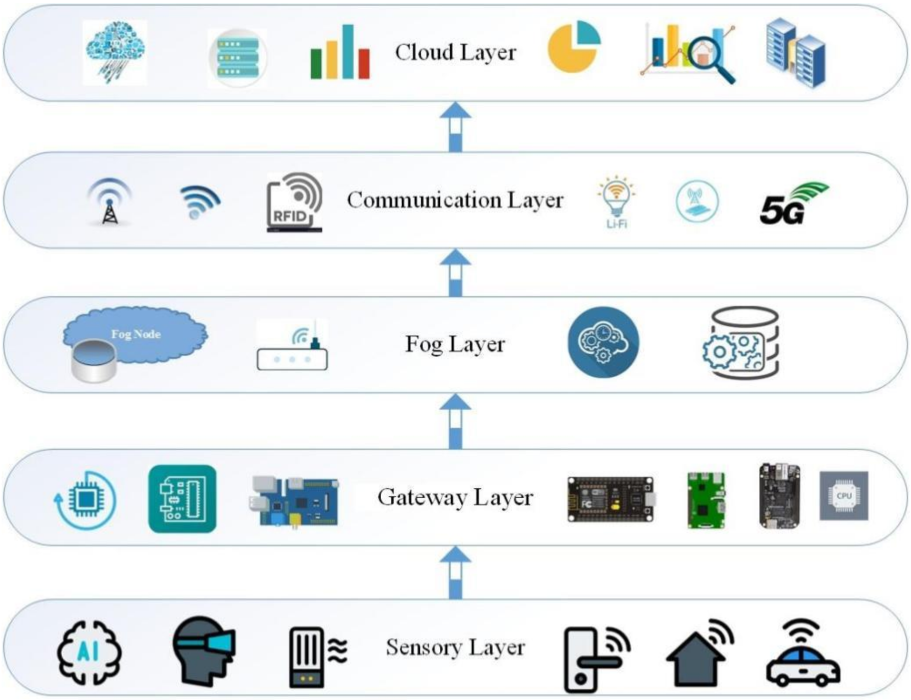


Figure 1-2 IoT Layered Architecture

1.1.1.2.1 Sensory Layer (SL)

The SL is mainly responsible for capturing physiological parameters and automatic identification of the pregnant woman. An electronic signal is generated by sensors placed in physical objects that receive a signal from a biological or chemical source and then convert it into an electrical output signal. Some of the most common sensor types include thermometers for measuring temperature and heat flow; magnetic sensors for measuring the magnetic flux density of a magnetic field; electrical sensors for measuring the current and voltage; mechanical sensors for measuring the flow of a fluid; optical sensors for measuring the optical properties of light (light intensity, polarization, etc.) The data packets from the sensors are sent to the next level [20].

1.1.1.2.2 Gateway Layer(GL)

The GL supports the task of, the transmission of health data packets via routing, and communication between smart devices and pregnant women using a wireless medium. For preprocessing or analysis, data from sensors is sent through the fog layer or straight to the cloud server, via the gateway layer. Sensors and microcontrollers are working together to create a smart and intelligent gadget that can collect data from a patient's body in real-time. In this layer, microcontrollers like Arduino, Raspberry Pi, Atmega, and so on may be found. By integrating sensors and microcontrollers into conventional devices, this layer enables the creation of smart ones.

1.1.1.2.3 Fog Layer(FL)

It includes the fog nodes (also known as fog servers) or fog nodes located near the smart devices and responsible for preprocessing real-time health data. When creating an E-healthcare system, it is beneficial to include an additional layer of complexity. The fog layer minimizes latency and boosts the processing capability of the e-healthcare system. This specific layer is accomplished by authenticating the patient, validating the metrics, establishing a baseline, and identifying crucial situations. Depending on the number of nodes in the FL, they may collaborate to accomplish the tasks mentioned above.

In some cases, fog nodes may gather and analyze data from many patients and send it to fog servers. After that, the fog servers are responsible for sending data to cloud servers in an emergency or for generating a certain type of warning message. In addition, several security methods can be implemented on this layer to safeguard patient data.

1.1.1.2.4 Communication Layer(ComL)

This technology ensures a secure connection between the middleware and the physical layer. A wired or wireless data transmission might be used depending on the application's needs. The network layer routes participant to the destination node. Wired communication includes fiber optic & coaxial cable [21] whereas WiFi, infrared, UMTS, 4G, Bluetooth, and Zigbee are examples of wireless communication technologies.

1.1.1.2.5 Cloud Layer(CL)

The data is accessed by health professionals and pregnant women, from any place via cloud devices. This layer has several advantages, including the ability to communicate between physicians or patients and access data from any place and any device. Cloud servers used in E-Healthcare systems aid in the extraction of meaningful data from a patient's healthcare records. This layer enables doctors to conduct a more in-depth analysis of a patient's condition. Furthermore, the cloud server provides quick and on-demand access to data from any place or device. This layer is sometimes used for intelligent decision-making following a deeper analysis of the data. At this layer, numerous cognitive algorithms may be deployed to provide suggestions in real time. These algorithms behave and make judgments in the same way that humans do by adapting to their surroundings.

It responds to user requests via the linked devices and offers the services accordingly. The Cloud layer sends the request to the service layer to deliver the response to the user/ Constrained Application Protocol (CoAP) is a common IoT application protocol that minimizes transmission bandwidth and processing time [22].

1.1.2 Fog Computing

According to CISCO [23], the term "Fog Computing" describes how cloud computing is being extended to suit the needs of cutting-edge technologies like 5G, the Internet of Things (IoT), artificial intelligence (AI), and more. Fog Computing (FC) provides IoT**Error! Reference source not found.** users with data processing and storage services. When using FC, data is stored on Fog Node locally rather than increasing the cloud's load by transmitting data to Fog Node for storage. Improved cloud performance and efficiency are achieved via FC in this manner. As a result, FC reduces its time to process, transport, and analyze data to and from the cloud. The pregnancy healthcare system monitors the sensitive health parameters of the pregnant woman. The result needs to generate within a fraction of a second in some emergency conditions, which is not possible with the cloud environment directly. The fog nodes ensure the processing of data in the absence of an internet facility or response latency by the cloud server due to heavy severe load or during server downtime. FC when implemented in pregnancy healthcare systems, offers quick results which result save the life of a woman[24]. The typical FC architecture implementation is shown in Figure 1-3.

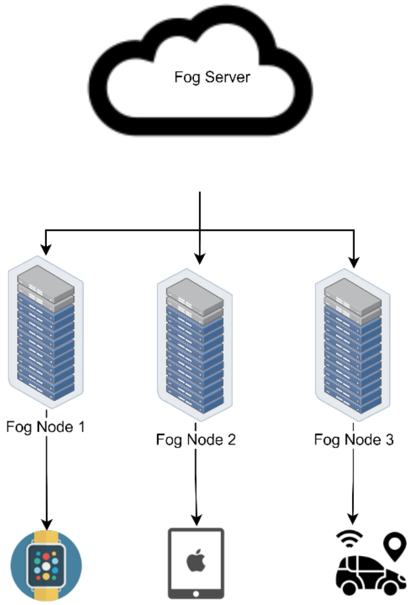


Figure 1-3 Fog Computing

There are fog nodes spread across the network. Targeted regions such as vehicles or homes are equipped with Fog nodes from the controller switch. Nodes are used to examine the data supplied by IoT sensors. Here at the Fog-node, the data is analyzed without sending it back to the cloud, hence minimizing latency and overcrowding of jobs for the cloud.

1.1.3 Cloud Computing

The term "Cloud Computing" (CC) is becoming increasingly popular in cyberspace. It is steadily increasing in popularity because of its extensive and well-executed offerings. CC refers to programs and services that run on dispersed networks employing virtualized resources and may be accessible using common internet protocols and networking standards. Over the past several years, cloud computing has proven as a useful tool for the healthcare system. Implementation of CC makes the effective utilization of smart healthcare systems. CC may offer to process patient data in bulk, which needs several computing resources as well as manpower(eg. Detection of a specific disease by comparing different MRIs or X-Rays), sending health information about the patient remotely, etc. Cloud computing can also be used to implement a smart ambulatory system that will send the health conditions of the pregnant woman, on the go so that hospital can start preparation of the treatment before the arrival of the patient[25].

1.2 Motivation

The everyday population is increasing rapidly and traditional healthcare does not fulfill the needs of individuals. There are still many regions of the country in which the population is not able to get medical services at low cost and near to them. People who live in rural areas need to move to urban areas for their treatment. The availability of a smart healthcare system allows people to get information about their health at their place. Furthermore, people can be connected with doctors remotely which can save their time or even resources such as time and money. E-Healthcare or smart healthcare offers efficient ways to manage emergencies remotely and improve user experience and health quality. Smart healthcare is possible through the utilization of IoT resources. IoT technology offers health monitoring at the patient's doorstep and transfers health data to health professionals and caregivers at a reduced cost in a quicker way[26].

The current pregnancy healthcare system is based on the manual recording of health parameters which may lead to errors while data entry that does not provide accurate predictions in most cases. Also, the present systems are not able to capture real-time healthcare data remotely without doctors' or healthcare professionals' intervention. Moreover, present systems do not implement fog computing aspects which are not capable to recommend any suggestion to pregnant women in the absence of network connectivity. Facial authentication is not implemented in present systems rather than passwords are implemented in a few which offer a low level of security also there is the bombardment of the data as the cloud server of the non-pregnant women.

The advantages of the Internet of Things and gaps found in the existing healthcare system become the motivation to create a pregnancy healthcare system that monitors the health parameters of pregnant women in a real-time environment and provides a connection between the patient and health providers or caregivers remotely. In addition, the recognition of patients is the second aspect of the pregnancy healthcare system to resolve the issue of dummy data collection at the cloud server end.

1.3 Problem Formulation

The proposed system is a method of providing healthcare to pregnant women. The objective is to design a system that protects the mother's health since "a healthy mother gives birth to a healthy baby." The proposed technology constantly analyses the mother's health and advises her to take preventative measures at every opportunity. The mother's relatives can also access her health records using this method. As a result, the suggested system reminds women to carry out their regular activities, including reminders to take medicine as per their prescription, set appointments with their doctor, and monitor their body changes. As a result, it helps the doctor to better understand the patient's health through her daily routine. Pregnant women with high-risk pregnancies find it to be a blessing.

E-Healthcare Kit, Fog Node, and E-Healthcare Interface are three technologies included in the proposed healthcare system.

a. E-Healthcare Kit

E-Healthcare Kit is based on IoT architecture, designed to monitor the health conditions of a pregnant woman in a real-time environment. The kit is made up of a sensor that a woman needs to wear for health monitoring. The sensors are connected to the microcontroller which is responsible for segregating the collected health information in health parameter packets. The E-healthcare Kit have embedded with several biomedical sensors such as blood pressure, Pulse Rate, heartbeat, body temperature, and ECG. The E-Healthcare kit sends the data to the fog node for further processing. The E-Healthcare kit mainly includes the components like sensors, microcontrollers, communication mediums like Bluetooth, and the nRF module. Sensors get power from the battery connected to them and collect health data which is further sent to the microcontroller. The microcontroller receives the data of all sensors collaboratively which further is divided into labeled data packets. These data packets are sent to the fog node via the communication medium nRF module. nRF module is best suited for data transmission wirelessly with a 2.4GHz speed.

b. **Fog Node**

The fog node is responsible to check the security concerns and health data classification based on the collected health parameters. It is responsible for authenticating the pregnant women so that the dummy data will not be bombarded onto the cloud servers. The fog node is placed near the healthcare kit to perform its task. The fog node is prepared from the RaspberryPi system with the PICamera attached to it. The real-time image of the pregnant woman is captured by the fog node for user authentication. If the user of the system passes the authentication the fog node analyzes the health packets received from the E-Healthcare kit. The analysis is performed to find the health condition class i.e. normal or critical. The outcome of the processing is further sent to the cloud server from where the doctors and caregivers can get the pregnant women's health condition. Furthermore, based on the outcome the fog node generates health recommendations for the pregnant woman to improve her health conditions.

c. **E-Healthcare Interface**

The intelligent E-Healthcare interface is designed for the user to interact with the system. The interface allows the patient to get connected with the doctors directly and retrieve health information efficiently. The E-Healthcare system is prepared in the form of a web application designed in HTML, CSS, and BootStrap and developed in Django and backend as Python technologies. The web application has a great user interface and allows user to get their health information with a single click. The healthcare kit allows health professionals to maintain the health records of all patients within a single database. Health professionals can get the latest information and history about the patient easily. The E-Healthcare web application has its database created in MySQL for storing historical information and is also connected to a cloud server to get the latest information about the patient. The web application also generates recommendations based on the health outcome which improves the quality of health.

So, the system provides a complete solution for a pregnant woman to monitor changes in her body and her health condition variations.

1.4 Objectives

- To design an E-Healthcare kit considering physiological symptoms of pregnant women.
- To develop intelligent algorithms to process and analyze the real-time data captured through the E-Healthcare kit.
- To design and develop a recommendation system for pregnant women and physicians.
- To test and validate the developed system.

1.5 Research Significance

Every day, around 295000 die during pregnancy or childbirth. It has been observed that 94% of this death occurred in rural areas due to less resource availability and preventable measures [27]. The major reason for maternal death is the inequalities between poor and rich people in getting healthcare recourses. As per the statistics, it was found that 463/100000 deaths occur in low-income countries while 11/100000 in high-income countries[27].

Several women in rural areas are not able to get proper treatment or care during pregnancy due to several reasons unavailability of the resources in rural areas, less income, lack of pregnancy knowledge, poor quality of the services available, or cultural practices and beliefs.

The reason behind maternal death is a complication during pregnancy or childbirth. The majority of these complications are curable or preventable. The issues such as high blood pressure, low heart rate, and panic attacks are usually found in every pregnant woman and are the major reason for death deficiencies. Every woman required extra care during pregnancy or after childbirth to save herself from maternal issues. Hypertension (high blood pressure) is the major concern during pregnancy due to which several other issues can arise. So it is required to monitor the blood pressure level of the pregnant woman regularly for safe pregnancy and childbirth.

The proposed system adheres to the major concerns during pregnancy and makes several facilities available on the women's doorstep.

1.6 Outcomes of Research Findings

The proposed research aims to offer health services to pregnant women. The proposed system is based on several research outcomes such as:

- Understand the health complications occurred during pregnancy
- Classify the health conditions of the pregnant woman as normal or critical
- Analyze the chances of health deficiencies during pregnancy and childbirth.
- Create a pregnancy healthcare system to monitor the health conditions of the pregnant woman.
- Develop a recommendation system to generate alert messages and suggestions based on real-time health conditions.

1.7 Thesis Contribution

The proposed pregnancy healthcare system aims to offer health monitoring facilities at the patient's doorstep by performing several actions through different layers and recommendation generation. The machine learning-based model is used to identify the health parameter classes and recommends suggestions in a real-time environment. The primary goal of the study is to offer healthcare services to every pregnant woman and to reduce the maternal death ratio or maternal complications during pregnancy and childbirth. The system helps in monitoring the health conditions of a pregnant woman and creates real-time doctor-patient interaction for health improvement. The system also offers necessary health information about the pregnant woman to the caregivers for assurance of the proper health of the mother and infant. The current investigation aims to answer the stated research concerns. The following is an example of the thesis contribution:

- Established a user and eco-friendly healthcare environment by proposing machine learning and IoT-based pregnancy healthcare system.
- Identify the role of machine learning to classify the health conditions of pregnant women.

- Analyze the health conditions for providing real-time recommendations to the pregnant woman and caregiver.
- Create a smart healthcare system by which patients and doctors can interact remotely to offer on-time and better health services.

1.7.1 Presumptions

The proposed system is based on the following presumptions

- The proposed system is capable to identify the health parameters of the pregnant woman only
- Network connectivity at the patient and doctor's end.

1.8 Thesis Organization

The presented thesis is organized into seven chapters. Chapter 2 focuses on the review of related studies in IoT and pregnancy healthcare systems. Chapter 3 describes the E-healthcare kit's implementation and the sensor information. In chapter 4, the algorithm is presented, which predicts the outcome of the pregnancy and results from the chances of a cesarean as per the collected health parameters. In chapter 5, the recommendation system is discussed, and in chapter 6, the proposed system is tested and validated based on a comparison made between popular classification algorithms. Finally, chapter 7 discusses the conclusion and future aspects of the proposed system.

Chapter 2

REVIEW OF LITERATURE

This chapter contains a comprehensive literature analysis of the healthcare system for pregnant women. This chapter covers all of the pre-processing, feature extraction, and classification approaches referenced in the literature. Additionally, this chapter provides a comprehensive evaluation of the datasets available for the Facial Emotion Recognition System.

2.1 Internet of Things (IoT)

The Internet of Things (IoT) is the current research topic in wireless telecommunications, and it's rising in popularity.

The fundamental premise of IoT is the pervasive presence of a variety of things or objects – such as sensors, Radio-Frequency Identification (RFID) tags mobile devices, and actuators – that are capable of interacting with one another and cooperating with their neighbors to accomplish common goals through the use of unique addressing schemes [28]. The utilization of IoT regularly creates a significant impact on individuals, which in turn increases their potential. When it comes to everyday life, IoT affects business organizations or domestic areas to a large extent. Domestics, E-health, assisted living, and enhanced learning are only a few application scenarios in which the new paradigm will play a significant role in the future. According to US National Intelligence Council, IoT is listed as one of the six “Disruptive Civil Technologies” which have a high impact on US national power [29].

The main threat associated with the utilization of IoT devices is also emphasized. Several objects used in daily life may store information further connected to the Internet, resulting in a high-security risk to the stored data. Before the Internet of Things (IoT) concept is broadly accepted and utilized, several challenging concerns need to be resolved. There are several critical concerns to address to make the interoperability of networked devices as well as to improve the capacity of these devices to adapt to the environment autonomously by ensuring privacy, trust, and security concerns as IoT has several issues related to the networking aspects. As a result, the connected Internet of

Things devices will have poor computational and energy capacity. As a result, IoT solutions must pay particular attention to resource efficiency in addition to the apparent scaling issues. Numerous research bodies and industries work together to fulfill the technological requirements demanded by IoT networks.

2.1.1 Internet of Things Related Technologies

There are several definitions of IoT that state the importance of IoT within the research community. These definitions originate after several discussions on IoT-related issues or technological interests. During the literature review, the researcher might face some difficulties in understanding the actual concept of IoT and its real implication for economic, social, and technical development. The term IoT is coined from two terms. First, it refers to the networked architecture, and second, it focuses on the integration of objects with the utilization of the network. "Internet" and "Things" combined take a meaning that brings disruptive innovation into the ICT world today. Internet of Things, in reality, implies "a worldwide network of networked items uniquely accessible, based on standard communication protocols" [30]. The IoT was first prescribed from the term “things-oriented”, in which the smaller object Radio-Frequency Identification (RFID) tags were taken into consideration. Then, the phrase "Internet of Things" was coined by The Auto-ID Labs[31], a global network of university research laboratories specializing in networked RFID and new sensing technologies. Since its inception, these organizations have been tasked with designing the Internet of Things with EPCglobal [32]. In a larger sense, IoT is not merely a worldwide EPC system in which only RFIDs are used. The same holds for the uID architecture, which uses a unique/universal/ubiquitous identifier (UID)[33]. The primary goal of such systems is to build IoT-based solutions constantly for global IoT object visibility. Using RFID-centric solutions initially might be beneficial because the IoT will undoubtedly solve the major aspects emphasized by RFID technology, namely item addressability, and traceability. IoT ideas, however, acknowledge that the word IoT connotes a far broader vision than the concept of merely identifying items. Although RFID is no longer at the forefront of this vision, it nevertheless plays a significant role. This is a result of RFID's maturity, cheap cost, and strong backing from the corporate community. They argue that a wide range of devices, networks, and service technologies will eventually come together to form the Internet of Things (IoT). "The atomic components that will link the actual world with the digital world" is how NFC Wireless Sensor and Actuator Networks (WSAN) and RFID are described. WISP (Wireless Identification and Sensing Platforms), a large effort aimed at establishing applicable platforms, is another example of this trend. Due to such kind of efforts, RFID is being matured and has strong support and low cost in business organizations. As a result interconnection of huge devices, service technologies and networks collaboratively made IoT-based networks. Gluhak and Presser [34] state the term “Things Oriented” which specifies the IoT beyond RFID. The United Nations made a similar prediction about the Internet of Things (IoT) during a conference in Tunis in 2005. According to a UN report, humans may become a minority in terms of traffic generation and reception, and the changes caused by the Internet would be dwarfed by those spurred by common items' networking [35].

Similarly, Internet Ø [36] reduces the complexity of the IP stack by designing a protocol that routes “IP over anything”[37][38][39][40]. Semantic technology might be critical in this situation. Modeling solutions for IoT objects, reasoning with IoT data-produced data, semantic execution environments and architectures accommodating IoT needs, and scalable storage and communication infrastructure may all be used [37]. Furthermore, IoT is also termed the “Web of Things” [41], in which the web standards are re-utilized to connect objects.

2.1.2 IoT Enabled Technologies

Several real-world technologies, when integrated, make the actual IoT concept. Next, this section describes the most relevant applications or technologies related to the IoT. Finally, the section describes the scenario where IoT can be proven helpful in solving problems.

2.1.2.1 The technology of sensing, identification, or communication

The goal of communication technology advancements has always been to make it possible to communicate at any time, from any location, using any media. Radios and people are now reaching the 1:1 ratio in this setting, and wireless technologies have played a significant role [42]. This ratio might rise by orders of magnitude if radios are made lighter, smaller, and consume less energy at a lesser cost. Adding "anything" to the above vision will allow us to include radios in nearly every device, which will lead to the Internet of Things (IoT). In this scenario, one or more readers and several RFID tags will be essential parts of the Internet of Things (IoT) [43]. The RFID tags include a unique identifier that can be applied to any object, including humans or animals. A signal generated by the reader initiates the transmission of tags, which acts as a search for nearby tags and a request to get their IDs. RFID uses this method to identify real-time objects without direct line-of-sight to map real-world objects to virtual objects. Therefore, RFID is used across several application areas, including healthcare and security. RFID is a single small microchip with 0.4 mm dimensions with zero energy consumption(used to transmit tag ID based on a request from reader signal) that is connected to the antenna and combined as a package similar to an adhesive sticker [44]. The transmission frequency of RFID is 124kHz to 135kHHz(low frequency) and 860MHz to 960MHx(ultra-high frequency).

An essential part of the Internet of Things (IoT) will be sensors. They can work with RFID systems to better monitor the state of goods, such as their temperature, location, motions, etc. Sensors can act as a bridge between the real world and the digital world, which may help people be more aware of their surrounding environment.

Intelligent transportation, Environmental monitoring, military use, e-health, and industrial plant surveillance are just some of the applications of sensor networks. A sensor network contains several sensing nodes that communicate wirelessly over many hops. Sinks are special nodes that receive information from sensors and report it to a small number of nodes. As a result, the scientific literature on sensor networks has grown significantly, covering various issues at every tier in the protocol stack [45]. Several WSNs based on IEEE 802.15.14 standards specify MAC or physical address for low bit-rate and power [46]. Incorporating sensing technologies into passive RFID tags would open up a wide range of new IoT applications, particularly in the E-healthcare sector [47]. There have been several recent proposals for this approach. These technologies will enable the creation of RFID sensor networks [46].

2.1.2.2 Middleware

Middleware refers to the software layer between the hardware and application layers. It offers the abstraction level to the programmers from the development issues of the specified application of IoT infrastructure. Middleware makes it easier to build new services and incorporate legacy technology into new ones, due to which has grown increasingly in recent years. As a result, programmers do not require to know the technology implementation at the lower layers. Many IoT middleware systems introduced in recent years use the Service-Oriented Architecture (SOA) methodology. In addition, a horizontal perspective of an enterprise system may be gained by using common interfaces and standard protocols. Several advantages to employing an SOA method include reusing hardware and software [48]. According to most research, middleware solutions for the Internet of Things tend to favor SOA approaches.

2.1.3 IoT Enabled Applications

IoT has been utilized in almost all aspects of life, including homes, cities, organizations, educational institutions, agriculture, the environment, the healthcare industry, etc. [49][50][51]. IoT has several capabilities for the production and consumption of data, offers online services, and improves different activities related to the real-time environment[52]. As per the increase in human desires, IoT applications are also increasing rapidly, which automate the management and monitoring of several human activities[53][54]. Moreover, IoT applications, when integrated with cloud services, offer better services to their users independent of their location[55][56]. IoT creates applications for smart devices which can be utilized in the real-time environment in several fields. Moreover, IoT offers the best facilities for management, monitoring, and decision-making activities[57]. The majority of these IoT applications shared a similar objective to increase the quality of an individual's life[58][59]. Several studies have been made that discuss several IoT applications[60].

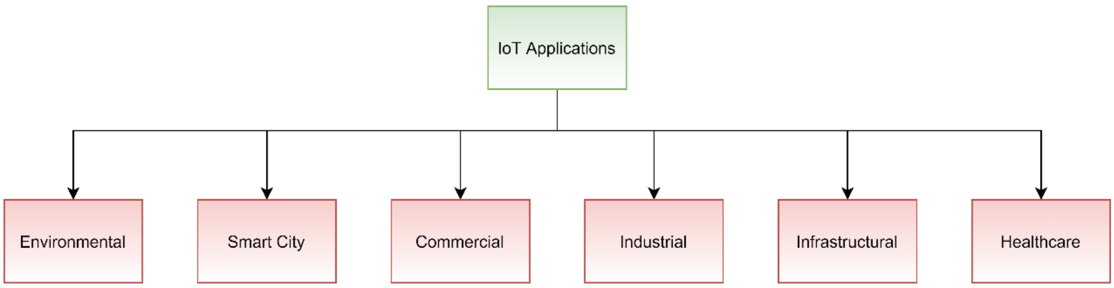


Figure 2-1Applications of the Internet of Things

As shown in Figure 2-1, the different application areas of IoT include the environment, smart city, business organization, infrastructural communities, and healthcare industry [61],[62],[63].

2.1.3.1 Environmental Applications

There have been many studies conducted that demonstrate the utilization of IoT in the environment. Li et al.[64] created a henhouses environmental monitoring system to capture parameters including humidity, ammonia(NH_3), carbon dioxide, and atmospheric temperature. According to the authors, earlier research focused on creating systems without regard for data transmission dependability. Accordingly, the authors proposed a transport protocol that utilized a loss recovery method to solve the data transmission dependability issue. Additionally, to increase the system's integrity or get an estimation of data rate, auto filtering of replicated data and filling of lost data methods were used. Furthermore, the proposed system also had a web-based remote monitoring system that allows the user to access information and manage the henhouse environment remotely via smart devices. As a result, this project has expanded to include new research enhancing data collecting precision and dependability while also cutting down on small maintenance expenditures. However, no consideration was given to energy use in this investigation.

In [65], an IoT-based ecological management system was presented. The primary goal was to identify the wild vegetation community as the primary objective, focusing on climate change. The research work is based on the WSN, which consumes significantly lesser energy. The soil temperature and humidity, carbon dioxide and tilt, growth conditions, and illumination of the habitat environment, indicated by the tree's diameter and the movement of its sap, are all monitored when it comes to controlling a natural vegetation environment. The authors proposed a model to build and examine a test bed utilized for rough trees to evaluate the recommended system. Unfortunately, no outcomes demonstrate the efficacy and implementation of the proposed strategy. Nordin et al. [66], at Lake Chini(Malaysia), investigated the revival of a rural hydrological control system. As a result of this investigation, the authors have insight into the reliability and performance limitations of the sensor network with low data capacity, particularly in rural areas where LoRa and 2G networks are deployed. Yen et al. [67] developed a low-cost smart home solution for pet owners or people with the issue of hearing or visual incapacities. The proposed smart house employs a variety of sensors to assure a real-time response to human needs in four primary areas, including clothing, transport, shelter, and food. Additionally, a web server is used to store the acquired data and give statistics and data analysis support. It was designed explicitly for humidity and temperature control, health, security, and safety control for pets, the handicapped, and the elderly control features. The experiments were successful, and as a consequence, devices for remote control through the Internet may be easily connected and inexpensive. Using the term "smart city," Sukmaninsigh et al. [68] classify information and technology relevant to natural catastrophe monitoring and management. It proposes a prototype for monitoring smart disasters utilizing ICT and the Smart City domain to minimize natural disasters' significant impact on sustainability and mitigate environmental consequences. Ahamad et al. [69] used IoT to study the ozone surface in three Malaysian locales to explore ozone movement. The acquired data was processed to show the variations in closer stations. IoT is a practical and feasible approach used to determine meteorological and foundations situations sensitivity. Recent research proposed by Suparta et al. [70], consider the greenhouse gas monitoring system to control the emission of gaseous substances using Netduino 3 WiFi-connected microcontroller. In addition to temperature, humidity, and pressure, the developed system could also gather surface meteorological data. The authors say that their technology works well in remote areas and has been successfully tested in the lab.

2.1.3.2 Commercial Applications

The number of IoT business applications has grown significantly in recent years. Alodib [71] utilizes a prototype-driven approach to develop a real-time control mechanism for the QoS-aware facility structure. The author raised the issue of SLA violations as a serious concern. It is vital to examine the Discrete Event System (DES) to see if the proposed technique can be integrated with the Petri net model. To ensure the quality of service (QoS), a cost-effective implementation study was constructed, although scalability was not included in the research.

Researchers Han and Crespi [72] designed a system for maintenance supply semantically for smart devices. The primary goals were to deliver smart device services based on the web through various standard application programming interfaces (API) which have some limitations, such as assets memory or computing resources, energy-efficient microcontrollers, and low-speed transmission channels. In various scenarios, Contiki Cooja used samples and web-based capabilities to test the system (simulator). Improvements in IoT applications on the web have increased their dependability, security, and scalability for service delivery.

According to Huo et al. [73], facility composition should be based on a multi-purpose prototype for cost-efficient optimization. The QoS aspects' reaction time, data rate, accessibility, and reputation were evaluated. It was decided to use the Artificial Bee Colony (ABC) algorithm to grow the specified quality of service (QoS) factors and save expenses. Two datasets were used to test the model's performance. A comparison was made between the new model's outcomes and those from prior iterations to see which was the most effective. However, the settings were not considered, such as cloud computing with its rapid data flow that generates extra critical demands.

For a dynamic approach to facility selection, Huo and Wang[74] developed a new ABC algorithm. An advantage of this method over others, such as a genetic algorithm, is that it has a more predictable reaction time and higher precision in chaotic solution spaces. The MATLAB software's results reveal a short response time and fewer repetitions of average convergence. Unfortunately, this approach hasn't studied the effects of sequential task node optimization.

Temglit et al. [75] propose a web service collection be structured using a multiagent QoS aware technique. It was suggested for optimization of service management design and context awareness. Using the SAW approach, researchers examined how existing QoS-aware services are organized and how they are collected. It was based on using a flowchart to demonstrate faster response time and integrate the new service with existing methods.

Cuomo et al. [76], [77]devised a new technique to extract data from different databases, followed by research, verification, and reporting for financial systems. Finally, according to the model, the interest rate may be calculated by looking at the data obtained. Through the recommended parallel technique, this strategy aids in reducing the complexity period for the project.

2.1.3.3 Industrial Applications

Additionally, IoT technology has a significant role in the industrial sector[78]. Several studies were conducted to identify the contribution of IoT to industry. Li et al. [79] developed a planning technique to improve QoS choice-making procedure top-down using the Markov decision algorithm. With MATLAB software, the authors created a scenario model and tested their proposed solution to the problem. End-to-end latency, Response time, bandwidth, and accessibility all were considered during the evaluation. The proposed resource planning strategy was examined, and the overall network latency was reduced.

Venticinque & Amato [80] describes the implementation issues of fog services. For example, the smart energy domain is a good example of an IoT application that might benefit from computing resources. This research project provides independent knowledge of energy profiles and an improved program plan via the use of multiple computing resources, which is the primary goal[81] [82] [83].

For industrial applications, Daell et al. [84] proposed an IoT-based Healthcare management system. Prognostics and systems health management (PHM) is defined in terms of the following four key components: sensing, diagnosis, prognosis, and management. There is a strong likelihood that the use of PHM will have a substantial impact on the development and forecast of new business possibilities.

Industrial IoT (IIoT) was mentioned by Michele et al. [85], who focused on Low-Power Wide-Area Networks (LPWANs). Creating a realistic LoRaWAN simulation model aimed to test various network configurations often used in industrial monitoring applications for their effectiveness. For example, IEEE 802.15.4 has also been compared and found to be a promising WPAN architecture.

2.1.3.4 Health-care applications

Sharma et al. [86] focused on implementing IoT in medical applications. The authors discussed that IoT in healthcare improves the system's efficiency and working and the network involved in traveling data between sensors and the cloud.

Kim and Kim [87] presented a complete guide for healthcare service providers based on the user’s point of view. According to this research, several key characteristics of the services supplied have an even greater influence on consumers' willingness to confirm their usage. In addition, trust and risk sensitivity were analyzed to determine whether or not the services were suitable. By concentrating on lifestyle illness, this study found that consumers in South Korea choose trustworthy and safe healthcare services. For IoT healthcare service providers, this study provides straightforward and novel guidance to help them increase the dependability of their services. However, this study has a flaw in that the results are drawn from a fictional service description rather than a commercial service used by a healthcare customer. Warsuzarina et.al. [88], proposed a model that will capture the heartbeat of the person and send the data to doctors or the patient’s near dears via SMS. They use a PIC circuit connected to the device that measures the heartbeat and this device in turn connected to the Modem and sends SMS. This system senses the heartbeat by placing a figure between LDR and Super-Bright LED at the sensor circuit. Mamidi et al. [89], proposed a model that detects heart attacks and monitors heart rate. They proposed a model based on IoT for heart attack detection in old age people and notify the heat anomaly of the person to the family by an alert SMS. They filter the collected data from pulse rate by techniques of big data analytics.

Fafoutis et al. [90] presented a monitoring system capable to prevent & detect chronic diseases such as obesity, diabetes, and depression in today's home environment. The issue of energy limits is discussed in this article due to the associated expenses of recharging or replacing the batteries in wearable devices. Therefore, only battery-powered methods are considered in this study.

Hassan et al. [91], created an ECG monitoring system that captures the ECG signals of heart patients at their homes. The designed model allows doctors to remotely monitor the patient's health conditions through the IoT Blynk application. The proposed system allows remote patient monitoring by using IoT sensors attached to a microcontroller to capture data. The data transmission is performed using a WiFi module through the Blynk application.

Jimenez and Torres [92] created a low-cost prototype for a healthcare monitoring system based on IoT whose term of use might be prolonged. Furthermore, it adds humidity and temperature to get the impact of environmental conditions on the health of the patient.

Ding et al. [93] developed an IoT-based system for remote health monitoring via mobile devices. The proposed system captures the physiological characteristics and human interaction model through intelligent nodes. It enables effective emergency alert systems by recording vital information in the hospital’s data center. The work's flaw is that it was completed without regard for expense.

Savola et al. [94] proposed an adaptive approach for managing security metrics. The security intents of E-health IoT applications are evaluated, with a special emphasis on the health of seniors and the treatment of chronic diseases. Additionally, this article discusses the security requirements and implementing adequate security controls in the face of evolving security risks in such systems. The adaptive security management system described here considers a variety of including security accuracy, efficiency, security parameters effectiveness, secrecy, and privacy level.

According to Baloch et al. [95], IoT healthcare applications can benefit from layered context-aware data combining. The suggested method consists of obtaining context, constructing conditions, and implying. This article covers these networks and how they function. "Data fusion" is a strategy for merging datasets from numerous heterogeneous sources since the data is obtained from multiple sources. In this research, an innovative technique of displaying the collected data is given to aid in making timely judgments.

Damis et al. [96] conducted an experimental investigation to detect the healthcare parameters of IoT applications. The purpose of this study is to demonstrate and assess Error-Vector Magnitude (EVM) exams and the BER factor[97]. The results demonstrate a correct relationship between the radiation forms and the refection factor[98].

According to Selveraj et al. [99], IoT deployment in the healthcare industry has been considered. The authors said that accuracy and power consumption are the most important factors determining the IoT implementation's performance. The writers examined the pros and drawbacks of IoT applications in healthcare.

According to Paul et al. [100] [101], incorporating IoMT into the healthcare sector will improve the healthcare system's efficiency, dependability, accuracy, and efficacy. The authors use cyber security to deploy IoMT in healthcare.

2.2 IoT Integration with Fog and Cloud Computing

The Internet of Things (IoT) is made up of various devices connected via a variety of networks. Every day, more and more things are becoming part of the IoT. This rapidly expanding network connects various hardware, software, sensors, and other physical items. As a result, IoT has grown in popularity across many people and businesses. IoT is a ubiquitous technology that provides several solutions to various application areas. As reviewed in the previous section, IoT systems prove to be useful in numerous fields, including smart cities, smart industries, healthcare, etc. Data from IoT devices may be mined and analyzed for trends, predictive analysis, or optimization to make better decisions at the right moment. Two types of data may be found in these situations[102]:

- Little Data: The term "Little Data" or "Big Stream" refers to the transitory data that is continually collected by Internet of Things (IoT) smart devices.
- Big Data: Big Data is a term that refers to durable data and knowledge that are kept and archived in a centralized cloud storage environment. For efficient real-time analytics and decision-making in IoT contexts, including smart cities and infrastructures, both Big Stream and Big Data are required[103].

The Internet of Things can allow real-time cities [104] to study city infrastructure, life, and new governance models. Currently, data is gathered and aggregated from IoT networks comprised of smart devices and transmitted uplink to cloud servers for storage and processing. The Internet of Things has evolved from technologies such as Radio Frequency Identification (RFID) [105] and Wireless Sensor Network (WSN) [106],[107], [108], [109], [110], [111] for offering different related services

A typical IoT system contains communication interfaces, sensors, a cloud interface, and complex algorithms. Sensing devices are used to collect data from a variety of devices. RFID and wireless sensor network technologies provide communication and network infrastructure. Through Application Program Interfaces (APIs) or applications, advanced algorithms are employed to process data and assess anything important. Thousands of client-server requests can be sent between mobile devices and cloud and Internet-based services, enabling users to access various services concurrently[112], [113]. There are four key categories of IoT services [114], [115], [116], [117].

To begin, smart wearable devices may be utilized by patients who require data about their health state, such as blood pressure, heartbeat, and glucose level, to be collected via sensors on wearable technology and transmitted to smartphones. Simultaneously, the health state of patients may be tracked. Second, IoT may be used to enhance smart houses. Sensors can detect temperature changes, but air-conditioning systems can be monitored. Using home security cameras, homeowners may receive alerts via mobile applications if intruders are spotted in their homes. Third, Smart cities may be achieved by using IoT to monitor traffic and transportation systems. This information may be used to better understand traffic networks and transportation systems changes by analyzing data. Fourth, the supply chain system may use IoT to record and track all deliveries in real time. It is possible to change delivery records once a shipment has arrived at its destination.

These IoT use cases may be translated to a generic paradigm that enables smooth integration with various services, ranging from APIs to big data processing, sensors to network infrastructure, and ultimately analytics to predictive modeling [118],[119]. This technique enables customers to have simpler access to services, track the status of service delivery, and compare service providers' costs and reviews. Additionally, service providers may increase their exposure to more clients, monitor their company's success, and quickly analyze market trends.

IoT technology provides us with several benefits to creating different applications, including reducing human efforts, real-time monitoring, health monitoring, and even lifesaving. IoT technology implements several sensors that work collaboratively. However, the increasing expansion of IoT and widespread adoption of small wearable biosensors have created new prospects for tailored eHealth and services. The sensors work along with several different but related technologies to build a complete IoT system capable of performing specific functions as per the requirements. There are several technologies that, when implemented with IoT-based systems, increase the performance of the system and improve system efficiency. This section discusses some related technologies that will enhance its efficiency when integrated with IoT-based healthcare systems.

IoT devices and sensors communicate with cloud data centers via fog computing, an intermediary layer between the two[120]. To provide Cloud-based services to the IoT devices/sensors, it provides computation, networking, and storage resources. In 2012, Cisco proposed the notion of Fog computing to overcome the issues of IoT applications in conventional Cloud computing[121].

Latency-sensitive and Real-time service needs demand that IoT devices/sensors be located close to the network edge. As a result, Cloud data centers typically fail to meet the storage and processing needs of the billions of geo-distributed IoT devices/sensors since they are located in the same geographic location. Congested networks and poor Quality of Service (QoS) are encountered due to this[122]. An IoT device or sensor can be positioned closer to the Fog computing environment's typical networking components (e.g. routers and switches), proxy servers, Base Stations (BS), and so on[123].

As a result, these parts may be used to run service-oriented applications with a wide range of capabilities. Cloud-based applications may be distributed across a wide geographic area because of Fog computing's networking components. Among other things, Fog computing provides location awareness and mobility assistance, scalability, real-time interactions, and interoperability[124]. In this way, Fog computing can perform well in terms of service latency, power consumption, network traffic, capital and operating expenditures, content distribution, and more. In this regard, Fog computing is superior to Cloud computing for IoT applications[125]. Even yet, the notion of Fog computing resembles several of the more well-known computer concepts.

The existing centralized cloud computing architecture is unable to handle IoT applications. For example, it does not enable time-sensitive IoT applications like gaming, augmented reality & video streaming [126]. In addition, because it is a centralized architecture, it cannot track a user's whereabouts. Fog computing is a solution to these problems. Furthermore, IoT devices may connect to large-scale cloud computing and storage services using fog computing. In the cloud paradigm, fog computing is a component that moves cloud computing closer to the network edge[127], [128], [129]. Cloud computing, fog computing, and jungle computing are examples of distributed computing[130]. There was a lot of discussion about these paradigms as well as the characteristics and application areas of each one. The authors also covered cloud, fog, and jungle computing paradigms and how they are used.

Fog computing will address IoT devices' real-time issues, which brings cloud computing, computation, and storage capabilities down to the edge of the network, allowing for safe and efficient IoT applications[131]. With widely dispersed installations, fog computing offers various services and applications. For example, the fog provides effective real-time communication between various IoT applications through the proxy and access points positioned along lengthy highway sand tracks, such as linked automobiles[132]. In addition, gaming, video streaming, augmented reality, and other low-latency applications are best served by fog computing.

Hao et al. [133] explain why fog computing is needed to replace cloud computing. The authors also examined numerous topics and obstacles associated with fog computing and how to evaluate the difficulties related to the field. It is expected that the IoT would benefit significantly from fog computing. IoT issues can be solved by fog computing[134]. But, unfortunately, fog computing is still a very new field of study. Hence there aren't any real solutions to support it [135].

The study by Yi et al. [136] provides an overview of fog computing by examining several fog computing application scenarios and potential stumbling blocks. Y. Shi et al. [137][138] highlighted Fog computing's basic properties. It has been mentioned by N. Peter[139] that fog computing has real-time applications. According to this research article, fog computing can handle the massive amounts of data generated by IoT devices. Fog computing may also handle congestion and latency concerns.

Research by C. Puliafito et al. [140] focused on mobile IoT devices and the primary issues they would encounter in a fog computing environment. As a result, they identified and detailed three situations in which mobility assistance is critical to integrating the IoT and fog computing systems. There have been several studies on fog computing reference designs. Dastjerdi et al. [141] provided an example of an architectural reference model for fog computing. Rather than relying on the cloud, this architecture handles all IoT queries locally in the fog [142].

Fog computing was also examined by F. Bonomi et al. [143], who looked at how fog complements cloud computing and how it may be used to enhance the IoT. In addition, they presented a distributed architecture for the fog, which is hierarchically distributed. They built a smart traffic signal system and a wind farm to see how well their architecture worked. Fog computing resource management has been discussed in several related studies. According to M. Aazam and E. Huh [144], fog computing may manage resources. Resources may be managed dynamically and realistically using this model's resource allocation techniques. According to the authors, their work might serve as a solid starting point for more realistic research and development in the Internet of Things (IoT) and fog computing.

Gill et al. [145] presented the particle swarm optimization approach as a model ROUTER for optimizing fog cloud-based environment. On iFogSim, the suggested model improved 12 percent of network bandwidth, 10% reaction time and 14% latency, and 12.35 percent energy usage.

It was highlighted by Aazam et al. [146], that fog computing faces several obstacles. There are a variety of difficulties that need to be addressed, such as determining the sort of device that will be used, determining how much power it will need, and determining how much data it will store and process.

To address security and privacy concerns in IoT contexts, A. Alrawais et al. [147] suggested a technique for security enhancement that uses the fog to distribute certificate revocation information more effectively across IoT devices. The researchers presented a case study on how fog computing might be used to address security concerns in the distribution of certificate revocation information in IoT systems.

It has also been shown that fog and IoT integration raises security and privacy concerns[148], [149], [150], [151]. Several security vulnerabilities, they suggested, are introduced by IoT adoption with fog. Therefore, security mechanisms already in use to protect the Internet of Things (IoT) were also covered, along with how to safeguard fog computing environments using various security technologies.

Using fog computing in healthcare is critical[152]. It delivers real-time processing and event reactions, which are essential in healthcare. In addition, a solid network connection is required for the interaction of many healthcare equipment for remote storage, processing, and retrieval of medical records from the cloud, which is not accessible. Therefore, it also deals with network connection and traffic [153]. The smart health solution was created by Craciunescu et al. [154] to record real-time fall detection and gas leakage.

Sood and Isha [155] proposed an IoT-based healthcare system for heart patients to continuously monitor the ECG level of middle or high-risk patients [172]. User-defined risk categories are used to determine what preventative actions or medicines should be taken in the event of an emergency. There is a layer of fog between the sensors and cloud servers in [156], study. The authors designed edge devices that execute data processing, resulting in the IoT network's energy efficiency, scalability, and dependability.

2.3 IoT-based Pregnancy Healthcare System

During pregnancy, there are lots of hormone changes in the women's body and several risk factors associated with the health of the woman, including depressed mood[157][158]. Due to these changes, a lot of diseases can raise in the body of women that can cause harm to the women as well as the baby. So, women must take special precautions during their pregnancy to save themselves and their babies from different issues.

Tomlinson, M. et al. [157][159][160][161] describes various risk factors occurred while pregnancy including High BP, High Pulse rate, Gestational Diabetes, seizures, etc. that leads to the occurrence of different health disorders, Polycystic Ovary

Syndrome, Preeclampsia, Eclampsia, Thyroid, Obesity, etc. which may lead to miscarriage, premature delivery, prodromal labor, fetus weaken, low birth weight, etc.

Moreover, as per the statics shown by WHO in 2017 [162], in 2017, every day approximately 810 women died due to the curable disease. Overall 94% of maternal mortality occurs in low or middle-income countries. To reduce maternal or infant mortality, skilled professionals are required during or during postpartum pregnancy.

To reduce the health impacts during pregnancy, several requirements of the body need to be fulfilled. One of these requirements includes the requirement of bed rest during pregnancy[163]. During bed rest again precautions need to be taken including the position of sleeping as the major concern[164]. Susan et al. [165], investigate the association between sleep position, age, gender, sleep quality, and prevalence of waking cervical pain and stiffness, headache, and aching between the scapulae and/or in the arm. The findings of this study support the need for health professionals to consider individuals' sleep positions and waking symptom history when developing a management plan for troublesome waking symptoms. Furthermore, there are several factors such as blood pressure, heartbeat, walking steps, depression level, and ambient air quality that needs to be monitored for a healthy pregnancy.

A similar study was done by Ganguly S et.al [166], in which authors describe the impact of high blood pressure on the body of a pregnant lady and her baby. There is an increased chance of cesarean due the high blood pressure. Furthermore, high blood pressure has an increased risk of adverse fetal, neonatal, and maternal outcomes, including preterm birth, perinatal death, acute renal or hepatic failure, etc.

Amanda R. et.al. [167][168][169], discussed the different issues that occurred with hypertension or high BP during pregnancy. Hypertension is a disorder that complicates 5% to 10% of pregnancies which leads to diseases like preeclampsia, and eclampsia[170]. Due to this elliptic stroke occurs in a woman's brain and can cause maternal or infant death. Moreover, the authors discussed the different ways to detect these diseases including the types of issues related to fetal growth or preterm delivery.

Charles et.al.[171][172], in discussing the causes and impacts of hypertension during pregnancies. Authors discussed that hypertension is related to different common problems with pregnancy like eclampsia, acute renal failure, maternal death, premature delivery, intrauterine growth restriction, HELLP(Hemolysis, Elevated Liver enzymes, and Low Platelet) syndrome, PIH(Pregnancy Induced Hypertension), etc. The author discussed four types and causes of hypertension disorder chronic hypertension, preeclampsia, eclampsia, and preeclampsia superimposed on chronic hypertension. Ganesh, et.al. [173][174][175], describe the information about preeclampsia and eclampsia. They discussed the symptoms of these diseases what are the risk factors and other syndromes associated with these diseases.

SM. et al. [176] discussed that around 2%-8% of pregnancies get affected by preeclampsia, which may have short or long-term woman health consequences. Sarah et al. [177], described preeclampsia as a pregnancy-specific syndrome of unclear aetiology that has been difficult to define. The diagnosis likely represents more than one disease, which has complicated research in this area. Yet, there is evidence that preeclampsia is not a problem of pregnancy alone, but rather a condition that alters long-term health outcomes for offspring, including effects on blood pressure, BMI(Body Mass Index), and stroke risk, as well as potentially adverse health outcomes outside the cardiovascular system. Examining older cohorts would also be helpful, although defining maternal disease precisely and by current definitions is more challenging in such groups. Further investigation to explore potential mechanisms for developmental programming is also required.

Ayad et al.[178] suggested a mHealth system for serving pregnant women. The proposed mHealth works on the mobile GIS system to select adjacent care centers on Google Maps for online registration of pregnant women. It is done by sending SMS via the GPRS network to the hospitals at the nearby location.

JAYANTHY et al. [179], the authors proposed a mobile-based system that provides information services to pregnant women and their spouses. The proposed model provides services like health care suggestions, Emergency care, and alerts, stages of pregnancy, pregnancy calendar and diary, nutrition and exercise, and post-delivery support by a java based mobile application. The survey is performed on 30 women and out of which 17 women take an interest to capture suggestions for the pregnancy support system.

Olugbenga et al. [180], proposed a real-time stress monitoring system based on the heart rate, of pregnant women using IoT. The study includes 3 layered architecture, sensing layer, edge layer, and cloud layer. The data is captured through the sensing layer via Garmin vivosmart 2 smart band to measure heart rate and activities performed. The edge layer includes the user's mobile phone which used the Qpython tool to create a local web server and process the captured data locally. The cloud layer stores the data globally and uses a k-means clustering algorithm to segregate the data received from the different users. Based on the received data, the calculation of stress level is performed.

Santhi et al. [181], proposed an IoT-based health monitoring system for pregnant women which continuously monitors the vital parameters using the CC3200 module and highlights the performance of the C4.5 clustering algorithm for the prediction of risk associated with health. Fatemah et al. [182], proposed an IoT-based health monitoring system for pregnant women. The system is divided into 4 different but related layers including, the perception layer, gateway layer, cloud layer, and application layer. The perception layer is responsible to capture data from the smartwatch, or mobile applications. The gateway layer is responsible to transfer data between the application layer and the server. The cloud layer analyzes the data to monitor the stress or physical activity level or sleep monitoring of pregnant women. To monitor stress the authors used heart rate or HRV parameters, while to monitor sleep, data is captured regarding step count or hand movement, whereas the physical activity is monitored using step count and wearing time of a smart watch. The application layer is responsible to provide sleep trends and health conditions. To represent data at the application layer, the authors created a web application using Angular 2. For performance, analysis authors capture the data from 28 pregnant women and monitor their stress levels as per the collected parameters.

Study	Year	Problem Specification	Sensor Used	Algorithm	Gaps
Venkatasubramanian [25]	2022	Ambulatory health monitoring system for pregnancy	Blood pressure, heart rate, oximeter, temperature	DCGAN	• Setup only in Ambulance • The system proposed by the authors had an accuracy level of 89.03% • Cloud layer is used for feature extraction but no specification is provided on how the system will work in absence of an Internet facility.
F. Sarhaddi et al.[182]	2021	Stress, sleep, and physical activity	Samsung Gear Sport smartwatch, OMRON M3 blood pressure sensor,	Bayesian RNN, CNN	• Manual data entry of blood pressure to application • The stress level or activity monitoring process is based on questionaries stored in the application
O.Oti et al. [183]	2018	Maternal Stress Monitoring	Zephyr in combination with Amulet wearable device	k-means clustering algorithm	• They need to be worn by a pregnant woman for 7 months continuously • Only heart rate and sleep activity are captured.
I.Azimi et al. [184]	2019	Maternal Sleep quality monitoring	Garmin Vivosmart HR including PPG	Bayesian RNN	• The existing Wrist band is used to

Study	Year	Problem Specification	Sensor Used	Algorithm	Gaps
			and IMU sensor.		monitor sleep pattern • Based on sleep efficiency no recommendations were generated to improve sleep pattern • Not to mention how sleep patterns impact health issues related to pregnant women and infants.
Munoz et al. [185]	2020	Maternity Records Application	-	-	• The record of pregnancy is stored by the application • No recommendations are generated based on the collected data
Moreira et al.[186]	2019	Post-Pregnancy Depression	Existing dataset with parameters age, hypertension, diabetes, and pregnancy-related issues	Decision Tree, Support Vector Machine, Nearest Neighbour, Bagging Tree	• The system predicts the chances of postpartum depression in pregnancy based on age and hypertension. • No real-time data is collected • Hypertension is identified based on age it is assumed

Study	Year	Problem Specification	Sensor Used	Algorithm	Gaps
					that women less than 32 age do not have hypertension. • No recommendations are generated
Santur et al. [187]	2020	Web application for maternal data collection	Mobile and Web-based application	Neural Network	• The system is based on questionnaires asked the users which have accuracy issues • No real-time recommendations are generated
Moreira et al.[188]	2019	Classifies health data of the pregnant woman	Based on existing data	Average one-dependence estimator	• The real-time data analysis is not performed • The recommendations are not generated based on the health classification.
Sunge et al. [189]	2021	Prediction of cesarean chances	Based on the existing dataset	Logistic Regression, k-NN, Random Forest, Decision Tree, Gradient Boosting, Support Vector Machine	• The system is based on an existing dataset • It predicts the chances of a cesarean based on age, not on the health factors of the pregnant women.

Study	Year	Problem Specification	Sensor Used	Algorithm	Gaps
					• The real-time analysis is not performed • The recommendations are not generated for health improvement.
Mario et al.[190]	2016	Hypertensive disorder	Blood Pressure Sensor	Naïve Bayes	• Not collected data of other health parameters like a heartbeat, pulse rate, and ECG. • The accuracy of the used algorithm is 84% only which is very less for healthcare devices.
Haymanot et al. [191]	2022	Pregnancy-related anxiety	Feedback based dataset	Random Sampling	• No recommendations are generated • Depend upon feedback • No prediction of health issues
Mario et al. [192]	2018	Hypertensive disorder in pregnancy	Existing dataset	Radial Basis Function, Multilayer Perceptron , Support Vector Machine, Decision,	• No real-time analysis is performed • No method is mentioned to predict the impact of hypertension in pregnancy.

Study	**Year**	**Problem Specification**	**Sensor Used**	**Algorithm**	**Gaps**
				Naïve Bayes	
Julien et al.[193]	2015	Wearable sensors during pregnancy	Activity Tracker, EEG	NA	• Based on the study of sensors available for pregnancy care
Usharani et al.[194]	2022	Pregnancy Stress Monitoring	Zephyr	k-NN	• Real-time health monitoring is not provided • The recommendations are not generated
Kirsi et al.[195]	2019	Pregnancy monitoring by wristbands	Wrist band	NA	• The requirement of the wristband is discussed during pregnancy • No discussion of how the parameters were calculated and retrieve health data of the pregnant women were.
Ghimire et al. [196]	2022	Pregnancy health monitoring system	Fetal heart rate, blood pressure sensor	NA	• Manual data packets sent through LoRA end node • Unnecessary utilization of Raspberry PI module • Cost of module is high • No real-time health suggestions

Study	Year	Problem Specification	Sensor Used	Algorithm	Gaps
					generated for pregnant women.
Bjelica et al. [197]	2020	Pregnancy care management	Study based on data collection from Google Form	NA	• The manual data entry to mobile app and web application • No real-time health monitoring or recommendation is generated.
Ohana et al.[198]	2021	Pregnancy health monitoring	DHT22, MAX30100, MPU6050, GSR Sensor, AD8232	NA	• The cost of the system is very due to utilization of RaspberryPI which can be avoided. • The system author tested on only one pregnant women which is not valid. Furthermore, the system also tested to kids and old age person which divert the main aim of the study.
Manivannan et al. [199]	2022	Pregnancy labor monitoring	Wearable patch including EMG and FECG sensors	Discrete Wavelet Transform	• The system detects the fetal heart beat and uterine contraction to detect labor pain. • No way to monitor health conditions of the pregnant women regularly.

Study	Year	Problem Specification	Sensor Used	Algorithm	Gaps
					• The application work with delay which can create problems during actual contraction starting. • The system does not proved accurate in the terms of medical emergency.
Song et al. [200]	2019	Fetal Health Monitoring	Accelerometer	Rule-Based Algorithm	• The system only detects the movement of fetal. • The system does not monitor real-time health conditions of the pregnant women.
Ivanov et al. [201]	2022	Pregnant woman health monitoring	MAX30001, MAX30205, ADS1299-4, MAX86141	NA	• Reminder about doctor appointment and pregnancy information. • Do not provide real-time health suggestions to the pregnant women. • No implementation offered to handle emergency during pregnancy.

2.4 Research Gaps

Based on the literature review discussed in the previous chapter, the following gaps are identified from the existing works:

- The current pregnancy healthcare system is based on the manual recording of health parameters which may lead to errors while data entry that does not provide accurate predictions in most cases.
- Also, there is the present systems are not able to capture real-time healthcare data remotely without doctors' or healthcare professionals' intervention.
- Moreover, present systems do not implement fog computing aspects which are not capable to recommend any suggestion to pregnant women in the absence of network connectivity.
- Facial authentication is not implemented in present systems rather than passwords are implemented in a few which offer a low level of security also there is the bombardment of the data as the cloud server of the non-pregnant women.

Chapter 3
Designing an E-Healthcare kit considering physiological symptoms of pregnant women

The chapter focuses on developing an E-Healthcare kit to capture the physiological parameters of the pregnant woman. Firstly, the hardware required to capture the health parameters from sensors is created. After that, the biomedical sensors are attached to the hardware to capture the pregnant woman's health-related data in a real-time environment.

3.1 Introduction

The E-Healthcare field is an emerging and buzzy field. It allows health information delivery over the internet, improving public health and controlling the cost of health services for both health professionals and patients. "E-healthcare" is a term that encompasses a range of concepts, including a significant change in consumer attitudes and a commitment by organizations to networked global thinking that aims to improve healthcare in the local, regional, and international contexts by harnessing the latest information and communication technologies (ICT) [202]. Several studies were performed to address the IT-related issues in the E-Healthcare system. Still, relatively lesser work was performed on marketing or management issues related to E-Healthcare systems. Numerous studies have indicated that a lack of proper clinical information has a negative effect on both the cost and quality of healthcare, jeopardizing patient safety. It has been suggested as a critical instrument for resolving these issues and promoting improved healthcare. E-prescribing, Electronic health records, electronic monitoring of chronic illnesses, decision support systems, and barcoding of pharmaceuticals and medical products have been proven to minimize healthcare expenditures and medical errors[203]. For example, research has demonstrated that automated physician order input dramatically reduces the risk of significant drug mistakes when medical data are stored electronically. For instance, when medical records are kept digitally, it improves doctor-patient communication electronically, reducing medication errors or health-related issues. Contraindication notifications can also be provided through point-of-care decision support technologies. New treatments and technologies are evolving daily, indicating the dependency of healthcare providers on the internet by which they can get the latest information regarding clinical practice guidelines [204][202].

Early in the 21st century, e-healthcare emerged. E-Healthcare applies ICT in healthcare, useful for educational, clinical, administration, and research purposes worldwide. E-healthcare empowers patients with up-to-date diagnosis and treatment information to make their own health-related decisions without moving to healthcare centers [205]. E-healthcare refers to any electronic interchange of health-related data that has been acquired or processed via an electronic medium to increase healthcare delivery efficiency and effectiveness. As a result, "computer-aided medicine" is often denoting nearly any information relevant to this field. The main objectives of e-healthcare include efficiency in healthcare, higher quality of treatment, enhanced healthcare quality, and empowerment of patients and consumers in addition to new and deeper patient-healthcare professionals. Several healthcare professionals and patients use digital cameras, scanners, or video conferencing facilities to offer remote healthcare facilities. E-healthcare networks, said, can overcome the time and distance barriers to the flow of health information and guarantee that collective knowledge is successfully brought to bear on health problems throughout the world.

The E-healthcare system performs four significant activities: consumer marketing, E-business, clinical customer service, and organizational management. While some are accessible via the public internet, others are password-protected LANs or intranets. For example, E-business involves online procurement between healthcare professionals and supplies, E-claim processing, and authorization of eligibility from insurance organizations. Additionally, it incorporates purchasing prescription medications from pharmacies and health insurance from insurance providers by consumers online. According to research, submission of E-claiming and material management were the most extensively used e-healthcare technologies in healthcare by the year 2000. For example, one significant practice association automated nearly half of its claims volume and reduced its per-claim processing cost by almost 40% using an internet-based claims submission system. Online healthcare marketing uses websites to attract new patients and deliver wellness and illness information to current patients. Displaying employee information on a firm intranet website, providing training programs, offering career opportunities, and publicizing employee health benefits are all part of e-healthcare organizational management. Administrative operations like strategy planning and billing are also included. In addition to allowing patients to undertake their risk assessments, clinical customer service comprises patient-physician communication via e-mail and electronic health records. Patients with an internet connection can use e-mail to communicate with their doctors and get answers to their inquiries. When it comes to improving patient-healthcare professional communication, electronic engagement can be an effective and efficient way to do so [206].

3.2 Proposed E-Healthcare System

The e-Healthcare system includes a set of sensors responsible for capturing the health-related data of pregnant women. The E-Healthcare system monitors pregnant women's activities. It is responsible for capturing the health-related data of the pregnant woman, which is further sent to the fog server for further processing and recommendations in a real-time environment.

The proposed E-healthcare system's architecture for pregnant women is described in Figure 3-1. As described in the figure, the proposed system is divided into three different but related layers. Each layer performs a specific operation and provides services to the other layer.

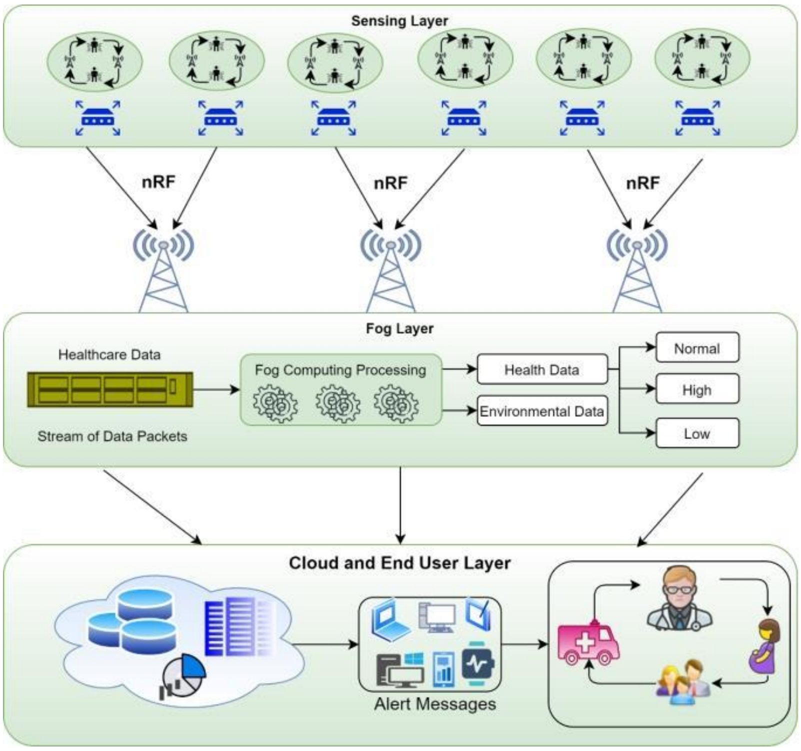


Figure 3-1Proposed System Architecture

3.2.1 Sensing Layer

The sensing layer (SL) is the initial layer of the proposed healthcare system. SL is responsible for capturing the healthcare data of the pregnant woman, which is further transferred to the other layers for processing. This layer includes several sensors that monitor the health conditions of pregnant women in a real-time environment. The woman needs to use the sensors attached to a customized healthcare kit to capture data. Once data is collected from the sensors, the authentication of the pregnant woman is performed by capturing a real-time image of the woman. This image is compared with the existing information to do authentication. If the woman's authenticity is approved, the data is directly sent to the fog layer for further processing. Moreover, during the authentication process, the fog layer collaborates with SL as the images are compared at the fog layer.

3.2.2 Fog Layer

The fog layer (FL) is responsible for authenticating the system user. Moreover, after receiving the data from SL, it first segregates the healthcare and environmental data and then compares it with the threshold values. The rule-based values divide the data into normal, high, and low categories. Then the data is passed to the cloud and end-user layer, which is further responsible for generating health recommendations or emergency alert messages as per the result obtained.

3.2.3 Cloud and End User Layer

The data received from FL is in processed format. The data at Cloud and End User Layer (CEUL) sends recommendations or emergency alert messages as per the data category. If the data is found normal, then the data is stored in the database and cloud server; otherwise, if the health conditions come under the category of high or low, then the emergency alert messages are generated at the doctor's or patient's attendee system. Moreover, the recommendation to the pregnant woman is also generated to perform specific tasks until the help reaches her end. Therefore, this layer includes a customized application from which the doctor can get a more profound analysis of the patient's historical data, which helps to reduce health impacts to a large extent. Moreover, this data can be found helpful in the case of future pregnancies of the specific woman.

3.3 Methodology & Implementation

This section deals with the collaboration of different sensors with customized nodes for data capturing. The first step is to find the healthcare sensors compatible with the customized boards and the other sensors collaboratively. There are several sensors attached to the boards to monitor the health parameters of pregnant women. This section describes the role and working principles of the connected sensors.

The presented system works in different stages as shown in Figure 3-2.

1. Firstly the physiological data is captured through biomedical sensors.
2. The captured data is sent to the fog node for further processing in the second step using the RF mode of communication.
3. Then the data processing is performed, which involves comparing obtained health-related data with the threshold values.
4. If the data is found normal as per the threshold, then the data is stored in the database; otherwise, the emergency alert message will be generated to the patient and doctor's end.
5. In the last step, the data is stored on the cloud server to access our data easily.

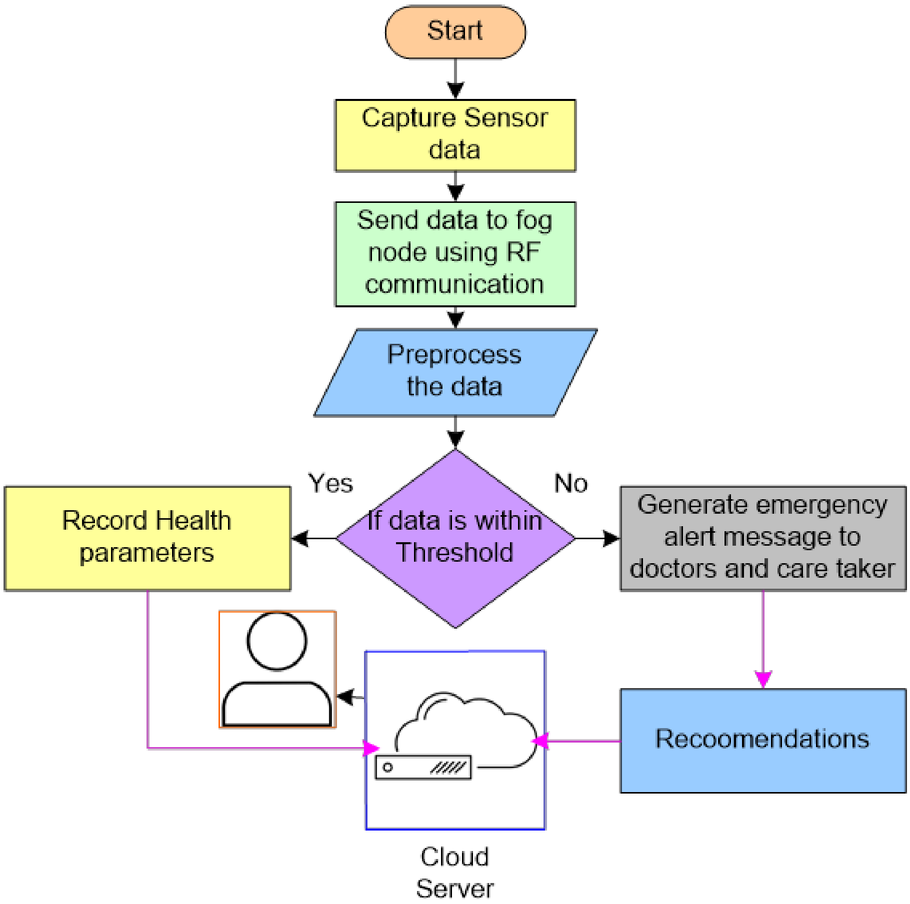


Figure 3-2Flow chart of Presented system

3.3.2 E-Healthcare Kit

The E-healthcare kit offers a complete health monitoring solution for pregnant women. It is responsible for capturing health-related data of pregnant women in a real-time environment and offers health suggestions as per the health parameters. The E-Healthcare kit is divided into three layers Sensing Layer, Fog Layer, Cloud computing, and End User Layer. The kit includes several sensors to monitor health conditions. These sensors are attached to a customized board that provides power to the different sensors and captures data sent by various sensors. There are mainly three types of sensors attached to the board to collect health-related data. The sensors are responsible for collecting real-time health-related data of the pregnant woman, which is further sent to the fog layer for further data processing. The E-healthcare kit developed in the present system is shown in Figure 3-3.

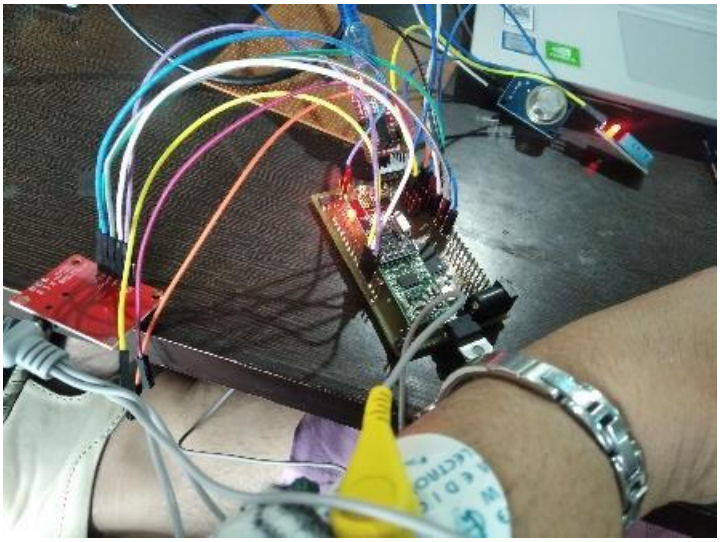


Figure 3-3Healthcare Kit

3.3.3 Sensing Layer

The sensing layer is the first layer of the presented system and is responsible for capturing the pregnant woman's health-related data. This layer includes several sensors that monitor the pregnant woman's health conditions and transfer collected data to the fog layer for further processing. The layer uses the proposed E-healthcare kit to capture health-related data. The proposed E-healthcare Kit has different features includes,

- Blood Pressure Detection

- Heartbeat
- Pulse Rate
- ECG Detection

The e-Healthcare kit needs to be worn on the wrist and the EGC pads need to be attached on the left side of the chest, right side of the chest, and left calf. The kit includes a customized processing board, which is the heart of the proposed healthcare kit. It consists of the microcontroller and different components that perform different functions. Each component has its functionality and collaborates with other components to allow the working of the complete system as a whole. Its circuit diagram Figure 3-4.

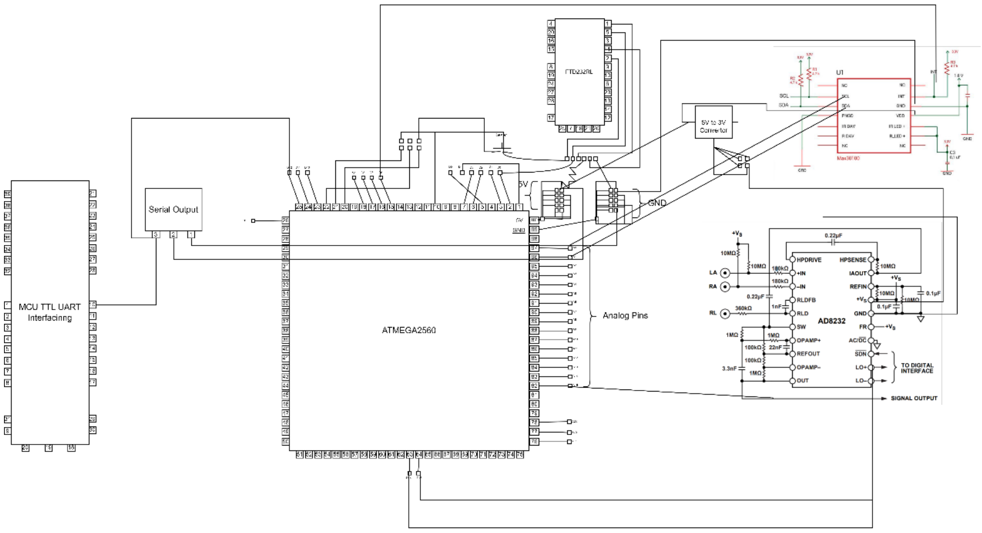


Figure 3-4: Circuit Diagram

The actual representation of the above circuit diagram is presented in Figure 3-5.

Figure 3-5Customized board

The customized board is prepared with the collaboration of several components. The configuration of the board is shown below:

3.3.3.1 FTDI (Future Technology Devices International)

The FTDI connectors connect parallel FIFO devices and RS232(Recommended Standard 232 for serial data transmission). It allows the connection of a second hardware device on a USB-less board without interfering with the boot loader code from Arduino IDE. A USB-to-serial bridge or any other device with an FTDI header may be connected to the FTDI232SmartBasic hardware, which is very simple to set up and uses the standard FTDI connector. The FTDI used in the proposed system is FT232RL. FTDI has expanded its range of USB UART interface Integrated Circuit Devices with the addition of the FT232R. The FT232R is a USB-to-serial UART interface that includes an optional clock generator and the new FTDIChip-ID™ security dongle. Additionally, there are synchronous and asynchronous bit-bang interface modes. The FT232R's USB-to-serial converter designs have been simplified further by fully integrating the device's external EEPROM, USB resistors, and clock circuits.

By using FTDI232RL, we are passing data or programs to our customized board. The component is connected to the board using different pins.

- GND: This pin connects the ground pin of the customized board to the FDTI module.
- CTS: CTS (Clear to Send) is a control input responsible for clearing the send data request.

- Vcc: Vcc is the voltage pin that connects the Vcc pin of the board.
- Tx: Tx(Transmit Asynchronous Data) is the output pin responsible for asynchronously transmitting data to the board.
- Rx: Rx(Receive Asynchronous Data) is the input pin responsible for reading asynchronously transmitted by the board.
- DTR: The DTR pin auto-resets the target board when the new code is downloaded.

3.3.3.2 ATMega2560

The ATmega2560 is an 8-bit CMOS low-power microcontroller based on the AVR-enhanced RISC architecture. The ATmega2560 delivers throughputs approaching 1 MIPS per MHz by executing strong instructions in a single clock cycle, allowing the system designer to balance power consumption vs processing performance.

It is designed as High-density non-volatile memory technology from Atmel and is used for manufacturing devices. Atmega2560 is a powerful system due to the combination of onboard self-programmable flash memory with 8-bit RISC architecture on a monolithic chip. As a result, it offers high flexibility and a less costly solution to several embedded control applications. The presented system used Atmega2560 as a processing unit to which sensors are connected to capture real-time health-related data of the pregnant woman. Therefore, we use this microcontroller as per the stated features above.

3.3.3.3 nRF24L01:

The nRF24L01 is a widely used wireless transceiver module for engineering applications, operating at 2.4GHz, which means that each module can transmit and receive data. When appropriately managed, the modules may reach a distance of up to 100 meters (200 feet), making them an excellent solution for any wireless remote-controlled application. In addition, the module is powered by 3.3V, which means it may be efficiently utilized with 3.2V or 5V systems**.**

3.3.3.4 Pins

There are several pins of the customized board which perform specific functions, including:

- 12V: The customized board has four 12V pins
- Digital: The board has 16 digital pins from D0 to D15
- Analog Pins: The board has 16 Analog pins A0 to A15
- 3.3V: The board has four 3.3V pins
- ICSP: ICSP (*In-Circuit Serial Programming*) represents several methods available for programming boards. Ordinarily, a bootloader program is used to program a board, but if the bootloader is missing or damaged, ICSP can be used instead. ICSP can be used to restore a missing or damaged bootloader. There are six ICSP pins arranged in a grid of 2x3 order.
- 5V: There are ten 5V pins present on the board.
- GND: Ten GND(Ground) pins are present on the board.
- AD Pins: There are three analog digital pins, AD0(22), AD1(23), and AD2(24), which can serve as dual-purpose pins.

3.3.3.5 Blood Pressure Sensor

The blood pressure sensor used in the presented system is used to sense blood pressure in a real-time environment. To sense the blood pressure, you need to wear a sensor cuff on the arm, as shown in Figure 3-6

Figure 3-6Blood Pressure Sensor

The above blood pressure sensor needs to be worn in a stable sitting position to capture blood pressure from blood vessels accurately. This sensor sense Blood Pressure & Pulse reading and is displayed with serial out for external embedded circuit processing and display projects. The parameters provided by the sensor include Systolic Blood Pressure, Diastolic Blood Pressure, and Pulse Reading. The sensor we used for the proposed system with a compact design fits your wrist like a watch. It is easy to use wrist style and eliminates pumping.

3.3.3.6 Pulse Oximeter Sensor

The pulse oximeter sensor used in our proposed system is Max30100 and is used to find the blood oxygen (SPO_2) and heart rate (Beats Per Minute). The pulse oximeter and heart rate monitor sensors are combined inside the MAX30100 sensor. Using two red and infrared LEDs, the sensor emits two wavelengths of light and then measures the absorption of pulsating blood through a photodetector to get its values. Reading data through the tip of one's finger is made easier using this LED color combination. The digital output data is kept in a 16-deep FIFO within the device, which is completely programmable using software registers. It has an I2C digital interface to communicate with a host microcontroller. Max30100 is shown in Figure 3-7

Figure 3-7 Pulse Oximeter Max30100

3.3.3.7 ECG Sensor

AD8232 Figure 3-8, measures electrical activity in the heart using a single lead. An ECG (Electrocardiogram) may record and display this electrical activity. AD8232 single lead heart rate monitor is an op-amp for ECGs that can be noisy; it helps get clear signals from the PR and QT intervals quickly ECG and other biopotential measurements may be made with the AD8232 integrated signal conditioning block. In noisy settings, such as those caused by mobility or remote electrode placement, it is designed to collect, amplify, and filter tiny biopotential signals.

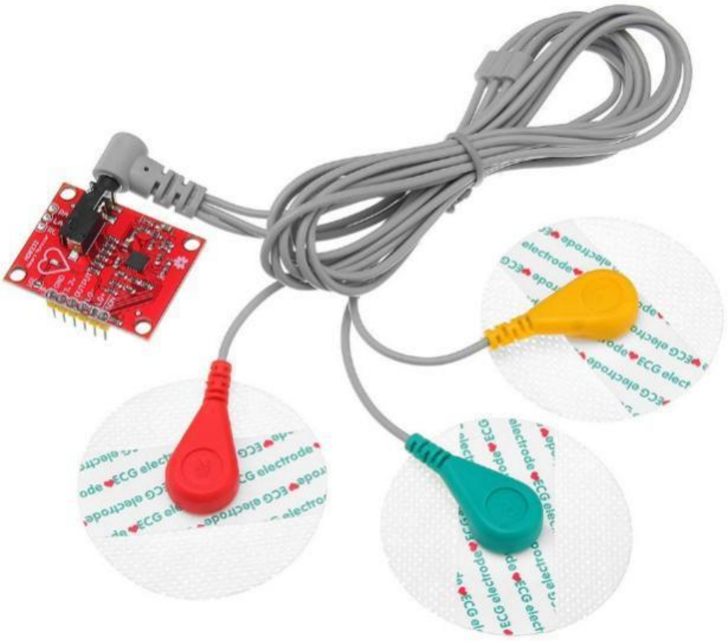


Figure 3-8 ECG Sensor

3.3.4 Working of sensing layer

The sensing layer is responsible to categorize data into different classes based on the probability technique, i.e. degree of vulnerability(DoV). The DoV is calculated for a particular parameter p_i that is unfavorable to the mother's health conditions. It allows finding a probabilistic estimation of the harmful effect of specific parameters on health. This estimation allows health professionals to set threshold values of the health parameters for a woman in various stages of pregnancy. The layer estimated the DoV by applying the Bayesian Belief Network(BBN) model. This technique was found useful for classifying parameters based on predefined threshold values. DoV and BBN allow for determining the classes of the collected dataset efficiently. Moreover, the system takes the average value of the health parameters after 15mins; so, DoV is calculated by sensing node after the interval of p_t.

3.3.4.1 Mathematical Modelling

The current section discussed the mathematical modeling of the BBN network to predict health categories. Let $P\left(\frac{p_n}{c}\right)$ and $P\left(\frac{p_c}{c}\right)$ represents the "Normal" and "Critical" probability of health conditions under the attributes $c > \theta$ (predefined threshold) at the given period of time T and W weight associated with predefined attribute c. The BBN model on weighted probability $P_w\left(c > \frac{\theta}{p_n}\right)$ is given as follows:

$$P_w\left(\frac{c}{p_n}\right) = w(c) \times P\left(\frac{c}{p_n}\right)$$

Accordingly, $P\left(\frac{p_n}{c}\right)$ can be inferred from the following formula:

$$P_w\left(\frac{p_n}{c}\right) = p_w\left(\frac{c}{p_n}\right) \times P(p_n)P(c)$$

More specifically,

$$P_w\left(\frac{p_n}{c}\right) = w(c) \times P\left(\frac{c}{p_n}\right) \times P(p_n)P(c)$$

Where,

$$P(c) = P_w\left(\frac{c}{p_n}\right) \times P(p_n) + P\left(\frac{c}{p_c}\right) \times P(p_c)$$

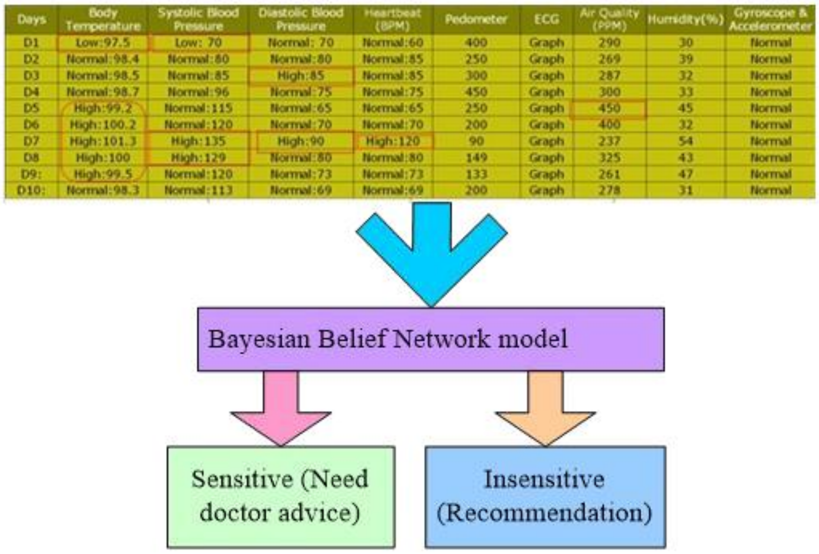
More specifically,

$$P(c) = w(c) \times P\left(\frac{c}{p_n}\right) \times P(p_n) + P\left(\frac{c}{p_c}\right) \times P(p_c)$$

As per the above calculations, DoV can be calculated as:

$$DoV = \frac{1}{k}\sum_{c} P_w\left(\frac{p_n}{c}\right)$$

When DoV is calculated more than the predefined threshold value, the health condition is critical. Every attribute is to be converted into two categories, as mentioned previously. Based on the calculated DoV, the parameter values will be segregated as shown in Figure 3-9



Days	Body Temperature	Systolic Blood Pressure	Diastolic Blood Pressure	Heartbeat (BPM)	Pedometer	ECG	Air Quality (PPM)	Humidity(%)	Gyroscope & Accelerometer
D1	Low:97.5	Low: 70	Normal: 70	Normal:60	400	Graph	290	30	Normal
D2	Normal:98.4	Normal:80	Normal:80	Normal:85	250	Graph	269	39	Normal
D3	Normal:98.5	Normal:85	High:85	Normal:85	300	Graph	287	32	Normal
D4	Normal:98.7	Normal:96	Normal:75	Normal:75	450	Graph	300	33	Normal
D5	High:99.2	Normal:115	Normal:65	Normal:65	250	Graph	450	45	Normal
D6	High:100.2	Normal:120	Normal:70	Normal:70	200	Graph	400	32	Normal
D7	High:101.3	High:135	High:90	High:120	90	Graph	237	54	Normal
D8	High:100	High:129	Normal:80	Normal:80	149	Graph	325	43	Normal
D9:	High:99.5	Normal:120	Normal:73	Normal:73	133	Graph	261	47	Normal
D10:	Normal:98.3	Normal:113	Normal:69	Normal:69	200	Graph	278	31	Normal

Figure 3-9Seggregation of health parameters based on DoV

Based on the capture parameters, it is valid to say that specific parameter are interlinked and may affect the normality of other related health parameters. As per these parameters, BBN further segregates parameters to decide on the further action to perform. If some abnormalities are found in the dataset, BBN creates classes for prediction, which allows the system to generate an alert message to the doctor and patient's family; otherwise, some recommendations can be offered to the pregnant woman. PSoV further determines the probability of affecting health parameters due to other health parameters or environmental conditions. This prediction helps to offer immediate health services to women's doorstep. As in the above case, it may be predicted that a woman may get a fever or abnormalities in heart rate or blood pressure level due to the bad PPM concentration. After predictive analysis, the data is sent to the cloud server using Quantum walks' secured method. The present study applies the quantum hash function to encrypt the health parameter so that it can be securely sent to the cloud server.

Algorithm 1 represents the working of the sensing layer and how the data is captured from different sensors in a real-time environment.

Algorithm1: Physiological Data Collection

Input: n number of physiological parameters α,β,γ with associated threshold values θ_1, θ_2, θ_3 ,θ_4, θ_5, θ_6.

Step1: Initialise serial

Step2: Identify the current timestamp parameter by splitting the passed data packet

Step3: Compare the collected health parameters with prefix threshold values.

Step4: If θ_1 <=α<=θ_2 and θ_3<=β<=θ_4 then find if θ_5<=γ<= θ_6 then

3.3.4.1.1.1.1.1 State=N

3.3.4.1.1.1.1.2 Return State

Step5: If $\alpha<\theta_1$ || $\beta<\theta_3$ || $\gamma<\theta_5$ then,

a. State=L, call *Algorithm2()*

Step6: If $\alpha>\theta_2$ || $\beta>\theta_4$ || $\gamma>\theta_6$ then,

b. State=H, call *Algorithm2()*

Algorithm 1 presented an approach for capturing physiological parameters and changing the pregnant woman's health according to the data obtained. The system performs the specific task based on the health parameter obtained at a particular timestamp.

Mathematically, the presented system is denoted by $P = \{S, R, \Delta T\}$. The symbol S represents the health state of the pregnant woman, i.e. $S = \{L, N, H\}$, where $L = Low, N = Normal, and\ H = High$, respectively. The symbol R represents the recommendation or action that needs to be performed according to the health parameters. ΔT represents the temporal timestamp representing the difference between the timestamp of health data collection during nine months. The health condition of the pregnant woman is classified according to Algorithm1. The threshold valuesθ_1, θ_2 are the lower and upper range of α(Systolic Blood Pressure), θ_3, θ_4 are the lower or upper range of β (Diastolic Blood Pressure) and θ_5, θ_6 are the lower or upper range of γ (Heartbeat) constants the doctor prescribes. These threshold values utilize by *Algorithm2* for rules formation. Moreover, the personalized recommendation system generates health-related messages to the patient and doctor based on the rules. The system. Initially, the physiological parameters of the pregnant woman were analyzed by Algortihm1. If the health state of the pregnant woman is found to be “Normal”, then the data is stored in the database attached to the recommendation system and sent to the cloud server. If at any timestamp $t, State! = N$, then *Algorithm 2* called for further process.

3.3.5 Fog Layer

The typical representation of the fog node is represented in Figure 3-10. The fog layer is mainly created with two components, including RaspberryPi and PiCamera. The components work collaboratively to capture the real-time image of the pregnant woman.

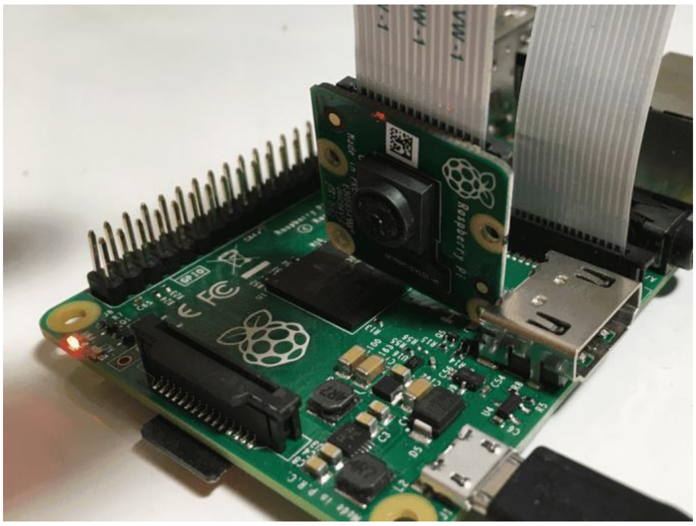


Figure 3-10Representation of Fog Node

The RaspberryPi is a low-cost pocket computer that allows us to create IoT-based devices with high performance compared to conventional microcontrollers. The RaspberryPi is a ready-to-use device that is ready to work when we install the operating system onto the memory card to be inserted. One can easily connect the normal keyboard, mouse, and monitor screen to RaspberryPi to work in a GUI environment. We can program RaspberryPi using Python and perform different tasks in a real-time environment. The RaspberryPi comes with an inbuilt communication medium, including Wi-Fi and Bluetooth, making the communication between the various IoT devices very effective. The presented system utilizes RaspberryPi as a fog node capable of capturing the image of the pregnant woman in a real-time environment.

Face recognition is used in several disciplines such as emotion detection, sentiment analysis, person authentication, etc. Face recognition is the best way to authenticate a pregnant woman. The face recognition performed in the presented system uses PiCamera attached to the RaspberryPi. The dataset of the woman is created during profile creation. The live image for the authentication is captured in a real-time environment using OpenCV, SciPy, Scikit learns, and other related python libraries. Firstly these libraries are installed on the RaspberryPi, which captures the image using PiCamera. The image will be stored only till the authentication is not performed. Once the authentication is performed, the signal is sent to the recommendation system.

At the fog layer, the user's authentication is initially performed with the individual's face through a recognition authentication server. This server is installed at the fog server, which calls the stored information about the woman from cloud storage, then applies the logic to compare the credentials before starting any pre-processing data. The fog node is created with Raspberry Pi. The cloud server sends the user credentials in encrypted form, which the fog server first decrypt and then compares the provided credentials with the stored ones. If the credentials are found matched, it further starts its task of pre-processing data. Still, if it is found to be unauthenticated, it triggers an error message and immediately discards the collected data.

3.4 Results and Discussion

The sensors discussed in the previous section are attached to microcontrollers to obtain results. This section addressed the output generated by the sensors in a real-time environment. The results are obtained using the cloud server of ThingSpeak. ThingSpeak is an IoT analytics service that allows aggregating, visualizing, and analyzing live data streams in the cloud. This service provides instant visualizations of the data you send to ThingSpeak. Online data analysis and processing may be done using ThingSpeak's MATLAB code execution feature. ThingSpeak is a popular tool for developing prototypes and proof-of-concept IoT devices that need analytics.

Rest APIs and MQTT may be used to deliver data straight to ThingSpeak from any internet-connected device. Several cloud-to-cloud connectors allow ThingSpeak to receive sensor data across LoRaWAN, 4G/3G cellular connections, and the Libelium

Meshlium gateway. Using ThingSpeak, we can store and analyze data in the cloud without setting up web servers. If you want to get email notifications based on data flowing from your linked devices, then we can do that, as well. Figures 3-12 to 3-15 show the results generated through MATLAB 2017b after categorizing the markers from a video.

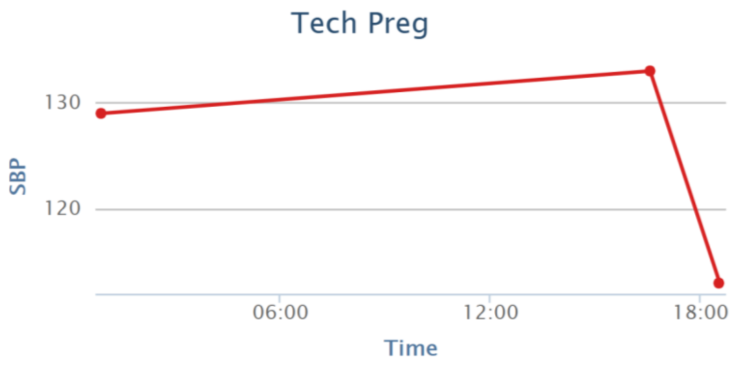


Figure 3-11Systolic Blood Pressure

Figure 3-11 shows the Systolic Blood Pressure (SBP) results at a specific period. Again, the blood pressure sensor generates the output in a real-time environment.

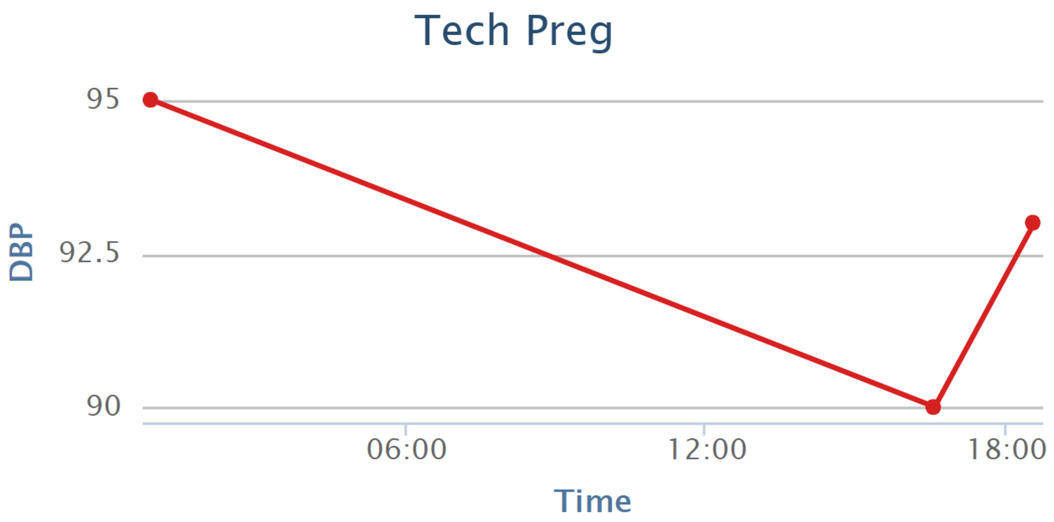


Figure 3-12Diastolic Blood Pressure

Figure 3-12 shows the Diastolic Blood Pressure (DBP) results at a specific period. Again, the blood pressure sensor generates the output in a real-time environment.

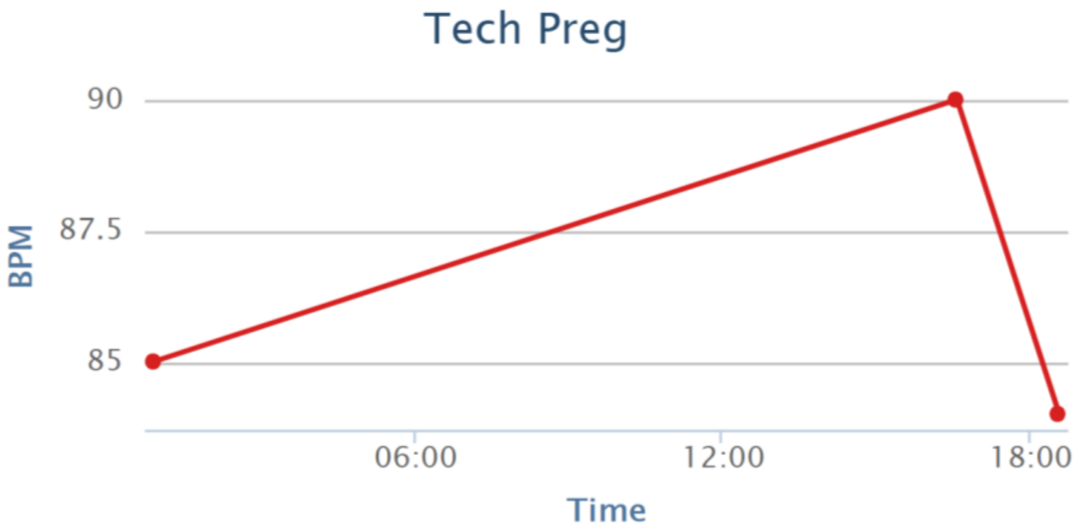


Figure 3-13Beats Per Minute

Figure 3-13 shows the Beats Per Minute(BPM) results at a specific time period. The pulse oximeter sensor generates the output in a real-time environment.

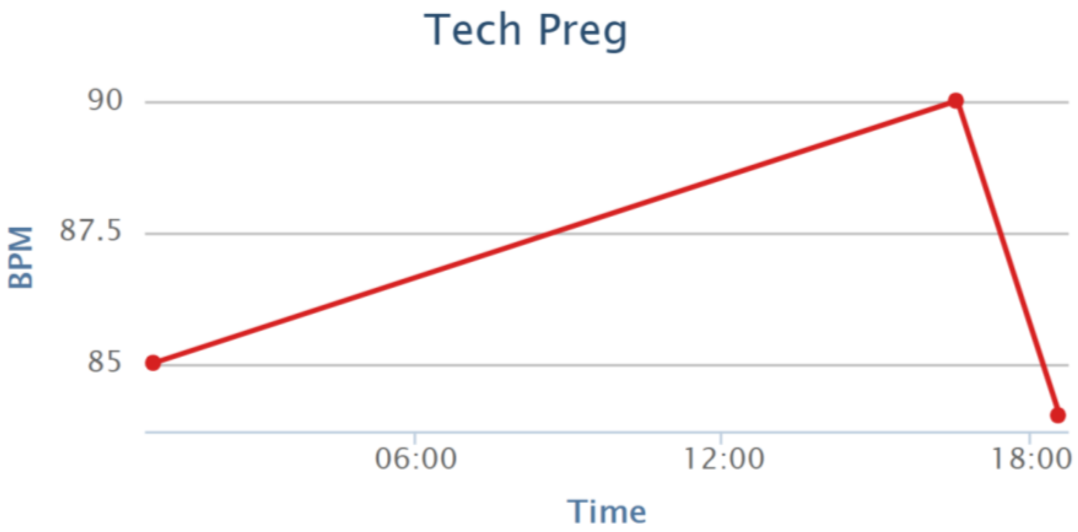


Figure 3-14ECG sensor Output

Figure 3-8 shows the ECG results at a specific period. Again, the ECG sensor generates the output in a real-time environment.

3.5 Comparative Analysis

Table 3-1 shows the comparison between the existing pregnancy healthcare system with the feature of the presented pregnancy healthcare system.

Table 3-1Comparative Analysis of Pregnancy Healthcare System

Study	Description	Features Offered	Research Gap
Wang Tao[207]	It includes a pregnancy ring that captures the health data of women and sends it to an intelligent mobile terminal that compares the collected data with a predefined limit range and if the data lies outside the range it displays the alert message	The ring includes Temperature Sensor, Blood Pressure Sensor, Heartbeat Sensor, and Pedometer. Intelligent Terminal includes Data Receiving, Data processing, memory, display, and alarm module.	1. No method to mentioned to transmit data from the ring to a mobile intelligent system 2. Only heartbeat, blood pressure, the temperature is detected in this system, and alerting is displayed on an intelligent terminal system not sent to the cloud or other servers for further processing.
Yanhui, Tianchi [208]	It is a smart wristband like a normal health wristband that measures the health parameters and displays it to the display of it.	Temperature Sensor, Heart Rate Sensor, Air Quality Sensor, LCD	1. Does not attach to the cloud devices 2. Does not provide Real-time suggestions.
Na et al.[209]	The System measures the humidity, or temperature of the environment as well as the body of women and uses an air conditioner infrared emitter to make	Temperature Sensor, Humidity Sensors, Air Conditioning Infrared emitter sensor, and a processor.	1. Does not measure the health parameter of the baby as well as women. 2. Does not attach to the cloud devices

Study	Description	Features Offered	Research Gap
	an accurate environment around women.		3. Does not provide Real-time suggestions.
Kai and Xin [210]	These systems are used for hospitals and capture data from ECG, Blood oxygen detector, or clinical information uploaded to the cloud server	It uses intelligent systems, cloud servers, and Bluetooth technology to transfer data.	1. Processor data gave by ECG. 2. Cannot be used anywhere 3. Uses slow-speed Bluetooth technology. 4. Does not measure other health parameters of women like temperature, stress level, or the health of the baby in the womb. 5. Does not provide real-time suggestions 5according to the health conditions.
Yan and Yuzhao [211]	The system discussed the server that acquires data on pregnant women by using different instruments like blood test machines, ECG, or other facilities available in maternal care centers. It also includes data	Data Acquisition module, Data Processing Module, Data Application Server.	1. Li6mited functionality to the hospitals. 2. Does not discuss the method to transfer the data from different devices to the server.

Study	Description	Features Offered	Research Gap
	processing and application servers to store or process data.		3. Does not capable to provide real-time health suggestions.
Yan et al. [212]	The system uses an ECG machine, smart terminal, Cloud Server, Fetal Heart rate, and Oxygen saturation detection system that capture and sends data to the cloud servers. Cloud servers receive information from maternity hospitals' laboratory tests.	ECG machine, Fetal Heart detector, Oxygen Saturation,	1. Its scope is limited to hospitals and cannot be used with portability. 2. It can store data and the capturing of data is performed using the ECG or other health monitoring devices available to the hospitals. 3. It is not capable to send real-time suggestions to the women as well as family or doctors.
Jang [213]	It uses a test strip obtained from the urine of the pregnant woman buried in yaw test paper to analyze the health variation of the women. In this system personal health care device is provided to the women which women need to insert the strip to further	Uses a strip to test urine and Bluetooth to transfer data to the smart devices	1. Does not connected to the cloud servers. 2. It needs a strip to analyze data from urine. 3. It is not capable to send real-time suggestions to the women as well as family or doctors.

Study	Description	Features Offered	Research Gap
	analysis and data is transferred to the smart devices using Bluetooth technology.		
Lee et al. [214]	It uses a stethoscope to hear the heart rate of the fatal and uses a temperature sensor to create a bit pattern of the fatal rate. It uses a MIC or speaker to hear the fetal heart rate	Stethoscope, Temperature sensor, MIC, Speaker, display	1. Its scope is limited to hospitals and cannot be used with portability. 2. It can be used to detect fetal heart rate only. 3. It is not capable to send real-time suggestions to the women as well as family or doctors. 4. Does not capable to send data to cloud servers.

3.6 Summary

The chapter focused on the pregnancy E-healthcare kit which captures the health-related data of the pregnant woman in a real-time environment. The chapter started with a discussion of the E-Healthcare system and its importance then moves toward the proposed system E-Healthcare system which specifies the number of layers used in the presented system and the working of these layers. Further, the chapter discussed the implementation of the customized E-Healthcare kit along with its specification and the sensor information that is used in the presented kit. Finally, the chapter compared the proposed kit with the existing healthcare systems available for pregnant woman and found that the presented system is very useful in the terms of utilization.

Chapter 4

Developing intelligent algorithms to process and analyze the real time data captured through E-Healthcare kit.

This chapter proposes an intelligent algorithm to analyze the real-time data captured through the E-Healthcare Kit. First, the data is analyzed through a machine learning algorithm. Further, the capture proposes the ensemble-based machine learning technique, which proved highly efficient in accuracy with a minimum error rate.

4.1 Methodology & Implementation

The major reason for the proposed algorithm is to monitor the health conditions of the pregnant woman and predict the chances of a cesarean at an early stage so that the required health-related services are provided on time. The system uses the classification approach to predict the outcome of the healthcare dataset. To obtain an accurate prediction, an optimized algorithm is proposed. We combine two different classification algorithms, i.e. XGBoost and Random Forest, to improve the accuracy of the prediction The process of prediction is performed in different steps as demonstrated in Figure 4-1:

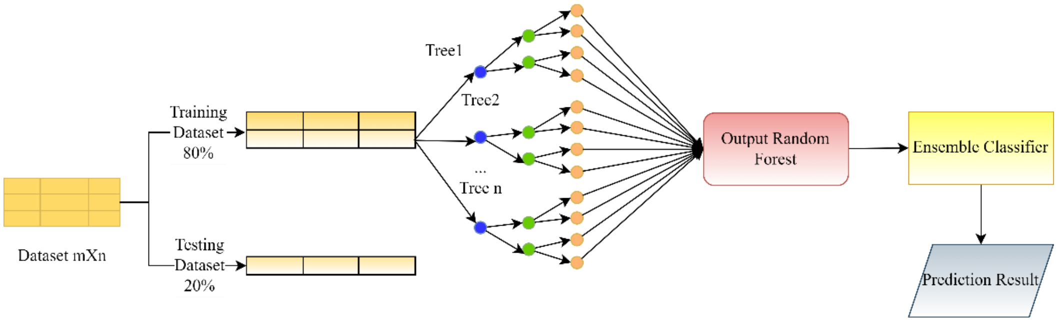


Figure 4-1Process of Ensembling

As shown in the above figure, the ensembling is done to predict the cesarean chances.

4.1.1 Dataset Description

The dataset was generated from the E-healthcare kit created in the present system. The dataset contains 1262 entries with no missing values. The dataset was collected from the real-time environment through an E-Healthcare kit under the supervision of Dr. Kawal and Dr. Jagdish. There are seven attributes in the dataset, as shown in Table 4-1.

Table 4-1: Attributes of the dataset

Attribute Name	**Description**	**Possible Values**	**Assigned Values**
Age	The current age of the pregnant woman	17-40	-
Delivery Number	The current pregnancy number	1-4	-
Delivery Time	The previous delivery has taken which time	Timely, Premature, Late	0-2
Systolic Blood Pressure	The Systolic blood pressure of the pregnant woman	120-200	-
Diastolic Blood Pressure	The Diastolic Blood Pressure of the pregnant woman	60-120	
Heart Problem	If the woman has any existing heart problem or not	Present or not present	0-1
Caesarean(Target)	Cesarean Chance	0-1	-

The above-stated dataset attributes are non-null and have the same data types.

The stated dataset description related to counting, mean, median, mode, and percentiles is represented in Table 4-2.

Table 4-2 Dataset Description

Attribute	Count	Mean	Standard Deviation	Min	25%	50%	75%	Max
Age	1262.0	28.909667	6.486471	17.0	23.00	29.0	34.0	40.0
Delivery Number	1262.0	2.449287	1.115195	1.0	1.00	2.0	3.0	4.0
Systolic Blood Pressure	1262.0	159.908082	23.557434	120.0	140.00	160.5	180.0	200.0
Diastolic Blood Pressure	1262.0	90.072900	17.407813	60.0	75.25	90.0	105.0	120.0
Heart Problem	1262.0	0.500000	0.500198	0.0	0.00	0.5	1.0	1.0
Caesarian	1262.0	0.514263	0.499995	0.0	0.00	1.0	1.0	1.0

The distribution of the dataset's attributes is shown in figures Figure 4-2 to 4-7. Figure 4-2, represents the age distribution of the woman dataset. The woman between the ages of 17 to 40 was taken into consideration for testing of an E-Healthcare kit.

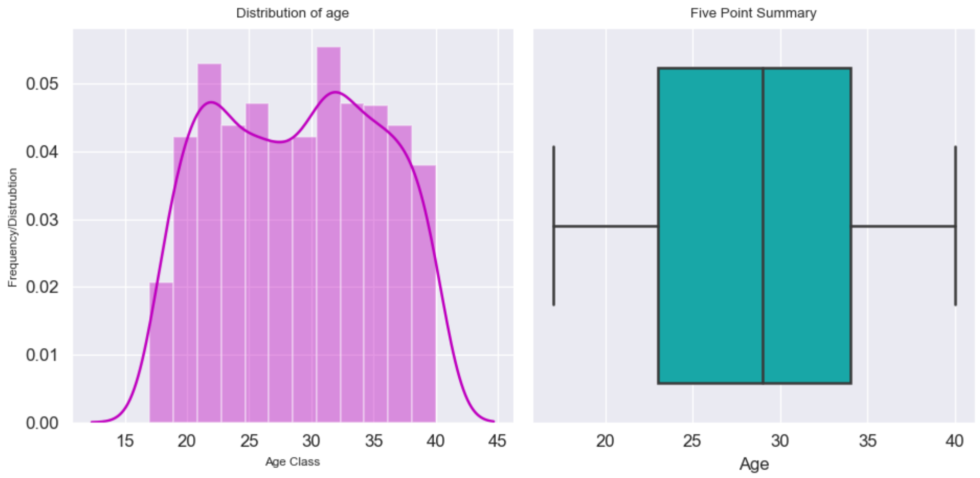


Figure 4-2Distribution of the age attribute values

Figure 4-3, represents the number of babies delivered already by the women taken into consideration. The woman who delivered a minimum of one baby and a maximum of 4 taken into consideration for identification of their health conditions.

Figure 4-3Delivery Number

Figure 4-4, represents the systolic blood pressure level of the pregnant women during observation. The minimum systolic blood pressure level found was 120 and the maximum systolic blood pressure level found was 200

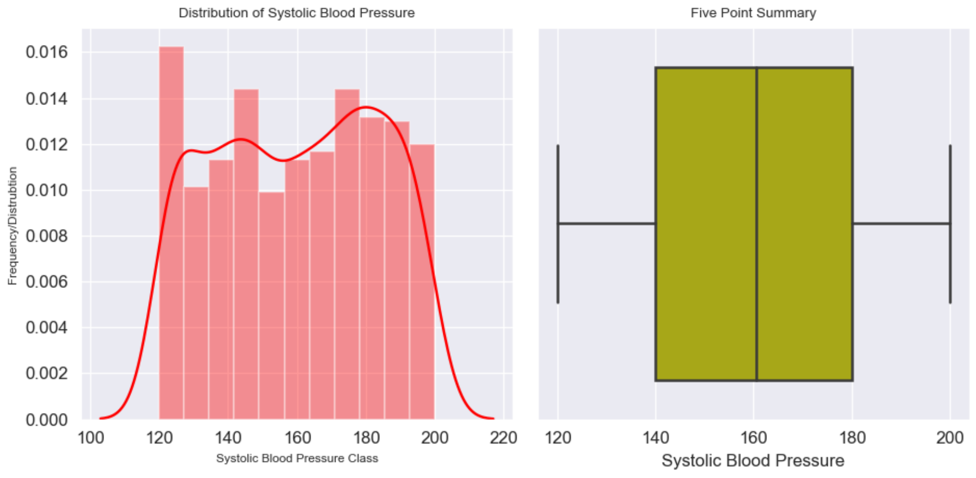


Figure 4-4Systolic Blood Pressure

Figure 4-5, represents the diastolic blood pressure level of the pregnant women during observation. The minimum diastolic blood pressure level found was 60 and the maximum systolic blood pressure level found was 120.

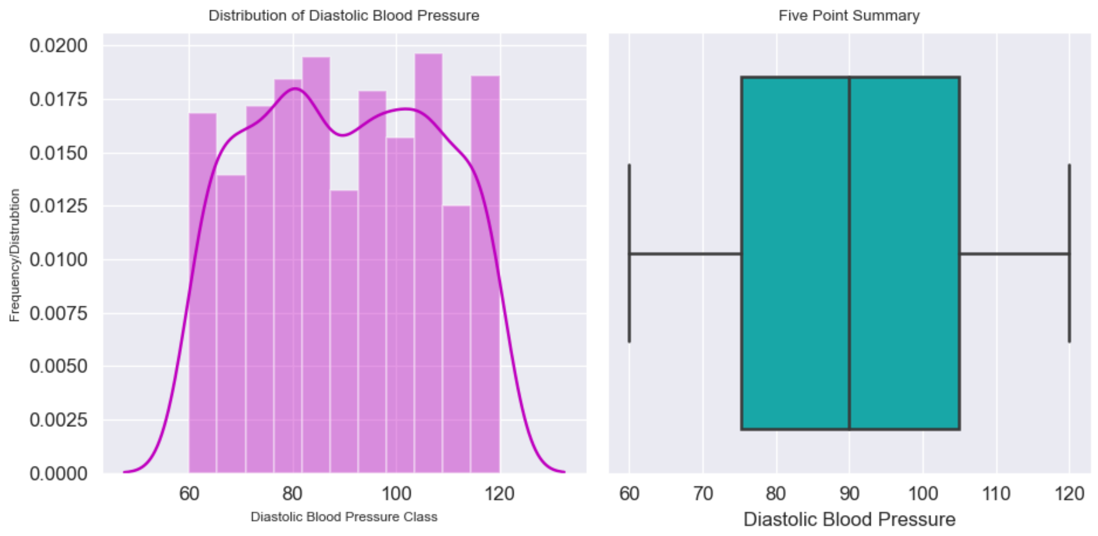


Figure 4-5Diastolic Blood Pressure

Figure 4-6, represents the heart problem existence in pregnant women during observation. This parameter only has the value 0 or 1 in which 0 means a woman does not have a heart problem whereas, 1 represents a woman who has a heart problem.

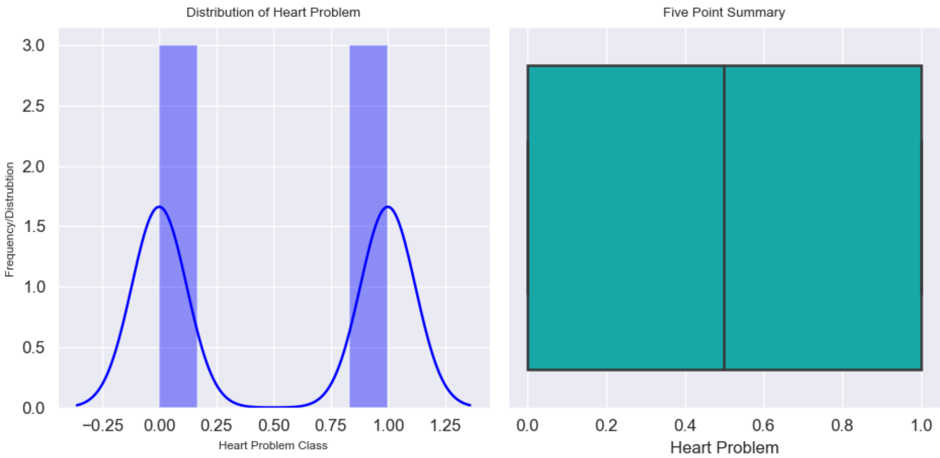


Figure 4-6Heart Problem

Figure 4-7, represents whether the previous delivery was cesarean or not for pregnant women under observation. This parameter only has the value 0 or 1 in which 0 means a woman does not have a cesarean previously whereas, 1 represents a woman who had a cesarean previously.

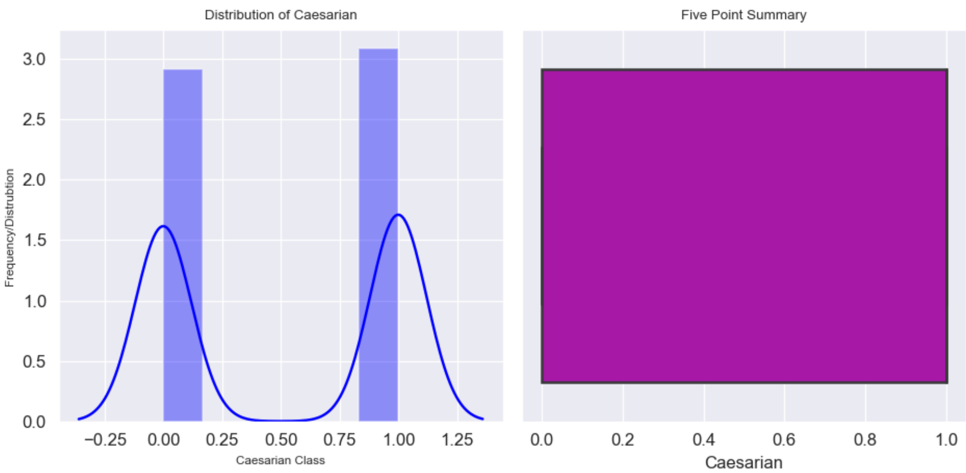


Figure 4-7Caesarian

The correlation between the dataset parameters is shown in Figure 4-8. From the correlation matrix, we found that all attributes have a negative correlation with each other, which states that an increase in the value of one attribute leads to increased chances of cesarean (outcome 1).

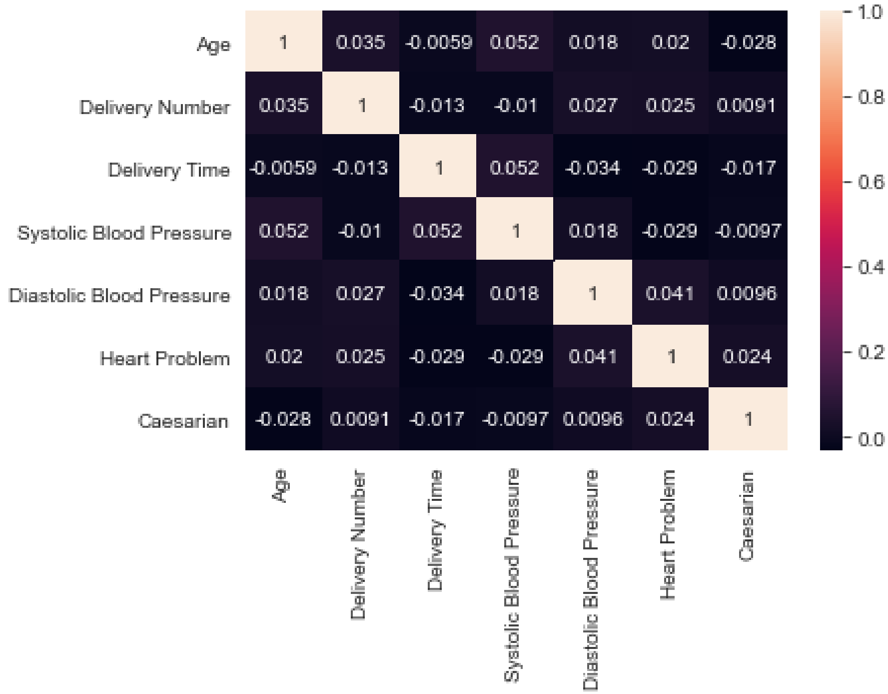


Figure 4-8 Correlation Matrix

4.1.2 Classification Methods

The method KNN, Decision Tree, Support Vector Clustering, Random Forest, and XGBoost, models are implemented using Python. Moreover, for prediction, we divide the dataset into 80% for the training dataset and 20% for the testing dataset. The methods are identified based on the true positive rate(TPR) and false positive rate(FPR). TPR is the correct prediction of positive class whereas FPR is the probability of falsely rejecting the null hypothesis. TPR and FPR are both considered the best measure of accuracy prediction for healthcare data.

4.1.2.1 KNN

K-Nearest Neighbor(kNN) algorithm is the most preferable and widely used algorithm for machine learning and data mining. kNN is widely used to solve various problems, including regression, classification, or imputation of missing values. The main principle of kNN is to predict the test data label based on the major classes of k similar training points from the dataset. The kNN was applied to the collected dataset with random neighbor choices ranging from 5 to 50. The cross-validation parameter is set to 10, with the refit parameter set to True. As per the calculated result, the best score was 52.28%, with an accuracy of 63.33%, respectively. The obtained results are tuned based on ten neighbors. The result of true positive and false positive rates obtained by applying kNN is shown in Figure 4-9

Figure 4-9kNN Receiver Operating Characteristic

The Mean Absolute Error(MAE) value obtained from testing and prediction of the dataset is 5.1%, whereas Mean Squared Error (MSE) was 5.33%.

4.1.2.2 Decision Tree

Decision trees are considered a powerful tool for prediction using classification techniques. It is represented as a tree structure like a flow chart in which the test is performed on the attribute defined as the internal node while the tree branch describes the test outcome. Moreover, the leaf nodes of the tree represent the predicted class labels. The decision tree is applied to the collected dataset with max_depth=9. The cross-validation parameter is set to 10, with the refit parameter set to True. As per the calculated result, the best score was 51.33%, with an accuracy of 71.36%, respectively. The result of the true positive and false positive rate obtained by applying the decision tree is shown in Figure 4-10

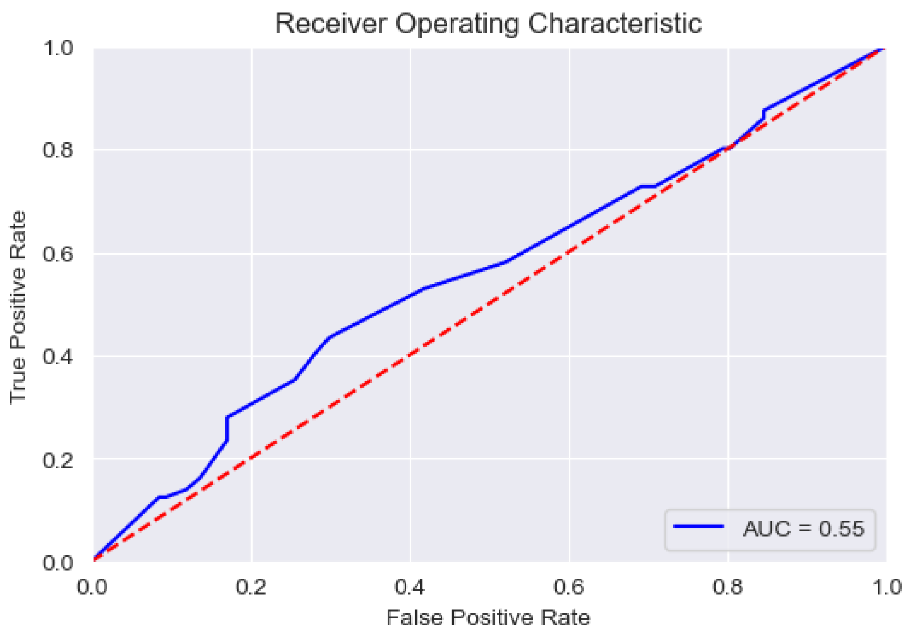


Figure 4-10Decision Tree Reciever Operating Characteristic

The Mean Absolute Error (MAE) value obtained from testing and prediction of the dataset is 4.8%, whereas Mean Squared Error (MSE) was 5.6%.

4.1.2.3 Support Vector Clustering

By utilizing a kernel function, data points in SVC are translated from the data domain into the high-dimensional feature domain. The approach uses the Support Vector Domain Description algorithm to find the smallest sphere that encompasses the picture of the data in the kernel's feature space. These outlines may be seen in the dataset when the sphere is translated back into data space. This way, SVC assigns the points included inside each contour to a particular cluster. The SVC is applied to the collected dataset with gamma=0.1. The cross-validation parameter is set to 10, with the refit parameter set to True. As per the calculated result, the best score was 50.84%, with an accuracy of 50.84%, respectively. The result of true positive and false positive rates obtained by applying SVC is shown in Figure 4-11.

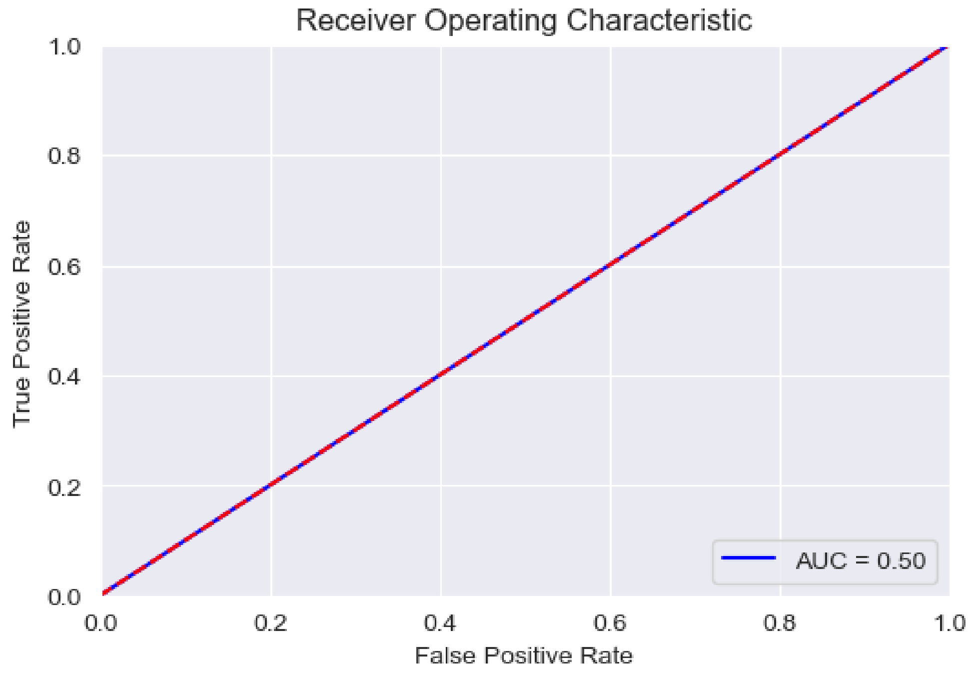


Figure 4-11SVC Receiver Operating Characteristic

The Mean Absolute Error (MAE) value obtained from testing and prediction of the dataset is 5%, whereas Mean Squared Error (MSE) was 5%.

4.1.2.4 Random Forest

Random forest is one of the most popular machine learning algorithms that solve regression and classification problems. It is based on an ensemble-based machine learning approach that integrates several classifiers to solve complex problems. It offers solutions to many complicated issues related to different fields including, business, education, and healthcare industries. Random forest is used as a base classifier for the proposed technique, which allows the ensemble of several decision trees to predict the results. The algorithm is trained based on the bagging aggregation technique. The training set T=((X1, Y1),(X2, Y2)…(X_n, Y_n)) make k vectors, $X \in A$ where A is a set of the numerical observations and $Y \in B$ where B refers to the set of labeled classes. The classifier $A \rightarrow B$ needs to be mapped in the classification problem. Every tress classifies a new input vector which yields some classification results. Random forest is based on the binary classification of the subtrees based on the samples taken from training set T and selects A’s subset randomly. The Random Forest is applied to the collected dataset with max_depth =3. The cross-validation parameter is set to 10, with the refit parameter set to True. As per the calculated result, the best score was 52.22%, with an accuracy of 65.71%, respectively. The result of true positive and false positive rates obtained by applying random forest is shown in Figure 4-12.

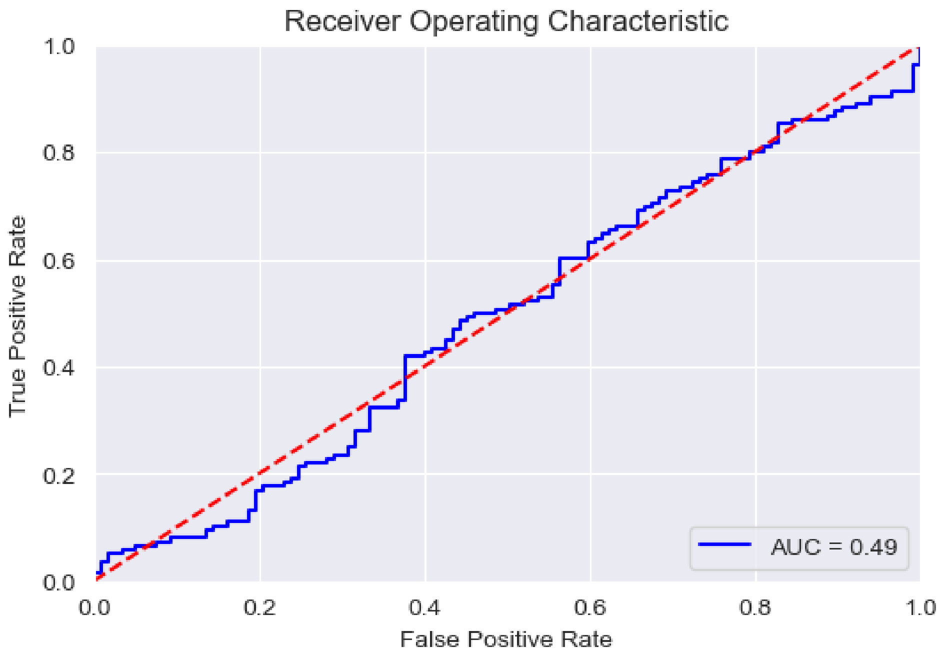


Figure 4-12Random Forest Receiver Operating Characteristic

The Mean Absolute Error (MAE) value obtained from testing and prediction of the dataset is 5%, whereas Mean Squared Error (MSE) was 5%.

4.1.2.5 XGBoost

The XGBoost(Extreme Gradient Boosting) is an ensemble machine learning approach based on a decision tree and utilizes a gradient boosting framework. It predicts preference ratings by attention semantic vectors based on aspects. XGBoost is based on gradient boosting used for different complex tasks, including distributed computing, GPU training, and parallel processing. Furthermore, XGBoost is based on supervised learning, which uses training data a_i to get the target value b_i. XGBoost is mainly considered for the optimization of principles and machine learning systems. It provides a highly accurate, portable, or scalable solution to the problem. XGBoost is mainly known for its high performance and speed. XGBoost enhances the functionality of gradient boosting by optimizing the system and strengthening the algorithm. It applies to medium-scale structured data. The XGBoost applied to the collected dataset with max_depth =4. The cross-validation parameter is set to 10, with the refit parameter set to True. As per the calculated result, the best score was 53.22%, with an accuracy of 79.68%, respectively. The result of true positive and false positive rates obtained by applying random forest is shown in Figure 4-13.

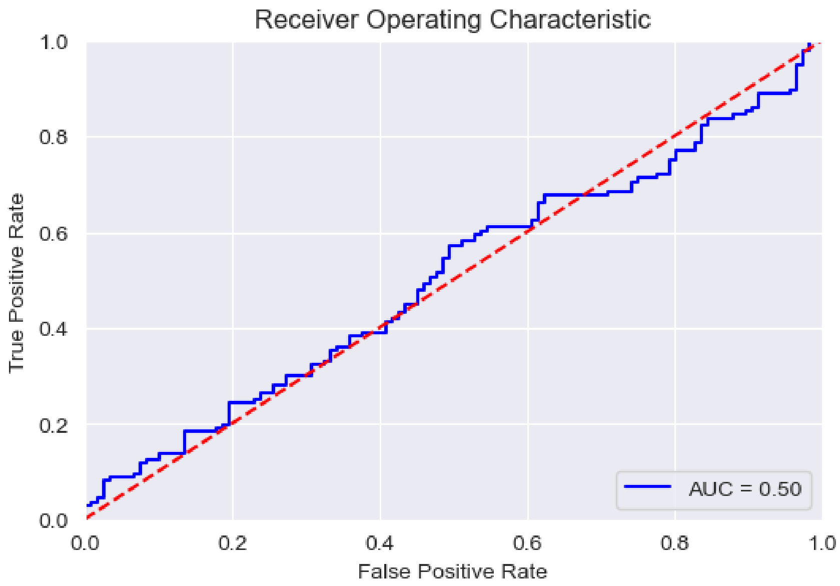


Figure 4-13XGBoost Receiver Operating Characteristic

The Mean Absolute Error (MAE) value obtained from testing and prediction of the dataset is 5%, whereas Mean Squared Error (MSE) was 5.4%.

4.1.3 Proposed Algorithm

The presented system is based on the combination of Random Forest and XGBoost (XGBRF) for classifying the dataset, which gives high efficiency. In addition, random forest generates several decision trees at the training stage. Finally, to predict the final labeled classes, the prediction outcome of intermediate trees is pooled to predict the final result. The bagging process applies to the random forest to train the classifiers. Bagging continuously (τ $times$) takes the random sample from the training set $A = \{A_1, A_2, \dots, A_n\}$ with response set $B = \{B_1, B_2, \dots, B_n\}$ and fit trees f_t, to these samples for $b = 1 \dots \tau$. A simple majority vote can take the predictions of all classification trees on A' for unseen data. Mathematically, it can be presented as:

$$\hat{f} = \frac{1}{\tau} \sum_{b=1}^{\tau} f_t(A')$$

Moreover, the uncertainty in the prediction can be calculated using the standard deviation of all regression trees A'.

$$\sigma = \sqrt{\frac{\sum_{b=1}^{\tau}\left(f_t\left(A^{'}\right) - \hat{f}\right)^2}{\tau - 1}}$$

Moreover, XGBoost is based on boosting algorithm. Therefore, the algorithm XGBoost combined with random forest will improve the system's performance and accuracy. XGBRF hybrid ensemble method is used to classify healthcare data to predict the outcome of the cesarean. The major benefit offered by XGBRF is the accuracy and stability of the results. It also overcomes the problem of over-fitting. The input of the pre-trained dataset is provided to boost the model. The output of the boosting is used to construct different forest trees. The bootstrap sample size must be the same as that of the samples used for training the dataset. Every tree extends to a large depth without pruning.

Algorithm 2 is the prediction of cesarean chances through the health parameters of the pregnant woman.

Algorithm2: Prediction Algorithm

Input: Collected labeled dataset

Step1: Initialise $f_{(x)}^{0}$

Step2: for p=1 to P do:

for t=1 to T do:

Create vector θ_i and weight $w_p(i)$

$S_t \leftarrow bootstrap\ Sample(S)$

$C_t \leftarrow build\ tree\ classifier\ (S_t, \theta_t)$

End for

End for

Step3: Return a hypothesis based on voting

Step4: Calculate $g_k = \frac{\partial L(y,f)}{\partial f}$ and $h_k = \frac{\partial^2 L(y,f)}{\partial f^2}$

Step5: Calculate leaf weight $W^* = -\frac{G}{H}$ and Base Learner $b(x) = \sum_{j=1}^{T} wI$

Step6: Add forest $f_k(x) = f_{k-1}(x) + b(x)$

Step7: $A = \frac{1}{2}\left[\frac{G_L^2}{H_L} + \frac{G_R^2}{H_R} + \frac{G^2}{H}\right]$

Algorithm2 demonstrates the working of the proposed algorithm. The algorithm works for iterations P, and in every iteration p, the t tree is taken from the set of trees T to build the classifier C_t. The algorithm starts by taking data from biomedical sensors in textual form. The algorithm filters the dataset and classifies the data based on health parameters systolic blood pressure, diastolic blood pressure, and heart rate. $f_{(x)}^0$ is the initial root vector based on which we need to create the tree for the classification. Based on this initial value the residuals are calculated. For every data point p, we need to create tree t recursively. The similarity index from the left and right nodes of the trees $\frac{G_L^2}{H_L} + \frac{G_R^2}{H_R}$. This similarity index allows to creation gain A factor from the model.

4.2 Results and Discussion

To predict the accuracy of the proposed algorithm, we apply simulation using Python. The result of the prediction is obtained as shown in Figure 4-14.

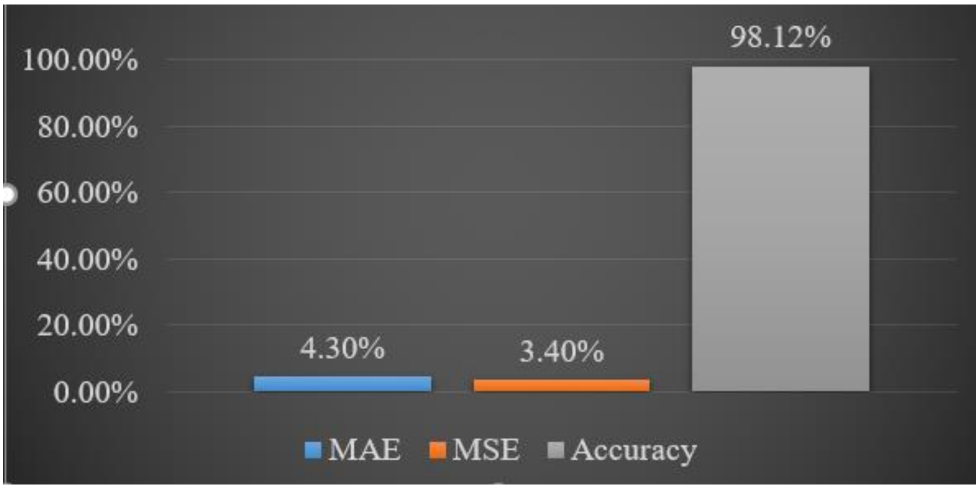


Figure 4-14Proposed Algorithm Prediction

The proposed algorithm describes the accuracy of 98.12% and MAE at 4.3% and MSE at 3.4%

4.3 Comparative Analysis

This section presents the comparison of the proposed pregnancy healthcare system with existing related studies. As stated in the previous sections, health is the crucial parameter as several attributes are associated. Moreover, the present study discussed the different concepts compared to the several state-of-the-art studies that present the system's overall efficiency. The comparative analysis is shown in Table 4-3

Table 4-3Comparative analysis of the proposed system with existing studies.

Parameters	Moreira et al.,[186]	Abdullah et al., [215]	Omesh et al., [216]	Oti et al., [217]	Proposed System
Domain-Specific	Depression prediction in Pregnancy	Telemonitoring the health of the pregnant woman	Health monitoring pregnant woman	Stress monitoring of Pregnant Women	Health Parameter of pregnant Woman
Focused Area	Emotions of a Pregnant Woman	Fetal rate, body temperature	Heartbeat	Heart rate vulnerability	High Blood Pressures impacts
Sensing Technology Used	Machine Learning	IoT	IoT	IoT and Edge computing	IoT
Data Classification Model Used	Decision Tree	Not Applicable	Not Applicable	K Means clustering	Physiological (Blood Pressure, Heartbeat, Pulse Rate) Atmospheric pollution
Data Extraction	Dataset	Sensors directly	Not Applicable	Not Applicable	Heterogenous
Information Mining	Analytics	Not Applicable	Location-based	Classification	Decision-based mining
Data Storage	Not Applicable	Cloud	Database	Cloud	Cloud and MySql
Output presentation	No	Yes	Yes	Yes	Yes
Security Mechanism	No	No	No	No	Yes

- *Domain Specific* parameters discuss the information regarding the healthcare domain based on which the study is carried out. Furthermore, the discussion about the information related to the proposed system in the healthcare domain is presented.
- *The focused Area* parameter discussed deep information about healthcare-focused by the existing studies and proposed study. The parameter mainly discussed the influence of the studies in the pregnancy healthcare industry.
- *Sensing technology* parameter presents healthcare data at the core of the research. Therefore, it is critical to find out
- *The data classification model* parameter presents information about the specific category of data classifier model implemented in different studies for effective vulnerability determination, as stated in the preceding sections concerning the efficacy of healthcare data categorization before vulnerability assessment.
- In the *data extraction* parameter for the evaluation of the effectiveness of the system with feature extraction technique for heterogeneous data. This parameter compares the presented system with comparative research based on the feature extraction mechanism.
- The technique of *data mining* is implemented on continuous data extraction from the database for realizing real-time healthcare assessment. Henceforth, it becomes an important parameter for analyzing the proposed model based on the underneath data mining technology indulged for data extraction.
- *The data storage* parameter presents data that has been saved in the database for evaluation. In other words, it includes the details of the data storage strategy that researchers have employed to store real-time heterogeneous health-related data.
- *The output presentation* parameter compares the suggested model to existing research in the field based on the output result presented to the target user. It will also provide information about the health-on-health care user interface for evaluating user health.
- *Security mechanism* presents appropriate security measures for the acquired data containing personal health information. In addition, this parameter

includes details on the various security approaches used by researchers to protect healthcare data.

Chapter 5

Designing and development of a recommendation system to the pregnant women and physician.

5.1 Introduction

The recommendation system is working at the cloud and end-user layers. It is responsible for providing real-time health suggestions to a pregnant woman. Figure Figure 5-1 shows the typical working of the recommendation system

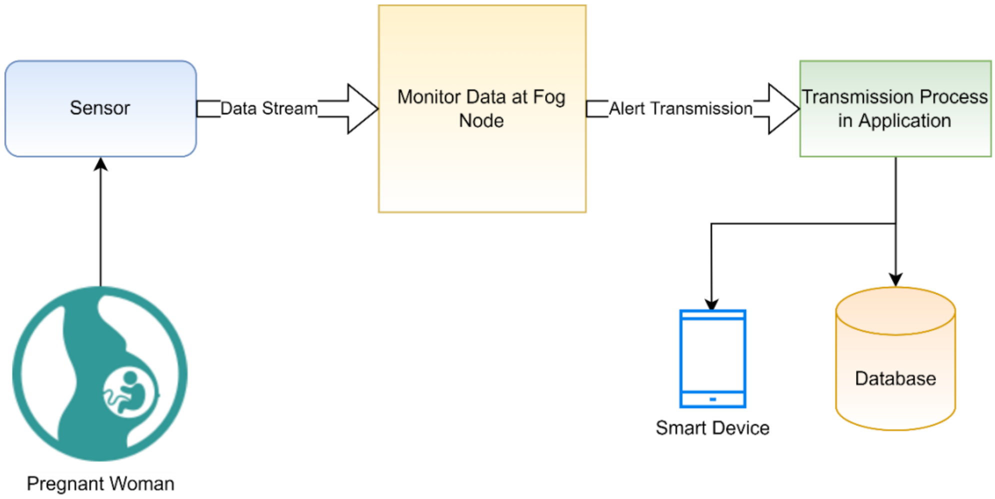


Figure 5-1Recommendation Model

The recommendation system as shown in Figure 5-1 likewise works as the "go-between" for the sensor design and the database. The associations with sensors for the application layer will shift from client to client, yet this layer can force and drive significant information from and to the database. There will be various types of uses given the introduced sensors and the client's need; everyone decided through the application age process. Necessities and plan contemplations are examined in the accompanying passages. The application's client should be thought about, and the interface should be outlined around that. Multifaceted nature should be limited for the patient, and expansive-hued catches should be given as one contrasting option to those not used to utilizing portable applications. The interface should be tab-based to support assist modules and guarantee that the application can be extended without the stress of an aggregate overhaul. A notice framework ought to be incorporated. This makes the shading coding a well-being plan and could likewise be dreamy to use messages. Email cautions might be a need for the patient may probably read a perpetual email than a little warning on their telephone. The patient's application layer ought to be propelled enough to give an extensive picture of the specific patient's well-being. Diagrams and outlines ought to be given that is anything but difficult to peruse and introduce pertinent data exactly and predictably. Diagrams may likewise be available in the patient application for individual utilization, however with a few information clouded full Physician-persistent data cover isn't wanted. The Physician application is completely extraordinary. It ought to be anything but difficult to utilize, yet client acknowledgment isn't as imperative a core interest. More catches and highlights can be utilized and the GUI might be more "crude." The Physician application should have a reliable client involvement with the patient application.

At last, the Physician application ought to consider examining different information focuses on numerous patients and an audit of patient history. The connectors in this piece of engineering are essentially associating the gadgets with the portable design and an association with the database that transmits the data pulled from the sensor gadgets. The subtle elements of the connectors are limited as the transmission is going from the sensors to the database. Nothing is put away locally aside from on account of a blackout, and after that, information is reserved, however later erased after transmission.

5.2 Methodology & Implementation

The proposed recommendation system uses Python as a tool and Django as a framework. These both have powerful functionality as by using python, we can create any smart application. In contrast, we can create web applications that have smart functionality and are created with lesser LOC by using Django. The proposed recommendation system is based on different panels. This section discussed these panels' purpose and work and how these panels perform in interaction with the other panels.

5.2.1 Main Panel

The main panel is represented in Figure 5-2. This is the main website starting point from where all the users of the system can move to any other part of the application.

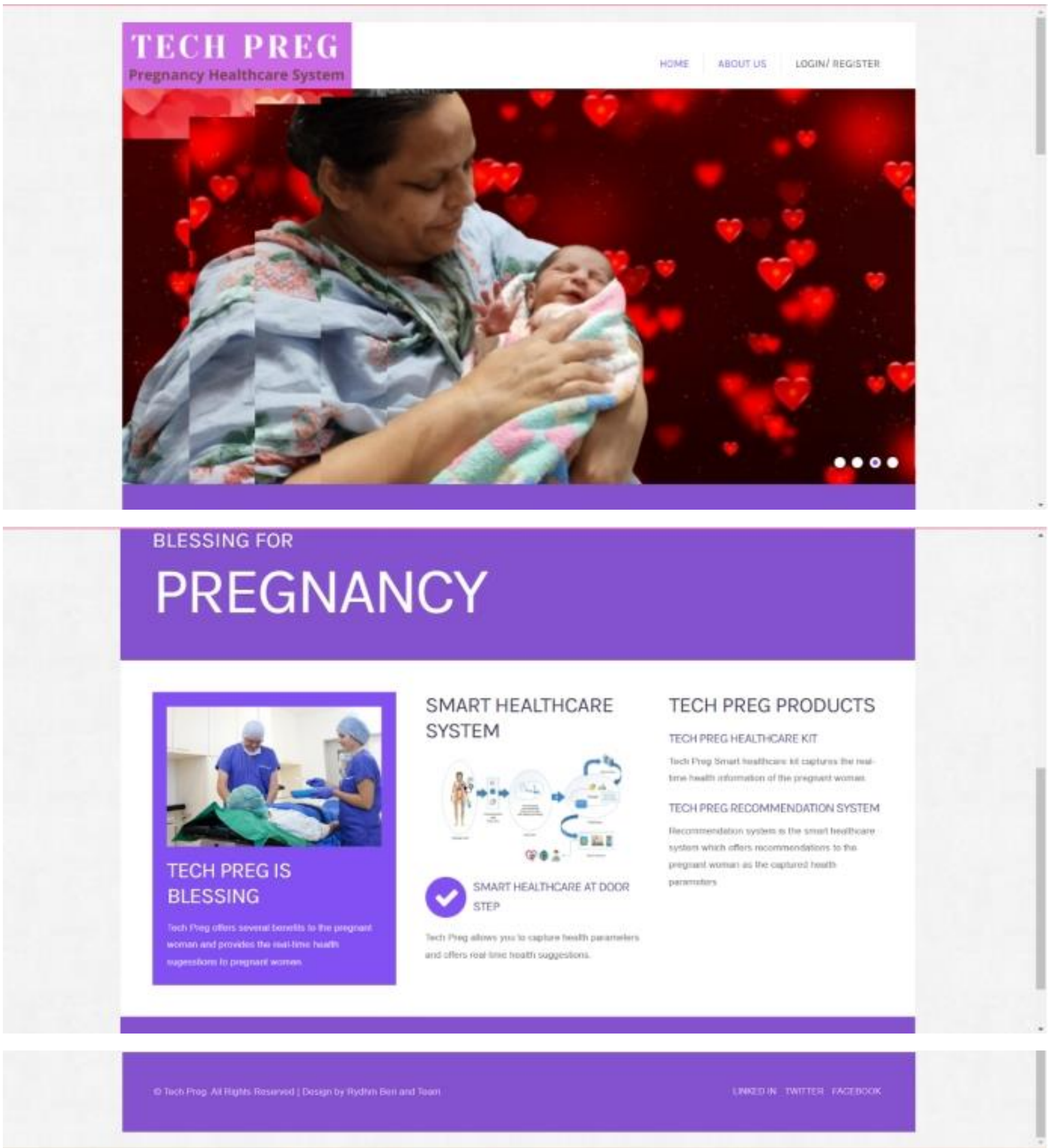


Figure 5-2Main Panel

The purpose of the main panel is to provide information regarding the Tech Preg: Pregnancy Healthcare system and also about the members of the system. The main panel has a navigation bar at the top to move to the different pages of the web application.

5.2.2 About Us

The about us page is represented in Figure 5-3. The page represented the information regarding the team members associated with the proposed system. The page is static and is used to provide only static information about the team so that users can have information regarding the creator of the proposed system

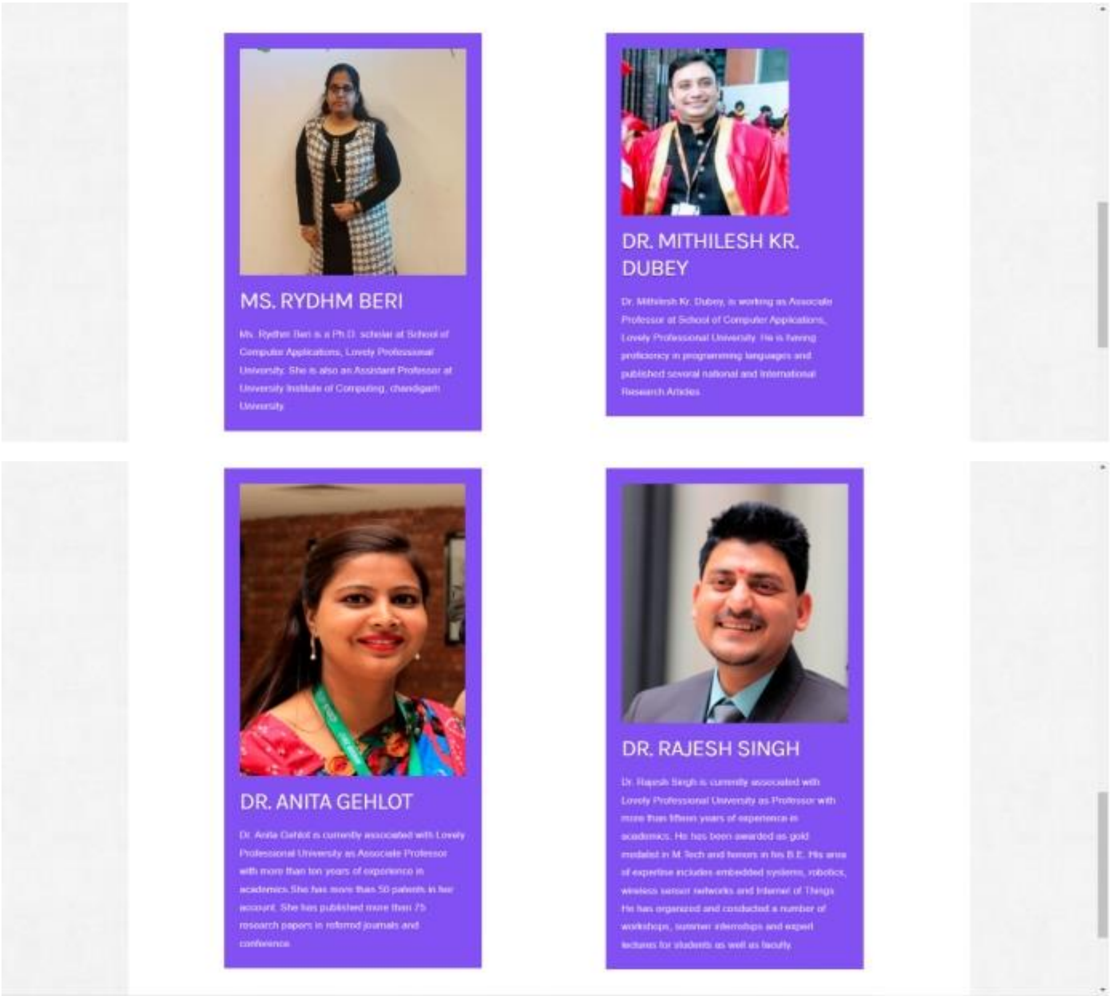


Figure 5-3About team

5.2.3 Login Panel

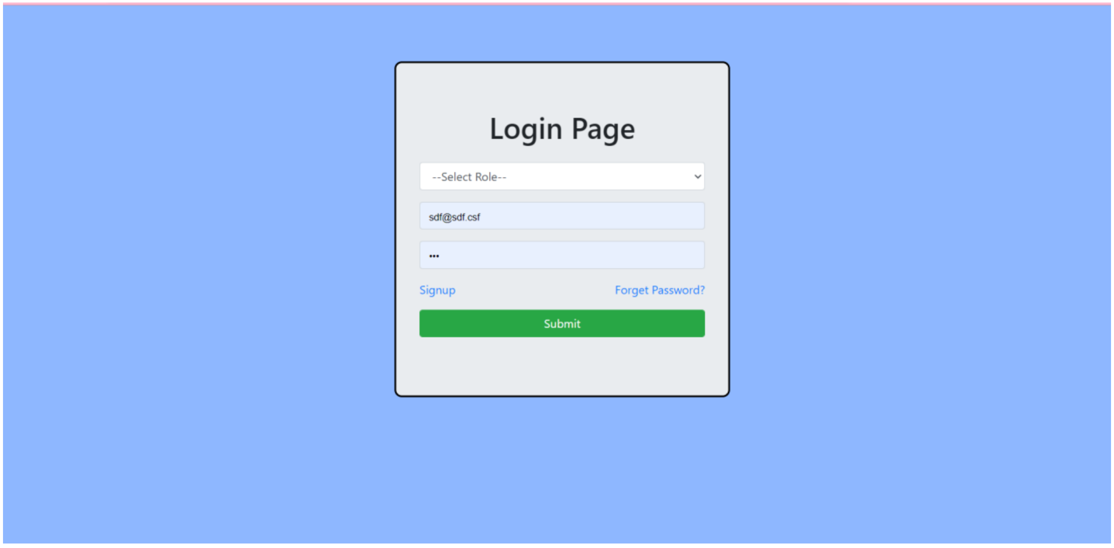


Figure 5-4Login Panel

The login panel as shown in Figure 5-4 is created for the authenticity of the user. Four users can log in to the system including, admin, user, hospital, and doctor.

a. **Admin Panel:** Admin panel is created to create different roles in the system. From the admin panel what features a specific user can access about the system is decided. Through this panel, we can have access to the database as a whole.
b. **User Panel:** This is the patient's panel from where the patient can monitor their health conditions and directly log in to the system for connecting with the doctors. The patient needs to fill in all information about her health, her feeling, her mood, or her previous pregnancy history in one place. This information will be used by doctors to identify the health condition and prediction of depression or other health issues in women's bodies.
c. **Doctor's Panel:** This panel is utilized by doctors to get the complete health information of their patients in one place. Doctors can get a historical profile of the patient, her present health conditions, and the prediction result of chances to get any issues during or post pregnancy.
d. **Hospital Panel:** This panel is used by hospitals to enter their doctor's and patients' conditions or the observation found about the patient during regular checkups. This panel helps hospitals to manage their staff and maintain the health profile of

the patient. Also using this panel doctors can maintain the tests to refer to the pregnant women during pregnancy and can store the reports of the test.

5.2.4 Signup Page

To use the recommendation system, the user first needs to register to the system by providing their information. The signup panel shows in Figure 5-5. Using the signup page four types of users can register to the system i.e. Hospitals, Users (patients), Doctors, and Admin.

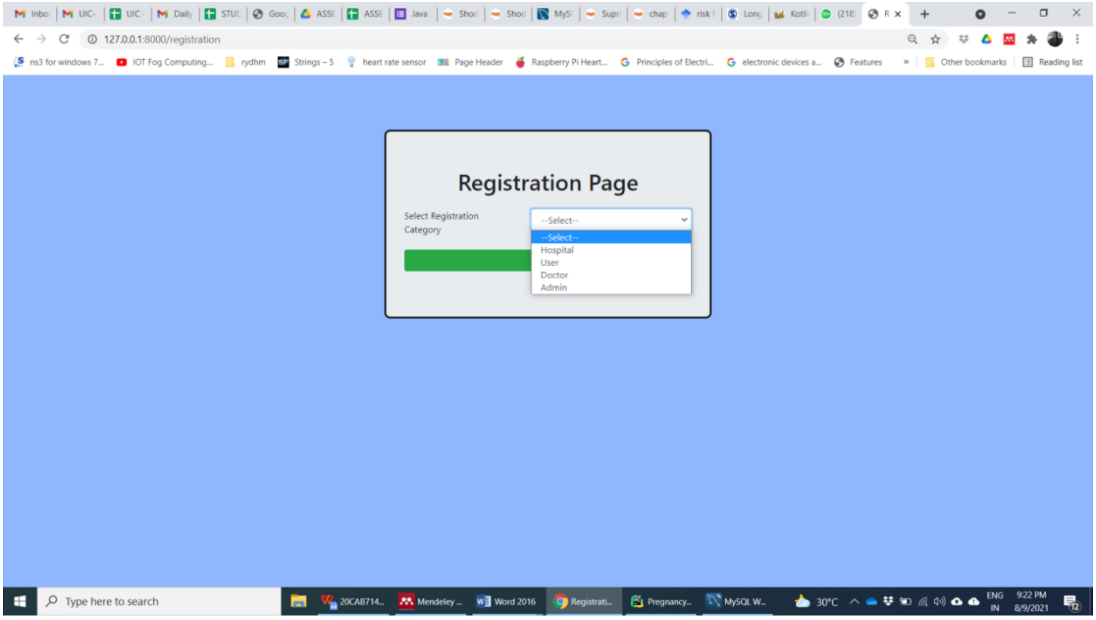


Figure 5-5Signup Panel

a. **Admin Panel:** Admin panel is created to create different roles in the system. From the admin panel what features specific users can access about the system is decided. Through this panel, we can have access to the database as a whole. Using this panel we can create more than one admin to manage access and provide roles to the other users of the system.

b. **User Panel:** This is the patient's panel from where the patient can monitor their health conditions and directly log in to the system for connecting with the doctors. The patient needs to fill in all information about her health, her feeling, her mood, or her previous pregnancy history in one place. This information will be used by doctors to identify the health condition and prediction of depression or other health issues in women's bodies.

c. **Doctor’s Panel:** This panel is utilized by doctors to get the complete health information of their patients in one place. Doctors can get a historical profile of the patient, her present health conditions, and the prediction result of chances to get any issues during or post pregnancy.

d. **Hospital Panel:** This panel is used by hospitals to enter their doctors' and patients' conditions or the observation found about the patient during regular checkups. This panel helps hospitals to manage their staff and maintain the health profile of the patient. Also using this panel doctors can maintain the tests that refer to pregnant women during pregnancy and can store the reports of the test also.

5.2.5 Admin Panel

Once the admin authenticity is approved through login, the admin will get the screen as shown in Figure 5-6. The homepage provides the current time and local weather as per his location. The digital clock is created using JavaScript and the weather forecasting is performed using AccuWeather API. On the left side, there is a navigation bar through which the admin can set different roles for the user or set values to several options. This panel plays a great role in offering a dynamic environment in the recommendation system. As the new feature needs to be introduced in any panel, it can be done through the Admin panel only.

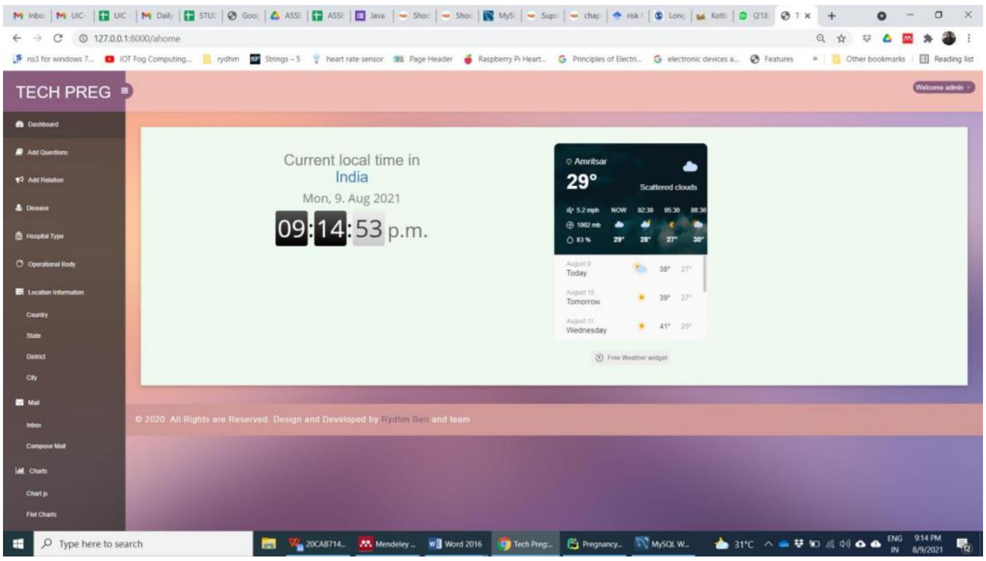


Figure 5-6Admin Homepage

5.2.5.1 *Security Questions*

The security question form as shown in Figure 5-7 is created for providing security questions and health-related questions to the patient panel. It is asking one entry from the Admin the question which needs to be asked from the user and the other entry is a description that specifies for what purpose the question needs to be asked from the user.

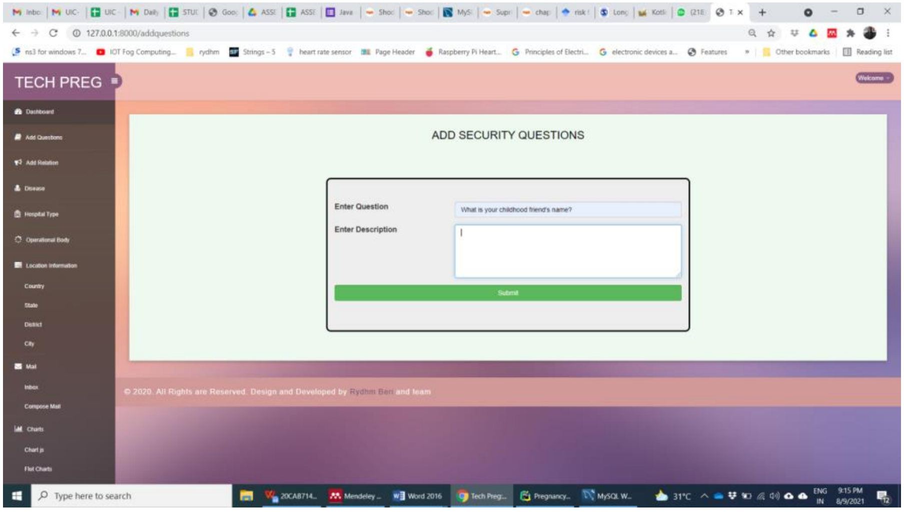


Figure 5-7Security questions

5.2.5.2 *Add Relation*

The add-relation form as shown in Figure 5-8 allows the admin to add the type of relation the user can select in their disease history or contact person form. This further will allows the doctors to retrieve the health history of the pregnant woman so that necessary actions can be taken to save the infant from any hereditary disease.

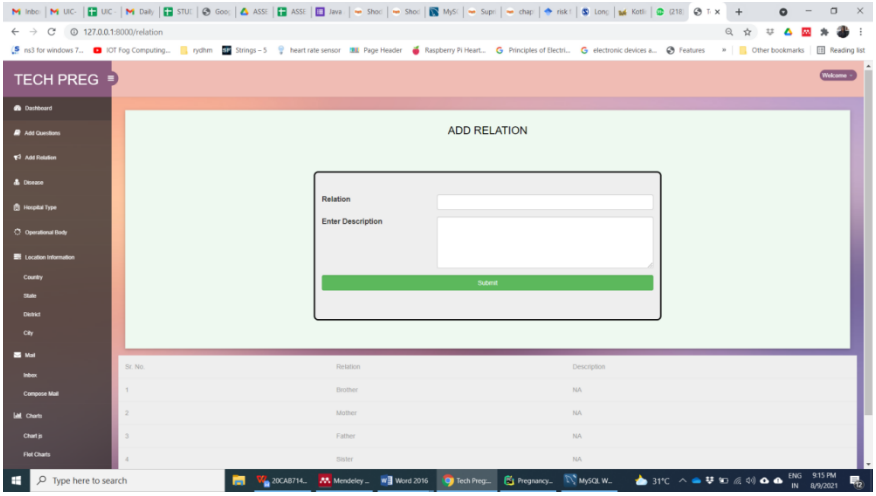


Figure 5-8Add Relation

5.2.5.3 *Add Diagnosis Information*

Add diagnosis information form as shown in Figure 5-9, allows the admin to add which kind of disease information is necessary to take from pregnant women to know about hereditary health issues. This information will be entered by the patient from the user's panel.

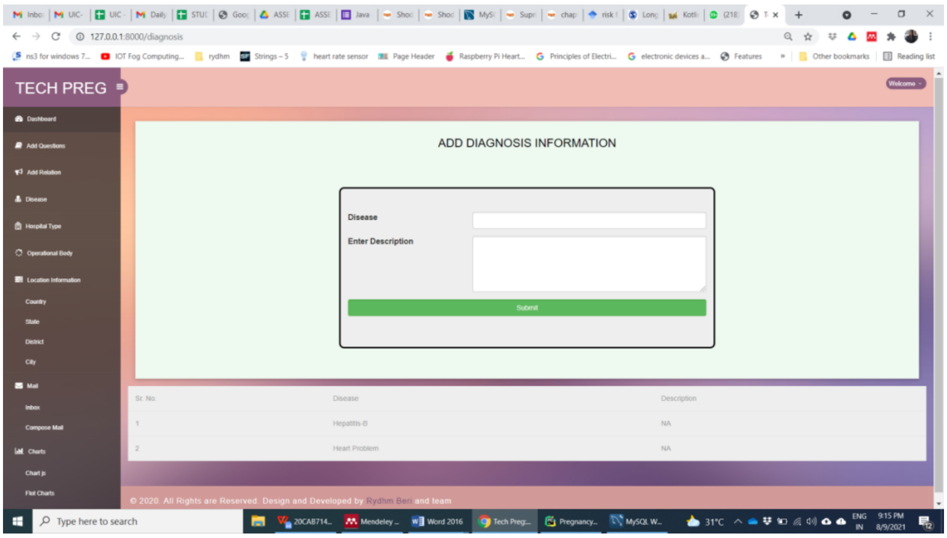


Figure 5-9Add diagnosis information

5.2.5.4 *Add Hospital Type*

Add Hospital Type form as Figure 5-10 offer provisioning for different types of hospital register. The created web application allows hospitals to directly register themselves or the hospitals can be registered by any third party bodies. By registration, only the hospital staff can use the system.

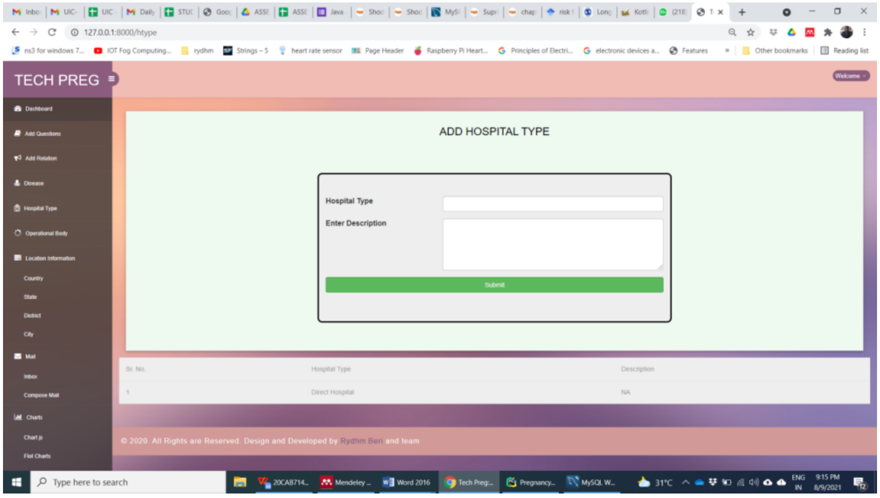


Figure 5-10 Add Hospital Type

5.2.5.5 Add country information

Add country information form as shown in Figure 5-11 allow admin to permit users from only those countries which are entered here. The user, hospitals, and doctors only belong to those countries offered by the admin and can register themselves in the created application.

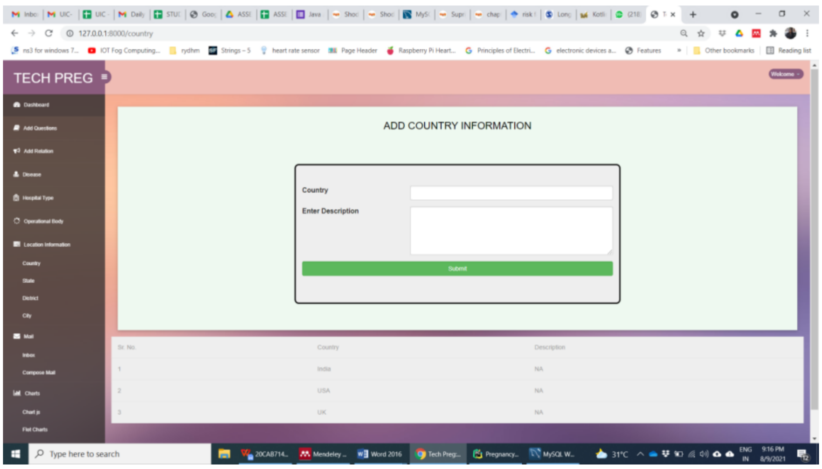


Figure 5-11Add country information

5.2.5.6 Add state information

Add state information form as shown in Figure 5-12 allow admin to permit users from only those state as per the country selected which are entered here. The user, hospitals, and doctors who only belongs to those state of the selected countries offered by the admin can register themselves in the created application.

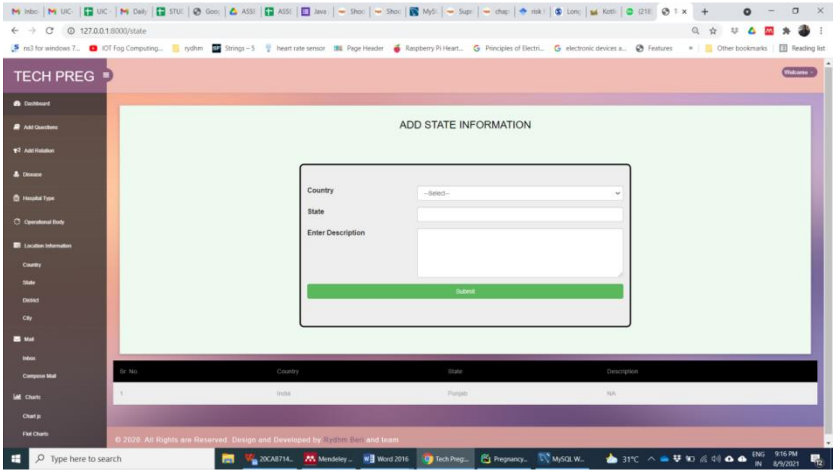


Figure 5-12Add State Information

5.2.5.7 Add district information

Add district information form as shown in Figure 5-13 allow admin to permit users from only those district as per the country and state selected which are entered here. The user, hospitals, and doctors only belong to those districts of the selected state and countries offered by admin and can register themselves in the created application.

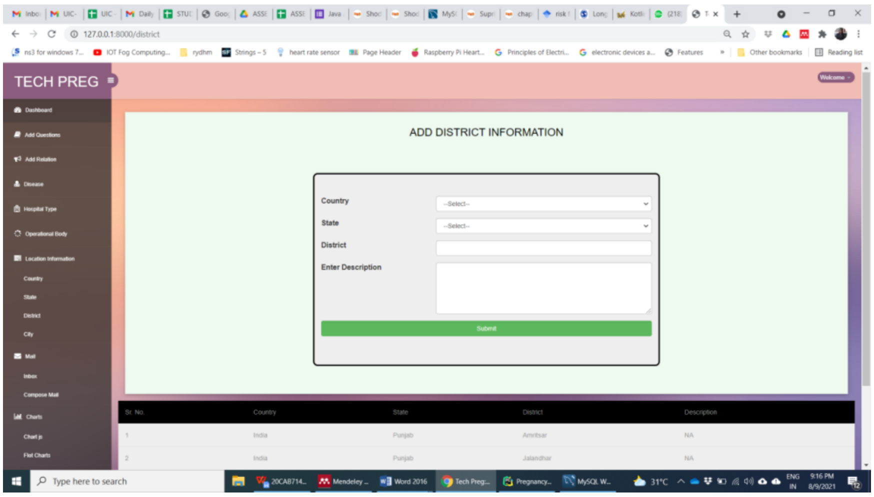


Figure 5-13Add District Information

5.2.5.8 Add city information

Add city information form as shown in Figure 5-14 allow admin to permit users from only those cities as per the country, state, and district selected which are entered here.

The user, hospitals, and doctors only belong to those districts of the selected state, and countries offered by admin can register themselves in the created application.

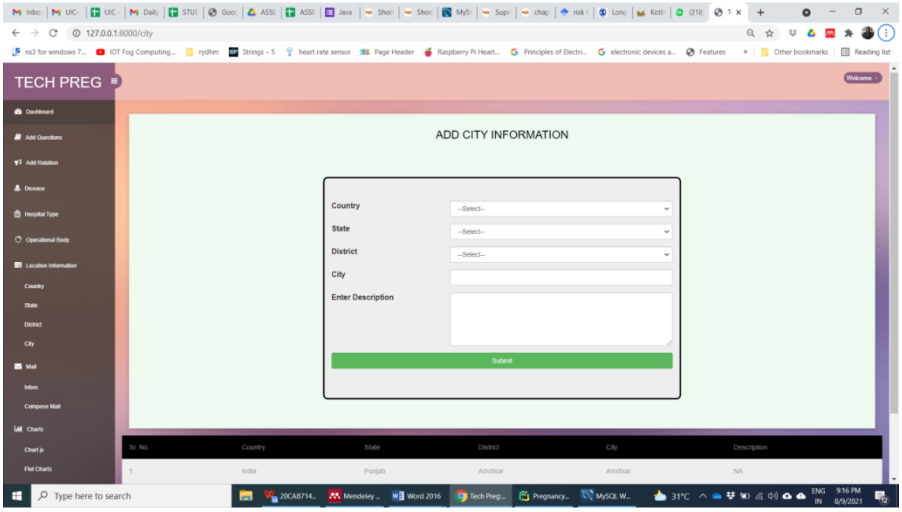


Figure 5-14 Add City Information

5.2.6 User Panel(Patient Panel)

The user panel is created for the patient to interact with the web application. By using this panel the user(patient) can maintain her health profile, review her health conditions, get connected with the doctor and monitor her health parameters. The user panel has separate web forms discussed below.

5.2.6.1 Registration Panel

The user registration panel as shown in Figure 5-15 allows users to register to the recommendation system. Only the registered students can get access to the system which allows her health monitoring. On the registration page, the basic information about the lady is asked regarding her contact information, date of birth, blood group, and security questions(retrieve account information if forget at a later stage).

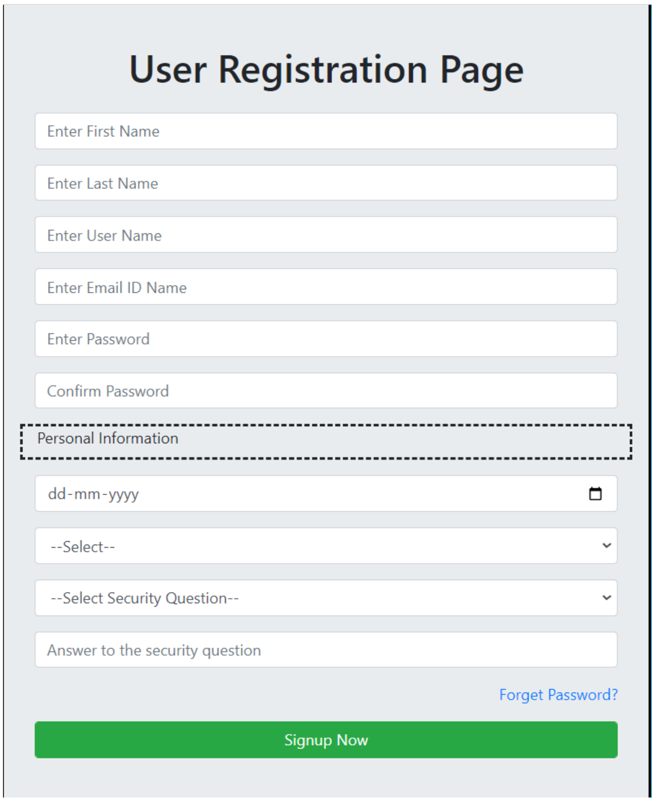


Figure 5-15User Registration

5.2.6.2 Forget password

The forget password form as shown in Figure 5-16 allow user, hospital, and doctors to retrieve passwords from registered email ID. This form is common for all panels to retrieve passwords through email.

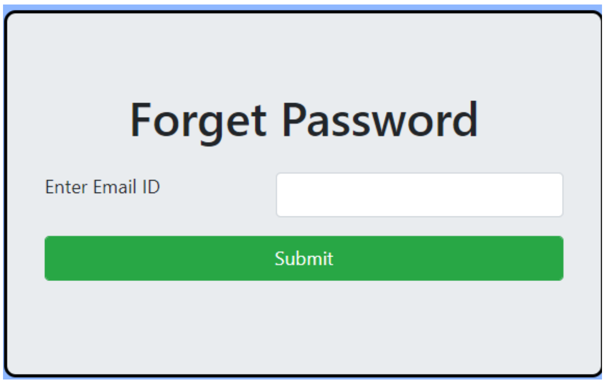


Figure 5-16Forget Password

5.2.6.3 User Home Panel

The user home panel as shown in Figure 5-18 shows the patient health conditions. The form shows the heartbeat, blood pressure, and health monitoring classification. This panel shows the recent health data monitored by biomedical sensors. The heart rate graph shows the heartbeat and pulse rate of the pregnant woman who logs into the system. The blood pressure graph shows the systolic and diastolic blood pressure of the woman date-wise. The health condition in the monthly pie chart show on average in a month what is the health condition of the pregnant woman. On the left side, the navigation panel allows the user to navigate to the user's panel.

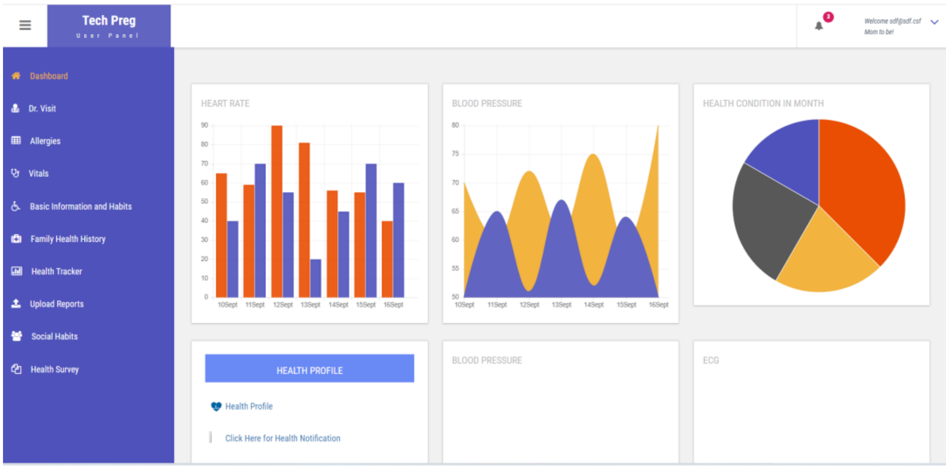


Figure 5-17User Home panel health parameters

Furthermore, the second part of the home panel as shown in Figure 5-18 displays the appointment calendar. In this view, the calendar is automatically maintained as per the health conditions monitored regularly or as per the previous checkup the calendar is updated by the hospital staff for a further appointments as per the availability of the doctor.

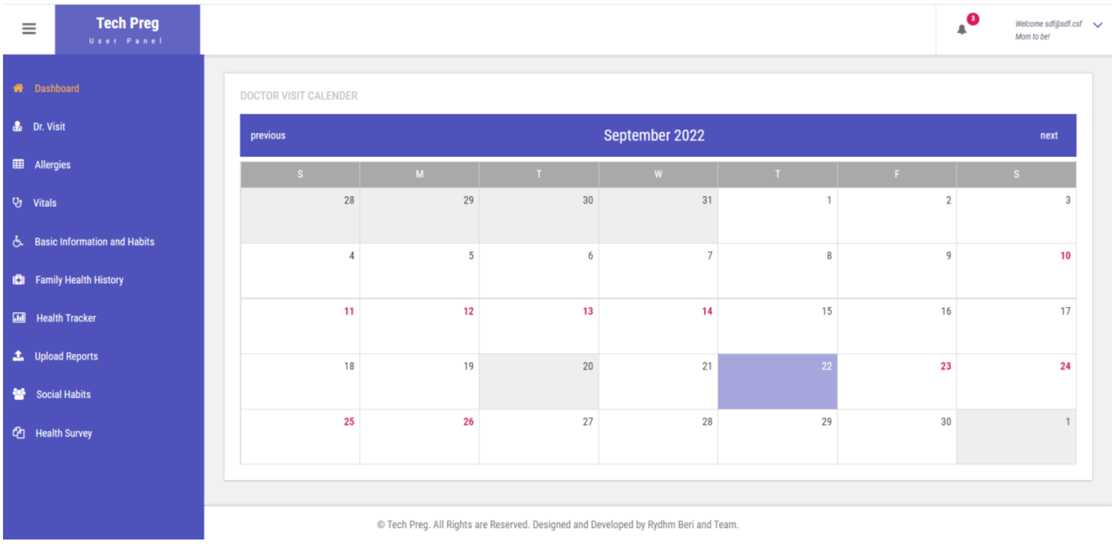


Figure 5-18 User Home Panel

5.2.6.4 Book Appointment

The book appointment form as shown in Figure 5-19 allows the user to book an appointment with the doctor whom the pregnant lady wishes to contact during pregnancy. The lady first needs to select the country, its respective state, respective district, and city. Based on the location the user will get the list of hospitals and clinics registered to the tech preg panel and based upon the selected clinic the doctor and his available timings are shown which the woman needs to select as per her convenient time. Furthermore, the woman needs to enter the reason for an appointment like any health issue she is facing or the lady wants to book the appointment for regular checkups. This form also displays the appointment history to the user.

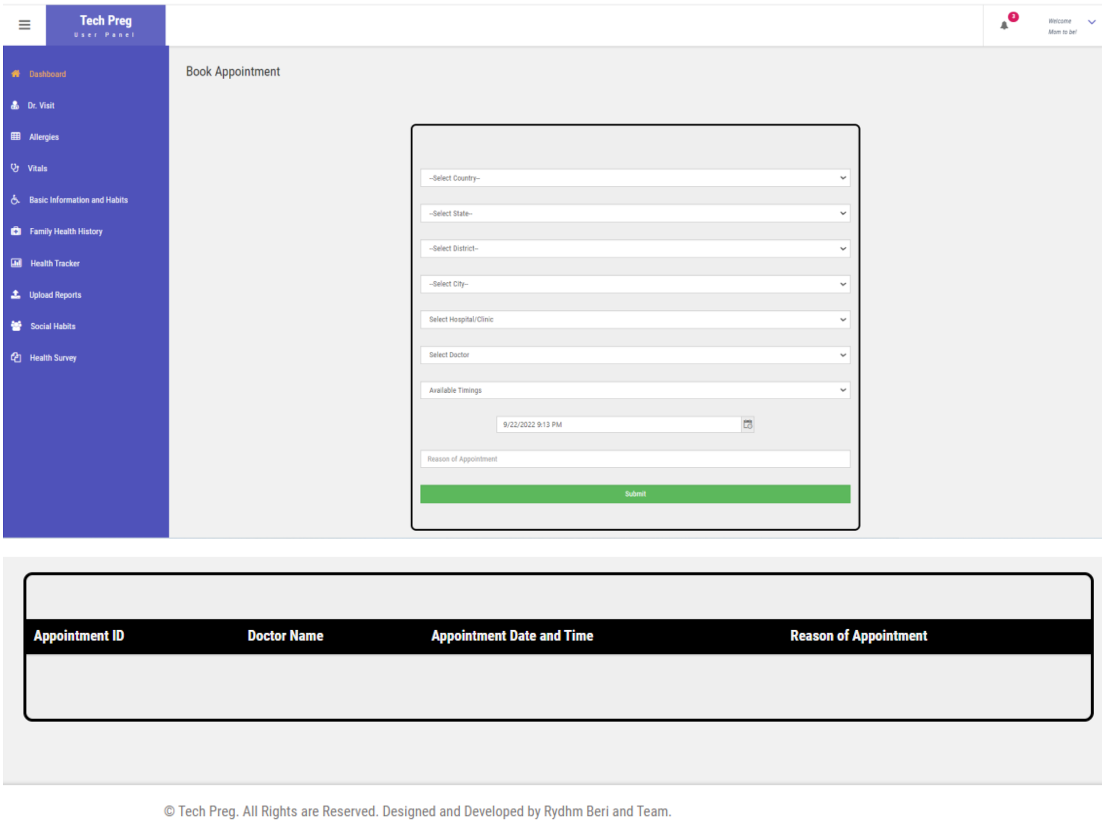


Figure 5-19Book Appointment

5.2.6.5 Allergies

The allergies form as shown in Figure 5-20 allows the user to enter her allergy information. This information will allow the doctor to identify which drug or other substance does allergy in the woman so that during pregnancy necessary precautions can be taken for the reduction of health issues.

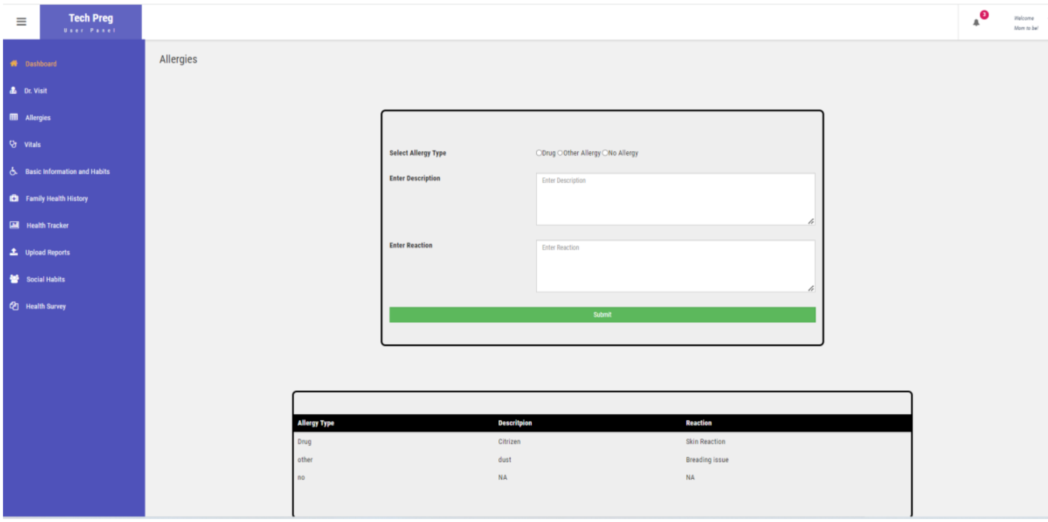


Figure 5-20 Allergy

5.2.6.6 Vitals panel

The vitals form in the user's panel allows the user to monitor the real-time health conditions of the pregnant woman. This form works only if the sensors get connected to the web application. It shows real-time blood pressure and heartbeat. Furthermore, the form offers recommendations as per the present health parameters monitored through the biomedical sensors.

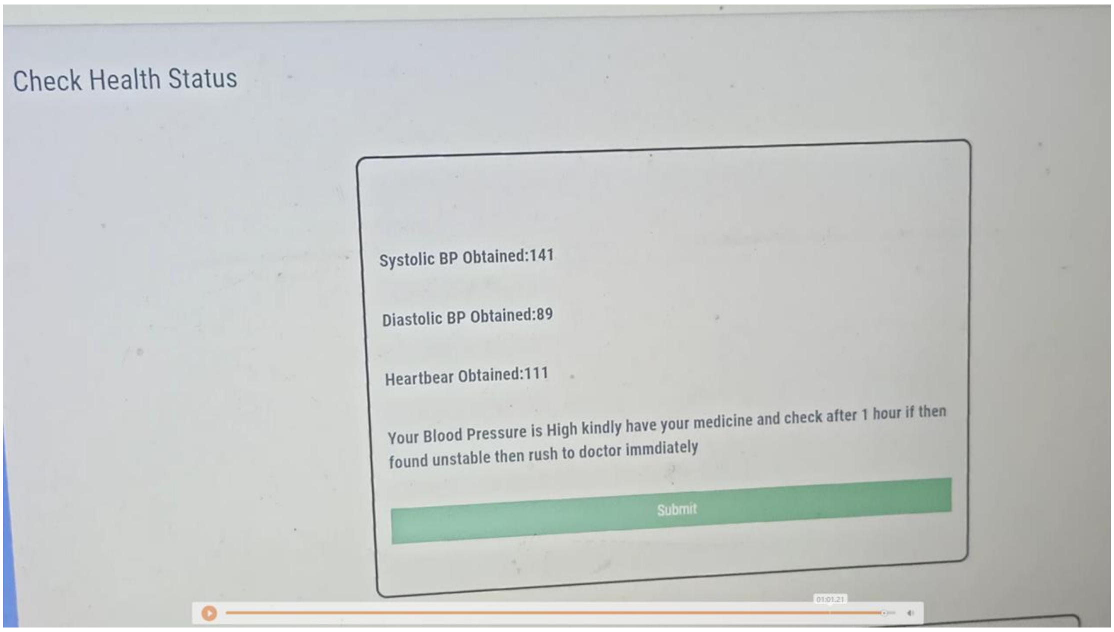
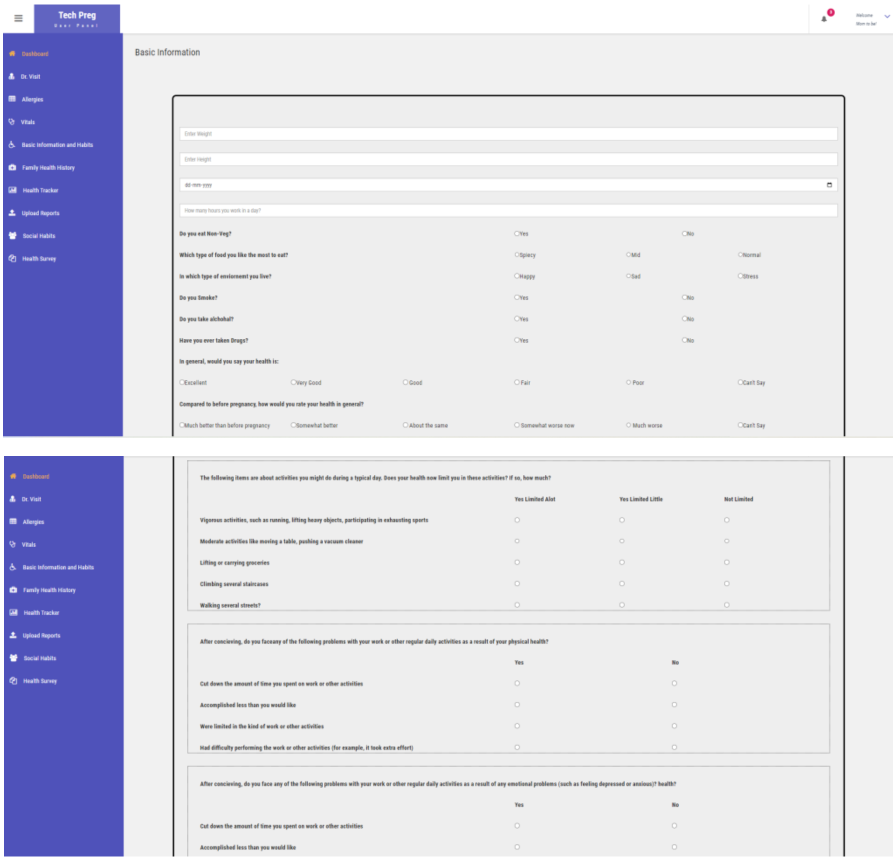


Figure 5-21Health Status

5.2.6.7 *Basic Health information*

The basic health information form as shown in Figure 5-22, allows user to input their personal information. This information takes user information including, body dimensions, weight, date of birth, working hours per day, eating habits, drinking or smoking habit, health conditions as per feeling, anxiety, depression, or happiness emotional conditions of the pregnant woman. This data is taken from the user from questionaries, which the user needs to fill in after registration on the portal. This data is helpful for the identification of depression or anxiety, or pre-eclampsia prediction. The user needs to fill in complete data first once she registers with the system. After the creation of the profile, a few question values will be asked from the user again to identify the present mental state of the pregnant woman.



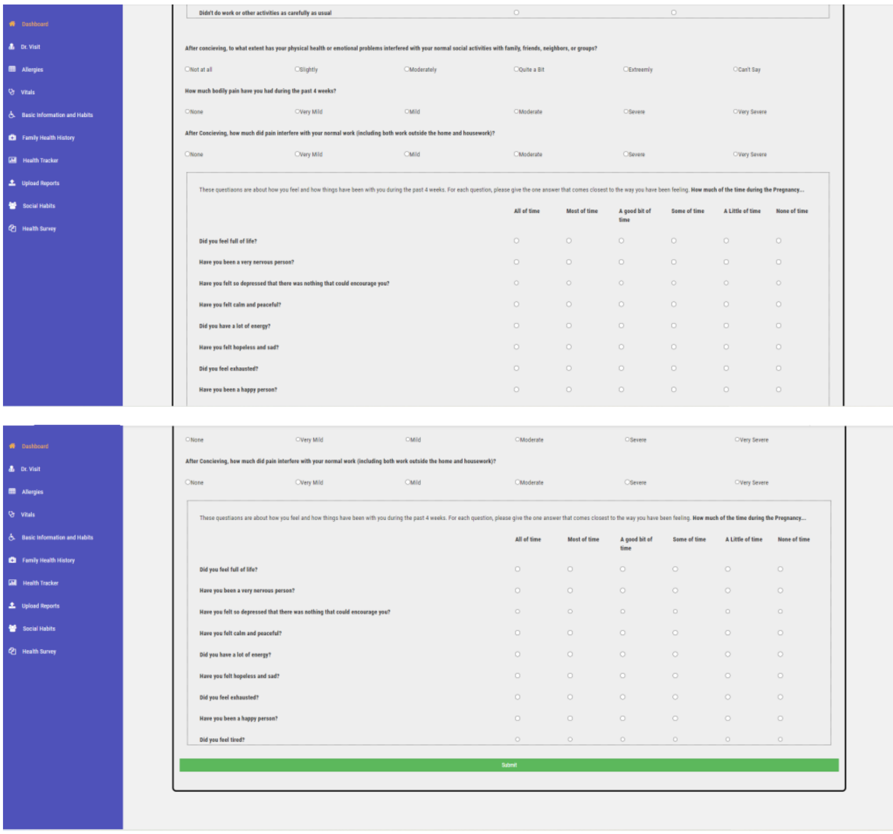


Figure 5-22Basic Health Information

5.2.6.8 Family Health History

Family health history form as shown in Figure 5-23 allows the patient to identify the health history of her family. This information will be used by doctors to give medication to the patient for the reduction of hereditary health issues chances in the infant. This information needs to be updated by the lady only once.

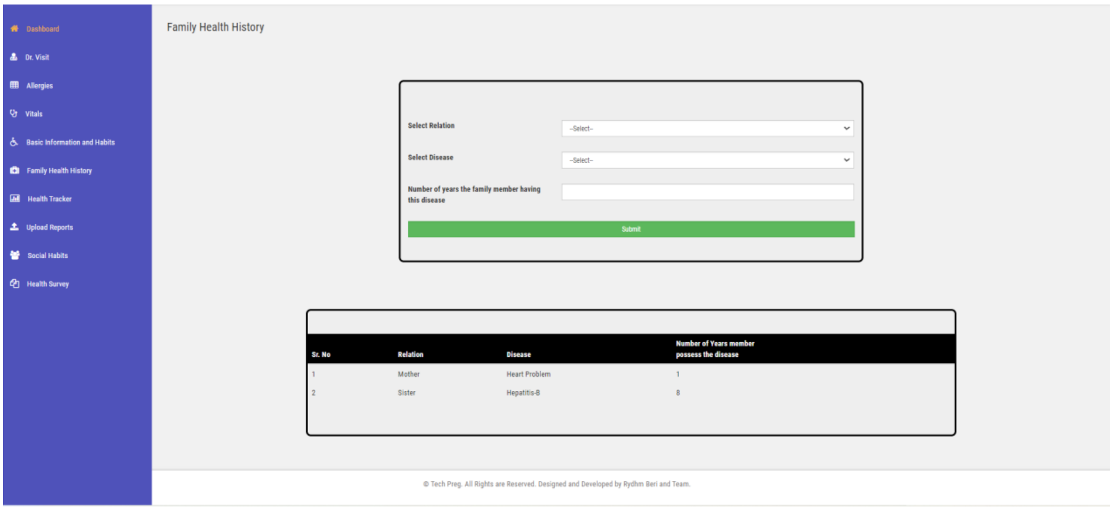


Figure 5-23Family Health History

5.2.6.9 Health Tracker

The health tracker form as shown in Figure 5-24 allows the user to enter data at the end of the day. This data includes the weight measured, steps taken, kicks felt, sleeping hours, KM walked, and blood sugar rating of the present day. Using this data the health conditions of the pregnant woman are classified whether the health condition is normal, or critical.

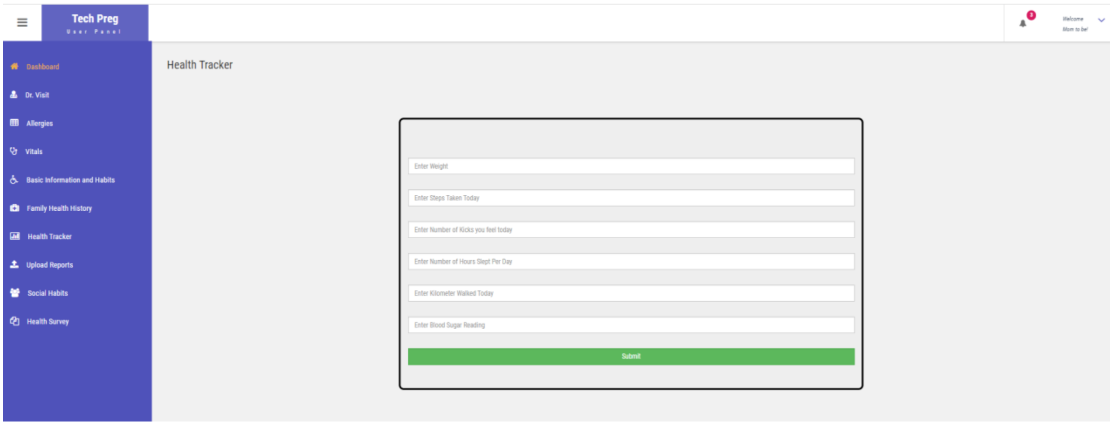


Figure 5-24Health Tracker

5.2.7 Hospital Panel

The hospital panel is a complete maternity home management solution. The system allows hospitals to manage their doctor's and patient's records in a single place with a single database. The hospital panel is discussed below:

5.2.7.1 Hospital Registration

The hospital panel started with the registration panel as shown in Figure 5-25. In this form, the hospital information is asked who wants to register to the panel. The hospitals can only use the panel only after verification from the admin. The form asked for the hospital name, address, nodal officer name, contact details, and hospital head person or society which is running that hospital. This information is used by the admin to verify the hospital information.

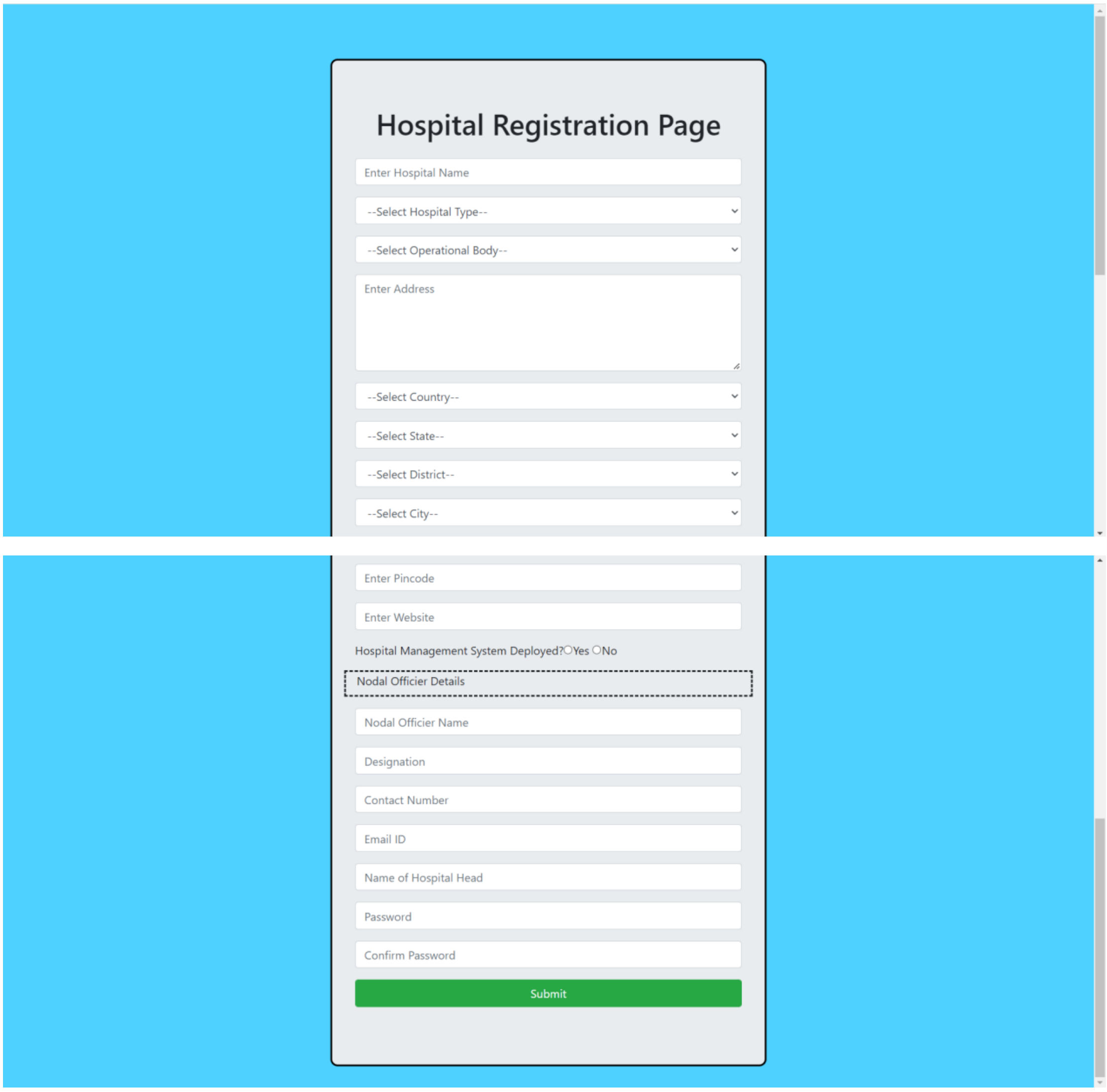


Figure 5-25Hospital Registration

5.2.7.2 Hospital Home Panel

The hospital home panel as shown in Figure 5-26 displays the total number of doctors who collaborate with the hospital and the patient under the care of the doctors appointed in the hospital. Furthermore, the digital clock created in JavaScript shows the current time, and the weather widget shows the present weather as per the current location. On the left-hand side, the navigation panel allows the hospital to move further to the other forms of the hospital panel.

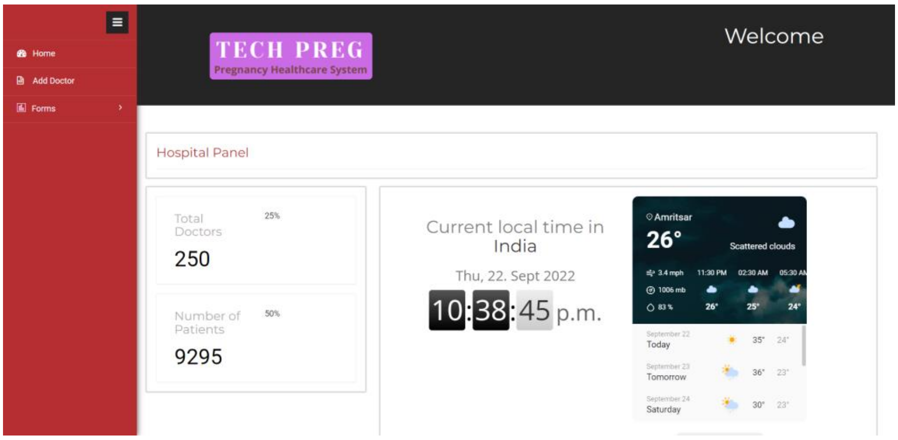


Figure 5-26Hospital Home Panel

5.2.7.3 Doctor Registration

The doctor registration panel as shown in Figure 5-27 allows the hospital to enter the doctor's information, the OPD timing, specialty, profile information, and login roles creation for the doctors. The doctors can be registered directly or by the hospitals through this panel.

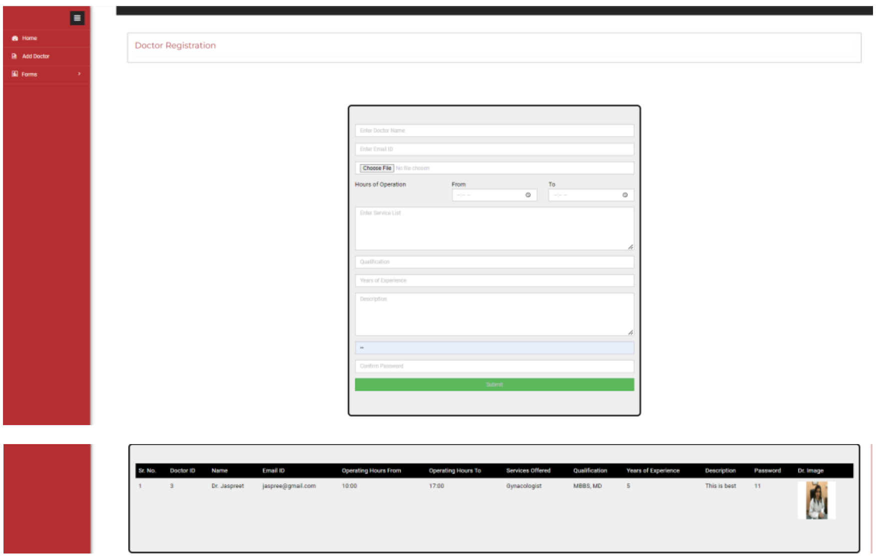


Figure 5-27 Doctor Registration

5.2.8 Doctor Panel

The doctor panel as shown in Figure 5-28, is a single place from where the doctor can get the health conditions of all the patients and their profiles in one place. With this panel, all information about the patient is just a single click away from the doctor. A doctor can directly check his schedule or vitals of the specific patient if not found normal. This allows the doctor to directly connect with the patient.

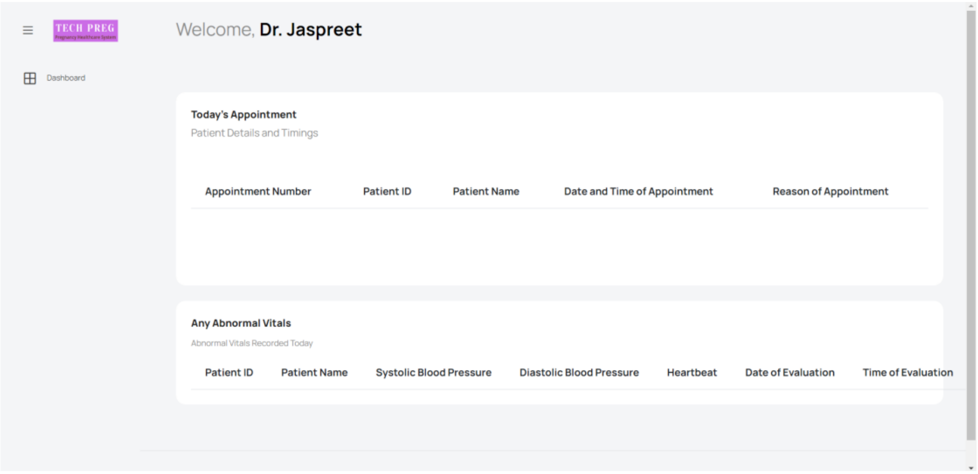


Figure 5-28Doctor's Panel

5.3 Comparative Analysis

The comparative analysis of the presented system with the existing application is shown in Table 5-1. The comparison of the presented system was performed based on different parameters such as Blood Pressure, Heartbeat, pulse rate, weight, health suggestions, messages, and health tracking. Based on the comparison it is identified that the presented system is more utilized and offers better services to the user.

Table 5-1Comparative Analysis of Pregnancy healthcare applications

App	Bellabeat Shell	Bloom Life	Biobands	Qardiobase wireless smart scale & body analyzer	Pregnancy+	Babyscript	Pregnancy++	Ovia Pregnancy App	Proposed System
BP	×	×	×	×	×	×	×	×	✓
Heart Beat of Women	×	×	×	×	×	×	×	×	✓
Pulse rate	×	×	×	×	×	×	×	×	✓
Weight	×	×	×	✓	×	×	×	×	✓
Provide Real-Time Health information	×	×	×	×	✓	×	×	×	✓
Send messages	×	×	×	×	×	×	×	×	✓
Internet Connected	×	✓	✓	✓	✓	×	×	×	✓

5.4 Summary

The chapter focused on a discussion of a recommendation system that works in a real-time environment. The system develops in the Django web application development framework. The chapter includes information related to the modules or panels created in the system and their work. As last, the comparison is made between the different applications. Based on the comparison, the presented recommendation was found useful for hospitals, doctors, and patients that are using the system.

Chapter 6
Performance Evaluation

This chapter focuses on analyzing the presented system based on the performance analysis of the presented system. The chapter finally, concluded with a comparative analysis of the proposed system with the existing systems.

6.1 Results and Discussion

Before performing any model construction, the dataset is divided into two parts, in which one part contains 80% of training data elements(1009 instances). In contrast, the other part contains 20% of the testing dataset (253 instances). As per the empirical study, it is recommended to take training and testing dataset ratio as 80% and 20% respectively[218]. The performance of the proposed model is evaluated based on 10-fold cross-validation by which the complete data is randomly divided into ten folds, where one fold out of all is provided to the model for validation and the rest k-1 fold consumed for training purposes. The final accuracy was further calculated based on all intermediate obtained accuracy.

Table 6-1 describes the calculated results for the efficiency of prediction by the proposed optimized algorithm and the other algorithms used for testing purposes.

Model	MAE	MSE	Accuracy
kNN	5.1%	5.33%	63.33%
Decision Tree	4.8%	5.6%	71.36%
Support Vector Clustering	5%	5%	50%
Random Forest	5%	5%	65.71%
XGBoost	5%	5.4%	79.68%
Proposed Algorithm	4.3%	3.4%	98.12%

Table 6-1Machine Learning Prediction Results MAE, MSE, Accuracy

The table depicts the calculated Mean Absolute Error (MAE), Mean Squared Error (MSE), and the accuracy obtained from other models and the proposed methodology. The comparison between different algorithms includes KNN, Decision Tree, Support Vector Clustering, Random Forest, XGBoost, and the proposed algorithm.

6.1.1 Mean Absolute Error

Mean absolute error (MAE) is defined as the absolute difference between the observed outcome and the predicted outcome.

$$MAE = \sum_{i=1}^{n} \frac{|predicted\ value - target\ value|}{sample\ size}$$

6.1.2 Mean Squared Error

Mean squared error (MSE) is defined as the average squared difference between the prediction outcome of the model with the target outcome.

$$MSE = \sum_{i=1}^{n} (Observed\ outcome - predicted\ outcome)^2$$

6.1.3 Accuracy

Accuracy is defined as the fraction of the correct predicted outcome over the total number of predictions.

$$Accuracy = \frac{Predicted\ outcomes}{Total\ predictions}$$

6.2 Comparative Analysis

The comparison chart of different algorithms in terms of accuracy is shown in Figure 6-1. The accuracy prediction specifies that the proposed algorithm offers high accuracy, i.e. 98.12%.

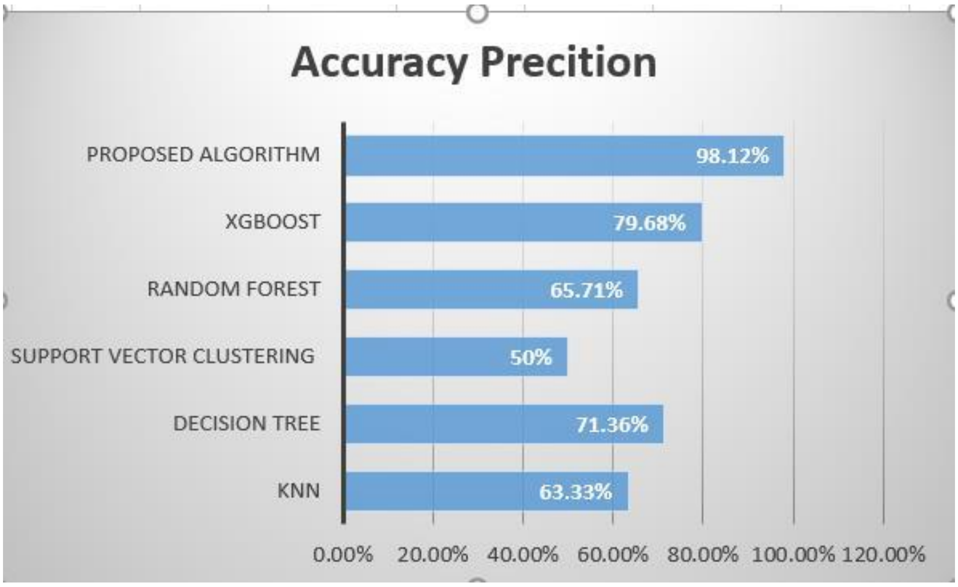


Figure 6-1Accuracy Prediction

The comparative analysis of the proposed and existing system's mean absolute error(MAE) is represented in Figure 6-2. The proposed system was found to be reliable in terms of less MAE.

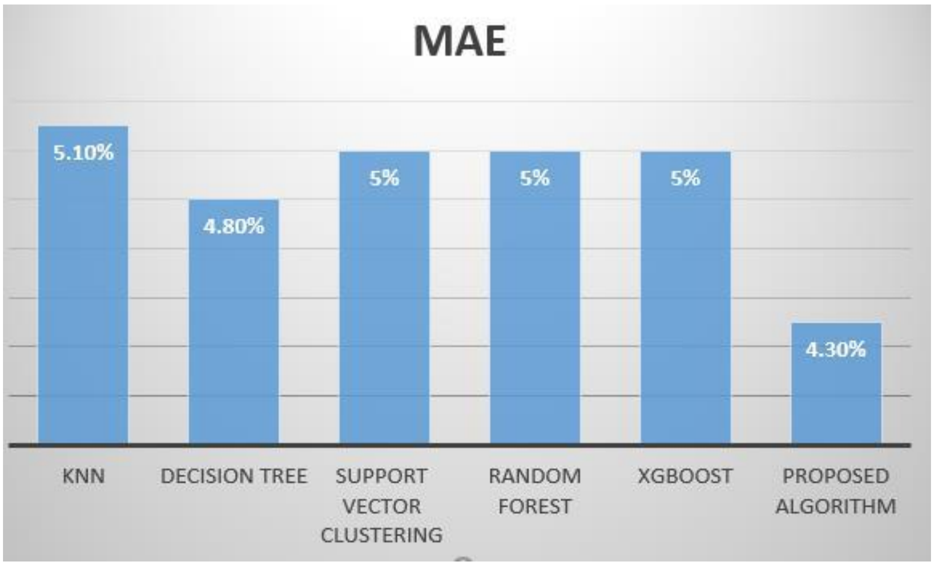
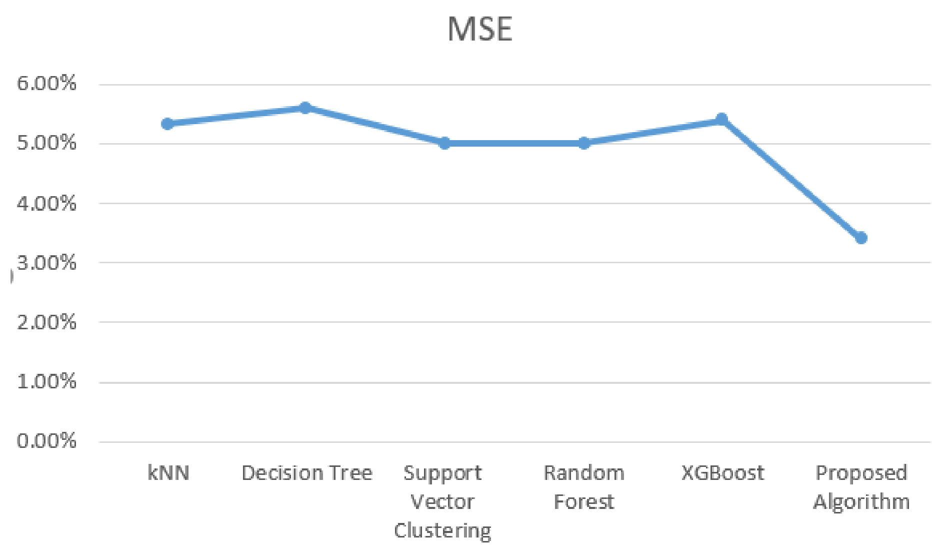


Figure 6-2MAE Calculated

The comparative analysis of the proposed and existing system's mean squared error(MSE) is represented in Figure 6-2. The proposed system was found to be reliable in terms of less MSE.



6.3 Summary

The chapter focused on the discussion of the results obtained from the overall system. The chapter discussed the comparative analysis of different existing algorithms with the created algorithm. Based on the comparison, it is found that the presented system is better in all aspects in the terms of accuracy and utilization.

Chapter 7
Conclusion and Future Work

This thesis identifies the usage of the Internet of Things, Fog computing, and Cloud computing in the field of healthcare. These technologies when used together, may result in a powerful lifesaver system that can reduce maternal health issues even in the absence of doctors. The continuous information on a patient's health can be monitored by biomedical sensors. Based on the monitored health parameters, the pregnant woman's health is categorized as normal or critical. The presented thesis offers a complete healthcare solution for the pregnant woman which monitors her health conditions and suggests real-time recommendations based upon the health classes. Furthermore, a novel ensembled algorithm is proposed for the system to work efficiently in a real-time environment.

7.1 Conclusion

An IoT-based pregnancy Healthcare system using fog computing is presented in this work. This system comprises three main tasks:

1) Identification of several health parameters of the pregnant women

2) Creation of algorithms for the sensors to work collaboratively for health issues detection

3) Provide the recommendations to the woman as per the found healthcare parameters.

The main focus of this work is to provide health recommendations to pregnant women for offering better health services at their doorstep. The novelty of this work is that as per the health parameters the pregnant women get suggestions in a real-time environment and directly get connected with the doctors remotely. The data is obtained by the real-time health monitoring of the women. No pre-trained data is used for calculations and capturing information. The system allows us to identify the type of recommendation needed to provide the pregnant woman. The health parameters are calculated and the categorization of the data is performed based on which the decision is taken that recommendation needs to be offered to the pregnant women. The data is stored in the database from where the notification is sent to the customized recommendation system. Moreover, the woman can store historical information about their health and get connected with doctors in a real-time environment.

7.2 Findings

- Chapter 3, presents the novel E-healthcare kit created during the research. The kit is responsible to monitor the health parameters of the pregnant woman in a real-time environment. The kit includes several components and a few biomedical sensors are attached to it, for monitoring critical health parameters during pregnancy. The main motive for the development of an E-healthcare kit is the monitoring of health parameters in the absence of doctors. In this study, a Bayesian network is used to classify the health parameters based on continuous monitoring. The Bayesian network was found accurate to classify health-related data. Furthermore, the fog node implements a novel ensemble-based technique to recognize the person wearing the sensor. The deep learning ensemble technique is used for authentication so that no person other than a pregnant woman can send data to the cloud server. It results in security implementation, saving time of processing and space to store monitored data at the cloud server.
- In chapter 4, an IoT and fog computing-based health monitoring system is presented. The system monitors the health parameters of the pregnant woman and based on this predicts the chances of a cesarean at the end of the pregnancy. For prediction, machine learning-based decision trees, and boosting techniques were used. The ensembling of these techniques offers wonderful results in real-time monitoring. The presented system was compared with other systems in the terms of domain, focused area, sensing technology, classification methodology, data extraction process, information mining, data storage, output presentation, security mechanism, and accuracy. The presented algorithm was found 98.12% accurate which proves the system is highly efficient. Furthermore, the presented system
- Chapter 5, describes the implementation of the recommendation system. The recommendation system is a web application, created using the Django framework including Python as a back-end technology with MySQL database connected to the cloud server. The application includes a patient, doctor, and

admin panel in which the roles of all panels are different. The patient panel shows the health monitoring parameters result and health classification of the patient. The doctor panel is used by doctors to get the profile history and present health conditions of the pregnant woman. The patient and doctors can get contacted each other in real-time from any location. The admin is responsible to offer services to the doctors and patients.

- Chapter 6, describes the testing and validation part of the presented system. The presented novel algorithm is compared in the terms of accuracy, MAE and MSE with existing techniques like, XGBOOST (MAE=5%, MSE=5.4%, accuracy=79.68%), Random Forest(MAE=5%, MSE=5%, accuracy=68.71%), Support Vector Clustering(MAE=5%, MSE=5%, accuracy=50%), Decision Tree(MAE=4.8%, MSE=5.6%, accuracy=71.36%), and KNN(MAE=5.1%, MSE=5.33%, accuracy=63.33%). Whereas, the proposed novel algorithm has (MAE=4.3%, MSE=3.4%, accuracy=98.12%)

7.3 Future Work

In this work, the health-related parameters of the pregnant woman are captured and real-time health suggestions are provided. Due to ever-increasing attention in the advancement of the healthcare domain, several health monitoring applications and products are available in the market for users. By considering the sensitive nature of healthcare, the future direction of the research is divided into two domains:

1. **Depression Prediction and precaution system:** The study can be extended to predict postpartum depression in women in the pregnancy phase. This kind of depression may be occurred due to many reasons like body weakness, first-time child care, health issues, etc. The depression issue may lead to the variation of several vitals in the woman's body which may cause harmful effects on the mother or infant who is taking breast feed.
2. **Security and privacy**: The study can be further extended to improve security concerns of data transmission over the network. Furthermore, the system can become more portable with the utilization of mobile-based applications through which the health conditions of women can be monitored easily and efficiently.

References

[1] M. Alotaibi, M. Albalawi, and L. Alwakeel, "A smart mobile pregnancy management and awareness system for Saudi Arabia," *Int. J. Interact. Mob. Technol.*, vol. 12, no. 5, pp. 112–125, 2018, doi: 10.3991/ijim.v12i5.9005.

[2] S. Shiny Amala and S. Mythili, "IoT Based Health Care Monitoring System for Rural Pregnant Women", Accessed: Sep. 19, 2021. [Online]. Available: http://www.acadpubl.eu/hub/

[3] M. Albalawi, M. Alotaibi, Z. Fabiola, and G. Romo, "A smart mobile pregnancy management and awareness system for Saudi Arabia A Smart Mobile Pregnancy Managem... Related papers St oryt elling and Social Net working as Tools for Digit al and Mobile Market ing of Luxury Fashion…", doi: 10.3991/ijim.v12i5.9005.

[4] L. E. May, A. Glaros, H. W. Yeh, J. F. Clapp, and K. M. Gustafson, "Aerobic exercise during pregnancy influences fetal cardiac autonomic control of heart rate and heart rate variability," *Early Hum. Dev.*, vol. 86, no. 4, pp. 213–217, Apr. 2010, doi: 10.1016/J.EARLHUMDEV.2010.03.002.

[5] E. KR, S. DA, and H. SL, "Leisure-time physical activity among pregnant women in the US," *Paediatr. Perinat. Epidemiol.*, vol. 18, no. 6, pp. 400–407, Nov. 2004, doi: 10.1111/J.1365-3016.2004.00595.X.

[6] H. JL, B. MP, L. JA, B. J, H. EB, and A. MA, "Dose and timing of text messages for increasing physical activity among pregnant women: a randomized controlled trial," *Transl. Behav. Med.*, vol. 7, no. 2, pp. 212–223, Jun. 2017, doi: 10.1007/S13142-016-0445-1.

[7] J. Huberty *et al.*, "Development and design of an intervention to improve physical activity in pregnant women using Text4baby," *Transl. Behav. Med.*, vol. 6, no. 2, pp. 285–294, Jun. 2016, doi: 10.1007/S13142-015-0339-7.

[8] F. Doran, K. Davis, F. Doran, and K. Davis, "Factors that influence physical activity for pregnant and postpartum women and implications for primary care," *Aust. J. Prim. Health*, vol. 17, no. 1, pp. 79–85, Apr. 2011, doi:

10.1071/PY10036.

[9] L. CF, do N. SL, H. FR, D. R. M. ML, D. R. MA, and C. RR, “An overview of maternal and fetal short and long-term impact of physical activity during pregnancy,” *Arch. Gynecol. Obstet.*, vol. 295, no. 2, pp. 273–283, Feb. 2017, doi: 10.1007/S00404-016-4204-9.

[10] K. Melzer *et al.*, “Effects of recommended levels of physical activity on pregnancy outcomes,” *Am. J. Obstet. Gynecol.*, vol. 202, no. 3, pp. 266.e1-266.e6, Mar. 2010, doi: 10.1016/J.AJOG.2009.10.876.

[11] K. Taylor, “Connected Health How digital technology is transforming health and social care,” *Deloitte Cent. Heal. Solut.*, 2015.

[12] Dave Evans, “The Internet of Things How the Next Evolution of the Internet Is Changing Everything,” *Cisco Internet Bus. Solut. Gr.*, 2011.

[13] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, “Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications,” *IEEE Commun. Surv. Tutorials*, vol. 17, no. 4, pp. 2347–2376, Oct. 2015, doi: 10.1109/COMST.2015.2444095.

[14] T. Firoz *et al.*, “Measuring maternal health: focus on maternal morbidity,” *Bull. World Health Organ.*, vol. 91, no. 10, pp. 794–796, Oct. 2013, doi: 10.2471/BLT.13.117564.

[15] “Women and health : today’s evidence tomorrow’s agenda.” https://apps.who.int/iris/handle/10665/44168 (accessed Aug. 08, 2022).

[16] X. Li, Y. Lu, X. Fu, and Y. Qi, “Building the Internet of Things platform for smart maternal healthcare services with wearable devices and cloud computing,” *Futur. Gener. Comput. Syst.*, vol. 118, pp. 282–296, May 2021, doi: 10.1016/J.FUTURE.2021.01.016.

[17] G. E. Iyawa, A. R. Dansharif, and A. Khan, “Mobile apps for self-management in pregnancy: a systematic review,” *Heal. Technol. 2021 112*, vol. 11, no. 2, pp. 283–294, Feb. 2021, doi: 10.1007/S12553-021-00523-Z.

[18] J. Runkle, M. Sugg, D. Boase, S. L. Galvin, and C. C. Coulson, "Use of wearable sensors for pregnancy health and environmental monitoring: Descriptive findings from the perspective of patients and providers," *Digit. Heal.*, vol. 5, Feb. 2019, doi: 10.1177/2055207619828220.

[19] T. M. Kadarina and R. Priambodo, "Preliminary design of Internet of Things (IoT) application for supporting mother and child health program in Indonesia," *2017 Int. Conf. Broadband Commun. Wirel. Sensors Powering, BCWSP 2017*, vol. 2018-January, pp. 1–6, Jan. 2018, doi: 10.1109/BCWSP.2017.8272576.

[20] P. P. Ray, "A survey on Internet of Things architectures," *J. King Saud Univ. - Comput. Inf. Sci.*, vol. 30, no. 3, pp. 291–319, Jul. 2018, doi: 10.1016/J.JKSUCI.2016.10.003.

[21] Z. Yang, Y. Yue, Y. Yang, Y. Peng, X. Wang, and W. Liu, "Study and application on the architecture and key technologies for IOT," *2011 Int. Conf. Multimed. Technol. ICMT 2011*, pp. 747–751, 2011, doi: 10.1109/ICMT.2011.6002149.

[22] V. Karagiannis, P. Chatzimisios, F. Vazquez-Gallego, and J. Alonso-Zarate, "A Survey on Application Layer Protocols for the Internet of Things," *Trans. IoT Cloud Comput.*, 2015.

[23] F. Bonomi, R. Milito, J. Zhu, and S. Addepalli, "Fog computing and its role in the internet of things," *MCC'12 - Proc. 1st ACM Mob. Cloud Comput. Work.*, pp. 13–15, 2012, doi: 10.1145/2342509.2342513.

[24] J. A. L. Marques *et al.*, "IoT-Based Smart Health System for Ambulatory Maternal and Fetal Monitoring," *IEEE Internet Things J.*, vol. 8, no. 23, pp. 16814–16824, Dec. 2021, doi: 10.1109/JIOT.2020.3037759.

[25] S. Venkatasubramanian, "Ambulatory Monitoring of Maternal and Fetal using Deep Convolution Generative Adversarial Network for Smart Health Care IoT System," *Int. J. Adv. Comput. Sci. Appl.*, vol. 13, no. 1, pp. 214–222, 2022, doi: 10.14569/IJACSA.2022.0130126.

[26] Z. N. Aghdam, A. M. Rahmani, and M. Hosseinzadeh, "The Role of the Internet

of Things in Healthcare: Future Trends and Challenges,” *Comput. Methods Programs Biomed.*, vol. 199, p. 105903, Feb. 2021, doi: 10.1016/J.CMPB.2020.105903.

[27] UNFPA, UNICEF, W. H. Organization, W. B. Group, and the U. N. P. Division, “Trends in Maternal Mortality: 2000 to 2017 | UNFPA - United Nations Population Fund,” *WHO, UNICEF, UNFPA,World Bank Gr. theUnited Nations Popul. Div.*, p. 104, 2019, Accessed: Aug. 08, 2022. [Online]. Available: https://www.unfpa.org/featured-publication/trends-maternal-mortality-2000-2017

[28] D. Giusto, A. Iera, G. Morabito, and L. Atzori, “The Internet of Things 20th Tyrrhenian Workshop on Digital Communications,” 2010.

[29] N. Intelligence Council, “Six Technologies With Potential Impacts on US Interests Out to 2025,” 2008.

[30] A. Bassi and G. Horn, “Internet of Things in 2020: Roadmap for the future,” 2008.

[31] “MIT AUTO-ID LABORATORY | MIT AUTO-ID LABORATORY.” https://autoid.mit.edu/ (accessed Sep. 11, 2021).

[32] F. Armenio Johnson and J. FArmeni, “The EPCglobal Architecture Framework EPCglobal Final Version 1,” 2007, Accessed: Sep. 11, 2021. [Online]. Available: www.epcglobalinc.org

[33] K. Sakamura, “Challenges in the age of ubiquitous computing,” pp. 713–720, May 2006, doi: 10.1145/1134285.1134399.

[34] A. Gluhak and M. Presser, “The Internet of Things: Connecting the Real World... - Google Scholar,” *EURESCOM Messag.*, 2009.

[35] M. Botterman, “for the European Commission Information... - Google Scholar,” *Networked Enterp. RFID Unit–D4, Internet Things An Early Real. Futur. Internet, Rep. Internet Things Work. Prague, Czech Repub.*, 2009.

[36] N. Gershenfeld, R. Krikorian, and D. Cohen, “The internet of things,” *Sci. Am.*,

vol. 291, no. 4, pp. 76–81, 2004, doi: 10.1038/SCIENTIFICAMERICAN1004-76.

[37] Ioan Toma, Elena Simperl, and Graham Hench, “A joint roadmap for semantic technologies and the Internet of Things,” 2009.

[38] A. Katasonov, O. Kaykova, O. Khriyenko, S. Nikitin, and V. Terziyan, “SMART SEMANTIC MIDDLEWARE FOR THE INTERNET OF THINGS”.

[39] W. Wahlster, “Web 3.0: Semantic Technologies for the Internet... - Google Scholar,” *Lecture at the 2008 Dresden Future Forum*. 2008.

[40] I. Vázquez, “Social Devices: Semantic Technology for the Internet... - Google Scholar,” 2009.

[41] Dominique Guinard and Vlad Trifa, “Towards the Web of Things: Web Mashups for Embedded Devices,” in *Integration The Vlsi Journal*, 2009.

[42] L. Srivastava, “European Commission Conference ‘From RFID to the Internet of Things’”.

[43] K. Finkenzeller, “RFID Hanbook,” *J. Chem. Inf. Model.*, vol. 53, no. 9, p. 480, 2010.

[44] A. Juels, “RFID security and privacy: A research survey,” *IEEE J. Sel. Areas Commun.*, vol. 24, no. 2, pp. 381–394, Feb. 2006, doi: 10.1109/JSAC.2005.861395.

[45] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, “Wireless sensor networks: a survey,” *Comput. Networks*, vol. 38, no. 4, pp. 393–422, Mar. 2002, doi: 10.1016/S1389-1286(01)00302-4.

[46] “IEEE 802.15 Working Group for Wireless Personal Area Networks (WPANs).” https://www.ieee802.org/15/ (accessed Sep. 12, 2021).

[47] G. Marrocco, C. Occhiuzzi, and F. Amato, “Sensor-Oriented Passive RFID,” *The Internet of Things*, pp. 273–282, 2010, doi: 10.1007/978-1-4419-1674-7_26.

[48] J. Pasley, “How BPEL and SOA Are Changing Web Services Development,”

IEEE Internet Comput., vol. 9, no. 03, pp. 60–67, May 2005, doi: 10.1109/MIC.2005.56.

[49] "一种基于手环的女性孕期特征监测系统及方法," Oct. 2014.

[50] F. Terroso-Saenz, A. González-Vidal, A. P. Ramallo-González, and A. F. Skarmeta, "An open IoT platform for the management and analysis of energy data," *Futur. Gener. Comput. Syst.*, vol. 92, pp. 1066–1079, Mar. 2019, doi: 10.1016/J.FUTURE.2017.08.046.

[51] T. hoon Kim, C. Ramos, and S. Mohammed, "Smart City and IoT," *Futur. Gener. Comput. Syst.*, vol. 76, pp. 159–162, Nov. 2017, doi: 10.1016/J.FUTURE.2017.03.034.

[52] L. Miao and K. Liu, " Towards a Heterogeneous Internet-of-Things Testbed via Mesh inside a Mesh ," *Proc. 14th ACM Conf. Embed. Netw. Sens. Syst. CD-ROM*, doi: 10.1145/2994551.

[53] T. R. Bennett *et al.*, "MotionSynthesis Toolset (MoST): A toolset for human motion data synthesis and validation," *Proc. Int. Symp. Mob. Ad Hoc Netw. Comput.*, vol. 2014-August, no. August, pp. 25–30, Aug. 2014, doi: 10.1145/2633651.2637472.

[54] S. Redhu, M. Maheshwari, K. Yeotikar, and R. M. Hegde, "Joint data latency and packet loss optimization for relay-node selection in time-varying IoT networks," *Proc. Annu. Int. Conf. Mob. Comput. Networking, MOBICOM*, pp. 711–713, Oct. 2018, doi: 10.1145/3241539.3267758.

[55] H. Shafagh, L. Burkhalter, and A. Hithnawi, "Talos a platform for processing encrypted IoT Data," *Proc. 14th ACM Conf. Embed. Networked Sens. Syst. SenSys 2016*, pp. 308–309, Nov. 2016, doi: 10.1145/2994551.2996536.

[56] M. Ghobaei-Arani and A. Souri, "LP-WSC: a linear programming approach for web service composition in geographically distributed cloud environments," *J. Supercomput. 2018 755*, vol. 75, no. 5, pp. 2603–2628, Oct. 2018, doi: 10.1007/S11227-018-2656-3.

[57] M. Ghobaei-Arani, A. . Rahmanian, A. Souri, and A. M. Rahmani, “A moth-flame optimization algorithm for web service composition in cloud computing: Simulation and verification,” *Softw. Pract. Exp.*, vol. 48, no. 10, pp. 1865–1892, Oct. 2018, doi: 10.1002/SPE.2598.

[58] O. Bello and S. Zeadally, “Toward efficient smartification of the Internet of Things (IoT) services,” *Futur. Gener. Comput. Syst.*, vol. 92, pp. 663–673, Mar. 2019, doi: 10.1016/J.FUTURE.2017.09.083.

[59] G. Fortino, W. Russo, C. Savaglio, M. Viroli, and M. Zhou, “Modeling Opportunistic IoT Services in Open IoT Ecosystems”, Accessed: Sep. 14, 2021. [Online]. Available: http://www.w3.org/2005/Incubator/ssn

[60] S. Li, L. Da Xu, and S. Zhao, “The internet of things: a survey,” *Inf. Syst. Front. 2014 172*, vol. 17, no. 2, pp. 243–259, Apr. 2014, doi: 10.1007/S10796-014-9492-7.

[61] A. Souri, P. Asghari, and R. Rezaei, “Software as a service based CRM providers in the cloud computing: Challenges and technical issues,” *J. Serv. Sci. Res. 2017 92*, vol. 9, no. 2, pp. 219–237, Dec. 2017, doi: 10.1007/S12927-017-0011-5.

[62] A. Souri, A. M. Rahmani, and N. J. Navimipour, “Formal verification approaches in the web service composition: A comprehensive analysis of the current challenges for future research,” *Int. J. Commun. Syst.*, vol. 31, no. 17, p. e3808, Nov. 2018, doi: 10.1002/DAC.3808.

[63] J. Moon, I. Y. Jung, and J. H. Park, “IoT application protection against power analysis attack,” *Comput. Electr. Eng.*, vol. 67, pp. 566–578, Apr. 2018, doi: 10.1016/J.COMPELECENG.2018.02.030.

[64] H. Li, H. Wang, W. Yin, Y. Li, Y. Qian, and F. Hu, “Development of a Remote Monitoring System for Henhouse Environment Based on IoT Technology,” *Futur. Internet 2015, Vol. 7, Pages 329-341*, vol. 7, no. 3, pp. 329–341, Sep. 2015, doi: 10.3390/FI7030329.

[65] N. S. Kim, K. Lee, and J. H. Ryu, “Study on IoT based wild vegetation community ecological monitoring system,” *Int. Conf. Ubiquitous Futur.*

Networks, ICUFN, vol. 2015-August, pp. 311–316, Aug. 2015, doi: 10.1109/ICUFN.2015.7182556.

[66] R. Nordin *et al.*, “The world-first deployment of narrowband IoT for rural hydrological monitoring in UNESCO biosphere environment,” *2017 IEEE Int. Conf. Smart Instrumentation, Meas. Appl. ICSIMA 2017*, vol. 2017-November, pp. 1–5, Mar. 2018, doi: 10.1109/ICSIMA.2017.8311981.

[67] M.-C. Yuen *et al.*, “A low-cost IoT smart home system,” *Int. J. Eng. Technol.*, vol. 7, no. 4, pp. 3143–3147, Sep. 2018, doi: 10.14419/ijet.v7i4.21554.

[68] D. W. Sukmaningsih, W. Suparta, A. Trisetyarso, B. S. Abbas, and C. H. Kang, “Proposing Smart Disaster Management in Urban Area,” *Stud. Comput. Intell.*, vol. 830, pp. 3–16, Apr. 2019, doi: 10.1007/978-3-030-14132-5_1.

[69] F. Ahamad, M. T. Latif, M. F. Yusoff, M. F. Khan, and L. Juneng, “So near yet so different: Surface ozone at three sites in Malaysia,” *IOP Conf. Ser. Earth Environ. Sci.*, vol. 228, no. 1, p. 012024, Jan. 2019, doi: 10.1088/1755-1315/228/1/012024.

[70] W. Suparta, K. M. Alhasa, and M. S. J. Singh, “Preliminary development of greenhouse gases system data logger using microcontroller Netduino,” *Adv. Sci. Lett.*, vol. 23, no. 2, pp. 1398–1402, Feb. 2017, doi: 10.1166/ASL.2017.8385.

[71] M. Alodib, “QoS-Aware approach to monitor violations of SLAs in the IoT,” *J. Innov. Digit. Ecosyst.*, vol. 3, no. 2, pp. 197–207, Dec. 2016, doi: 10.1016/J.JIDES.2016.10.010.

[72] S. N. Han and N. Crespi, “Semantic service provisioning for smart objects: Integrating IoT applications into the web,” *Futur. Gener. Comput. Syst.*, vol. 76, pp. 180–197, Nov. 2017, doi: 10.1016/J.FUTURE.2016.12.037.

[73] Y. Huo, P. Qiu, J. Zhai, D. Fan, and H. Peng, “Multi-objective service composition model based on cost-effective optimization,” *Appl. Intell. 2017 483*, vol. 48, no. 3, pp. 651–669, Jul. 2017, doi: 10.1007/S10489-017-0996-Y.

[74] L. Huo and Z. Wang, “Service composition instantiation based on cross-

modified artificial Bee Colony algorithm," *China Commun.*, vol. 13, no. 10, pp. 233–244, Oct. 2016, doi: 10.1109/CC.2016.7733047.

[75] N. Temglit, A. Chibani, K. Djouani, and M. A. Nacer, "A Distributed Agent-Based Approach for Optimal QoS Selection in Web of Object Choreography," *IEEE Syst. J.*, vol. 12, no. 2, pp. 1655–1666, Jun. 2018, doi: 10.1109/JSYST.2016.2647281.

[76] S. Cuomo, V. Di Somma, and F. Sica, "An application of the one-factor HullWhite model in an IoT financial scenario," *Sustain. Cities Soc.*, vol. 38, pp. 18–20, Apr. 2018, doi: 10.1016/J.SCS.2017.12.005.

[77] J. C. Hull and A. D. White, "Numerical Procedures for Implementing Term Structure Models I," *J. Deriv.*, vol. 2, no. 1, pp. 7–16, Aug. 1994, doi: 10.3905/JOD.1994.407902.

[78] J. H. Park, "Advances in Future Internet and the Industrial Internet of Things," *Symmetry 2019, Vol. 11, Page 244*, vol. 11, no. 2, p. 244, Feb. 2019, doi: 10.3390/SYM11020244.

[79] L. Li, S. Li, and S. Zhao, "QoS-Aware scheduling of services-oriented internet of things," *IEEE Trans. Ind. Informatics*, vol. 10, no. 2, pp. 1497–1507, 2014, doi: 10.1109/TII.2014.2306782.

[80] S. Venticinque and A. Amato, "A methodology for deployment of IoT application in fog," *J. Ambient Intell. Humaniz. Comput. 2018 105*, vol. 10, no. 5, pp. 1955–1976, Apr. 2018, doi: 10.1007/S12652-018-0785-4.

[81] Y. Jin, U. Raza, A. Aijaz, M. Sooriyabandara, and S. Gormus, "Content Centric Cross-Layer Scheduling for Industrial IoT Applications Using 6TiSCH," *IEEE Access*, vol. 6, pp. 234–244, 2018, doi: 10.1109/ACCESS.2017.2762079.

[82] M. P. R. S. Kiran and P. Rajalakshmi, "Performance Analysis of CSMA/CA and PCA for Time Critical Industrial IoT Applications," *IEEE Trans. Ind. Informatics*, vol. 14, no. 5, pp. 2281–2293, May 2018, doi: 10.1109/TII.2018.2802497.

[83] S. Ahmad, N. Alam, and M. Hasan, “Robust TFET SRAM cell for ultra-low power IoT applications,” *AEU - Int. J. Electron. Commun.*, vol. 89, pp. 70–76, May 2018, doi: 10.1016/J.AEUE.2018.03.029.

[84] D. Kwon, M. R. Hodkiewicz, J. Fan, T. Shibutani, and M. G. Pecht, “IoT-Based Prognostics and Systems Health Management for Industrial Applications,” *IEEE Access*, vol. 4, pp. 3659–3670, 2016, doi: 10.1109/ACCESS.2016.2587754.

[85] M. Luvisotto, F. Tramarin, L. Vangelista, and S. Vitturi, “On the Use of LoRaWAN for Indoor Industrial IoT Applications,” *Wirel. Commun. Mob. Comput.*, vol. 2018, 2018, doi: 10.1155/2018/3982646.

[86] R. Sharma, R. P. Mahapatra, and P. Agarwal, “Transforming Healthcare Through Various Technique in Internet of Things,” *Intell. Syst. Ref. Libr.*, vol. 165, pp. 171–190, 2020, doi: 10.1007/978-3-030-23983-1_7.

[87] S. Kim and S. Kim, “User preference for an IoT healthcare application for lifestyle disease management,” *Telecomm. Policy*, vol. 42, no. 4, pp. 304–314, May 2018, doi: 10.1016/J.TELPOL.2017.03.006.

[88] W. M. Jubadi, S. Faridatul, and A. M. Sahak, “Heartbeat Monitoring Alert via SMS”.

[89] M. Manisha, Katakam Neeraja, Vemuri Sindhura, and P. Ramaya, “IoT on Heart Attack Detection and Heart Rate Monitoring,” *Int. J. Innov. Eng. Technol.*, 2016, Accessed: Sep. 19, 2021. [Online]. Available: https://scholar.google.co.in/scholar?hl=en&as_sdt=0%2C5&q=IoT+on+Heart+Attack+Detection+and+Heart+Rate+Monitoring&btnG=

[90] X. Fafoutis, E. Tsimbalo, E. Mellios, G. Hilton, R. Piechocki, and I. Craddock, “A residential maintenance-free long-term activity monitoring system for healthcare applications,” *EURASIP J. Wirel. Commun. Netw. 2016 20161*, vol. 2016, no. 1, pp. 1–20, Jan. 2016, doi: 10.1186/S13638-016-0534-3.

[91] D. Hasan and A. G. Ismaeel, “Designing ECG Monitoring Healthcare System Based on Internet of Things Blynk Application,” *J. Appl. Sci. Technol. Trends*, vol. 1, no. 3, pp. 106–111, Jul. 2020, doi: 10.38094/jastt1336.

[92] F. Jimenez and R. Torres, “Building an IoT-aware healthcare monitoring system,” *Proc. - Int. Conf. Chil. Comput. Sci. Soc. SCCC*, vol. 2016-February, Feb. 2016, doi: 10.1109/SCCC.2015.7416592.

[93] Y. Ding, S. Gang, and J. Hong, “The design of home monitoring system by remote mobile medical,” *Proc. - 2015 7th Int. Conf. Inf. Technol. Med. Educ. ITME 2015*, pp. 278–281, Mar. 2016, doi: 10.1109/ITME.2015.168.

[94] Reijo M. Savola, Habtamu Abie, and Markus Sihvonen, “Towards metrics-driven adaptive security management in e-health IoT applications ,” 2012. Accessed: Sep. 19, 2021. [Online]. Available: https://dl.acm.org/doi/10.5555/2442691.2442753

[95] Z. Baloch, F. K. Shaikh, and M. A. Unar, “A context-aware data fusion approach for health-IoT,” *Int. J. Inf. Technol. 2018 103*, vol. 10, no. 3, pp. 241–245, Feb. 2018, doi: 10.1007/S41870-018-0116-1.

[96] H. A. Damis, N. Khalid, R. Mirzavand, H. J. Chung, and P. Mousavi, “Investigation of Epidermal Loop Antennas for Biotelemetry IoT Applications,” *IEEE Access*, vol. 6, pp. 15806–15815, Mar. 2018, doi: 10.1109/ACCESS.2018.2814005.

[97] M. Elappila, S. Chinara, and D. R. Parhi, “Survivable Path Routing in WSN for IoT applications,” *Pervasive Mob. Comput.*, vol. 43, pp. 49–63, Jan. 2018, doi: 10.1016/J.PMCJ.2017.11.004.

[98] J. Jebadurai and J. Dinesh Peter, “Super-resolution of retinal images using multi-kernel SVR for IoT healthcare applications,” *Futur. Gener. Comput. Syst.*, vol. 83, pp. 338–346, Jun. 2018, doi: 10.1016/J.FUTURE.2018.01.058.

[99] S. Selvaraj and S. Sundaravaradhan, “Challenges and opportunities in IoT healthcare systems: a systematic review,” *SN Appl. Sci. 2019 21*, vol. 2, no. 1, pp. 1–8, Dec. 2019, doi: 10.1007/S42452-019-1925-Y.

[100] H. Malik, M. M. Alam, Y. Le Moullec, and A. Kuusik, “NarrowBand-IoT Performance Analysis for Healthcare Applications,” *Procedia Comput. Sci.*, vol. 130, pp. 1077–1083, Jan. 2018, doi: 10.1016/J.PROCS.2018.04.156.

[101] J. P. A. Yaacoub *et al.*, “Securing internet of medical things systems: Limitations, issues and recommendations,” *Futur. Gener. Comput. Syst.*, vol. 105, pp. 581–606, Apr. 2020, doi: 10.1016/J.FUTURE.2019.12.028.

[102] P. Misra, Y. Simmhan, and J. Warrior, “Towards a Practical Architecture for the Next Generation Internet of Things,” Feb. 2015, Accessed: Sep. 19, 2021. [Online]. Available: https://arxiv.org/abs/1502.00797v2

[103] A. Labrinidis and H. V. Jagadish, “Challenges and opportunities with big data,” *Proc. VLDB Endow.*, vol. 5, no. 12, pp. 2032–2033, 2012, doi: 10.14778/2367502.2367572.

[104] R. Kitchin, “The real-time city? Big data and smart urbanism,” *Geoj. 2013 791*, vol. 79, no. 1, pp. 1–14, Nov. 2013, doi: 10.1007/S10708-013-9516-8.

[105] A.-M. Vilamovska, E. Hatziandreu, H. R. Schindler, C. van Oranje-Nassau, H. de Vries, and J. Krapels, “Study on the requirements and options for RFID application in healthcare: Identifying areas for Radio Frequency Identification deployment in health care delivery: A review of relevant literature,” 2009, Accessed: Sep. 19, 2021. [Online]. Available: https://www.rand.org/pubs/technical_reports/TR608.html

[106] H. Alemdar and C. Ersoy, “Wireless sensor networks for healthcare: A survey,” *Comput. Networks*, vol. 54, no. 15, pp. 2688–2710, Oct. 2010, doi: 10.1016/J.COMNET.2010.05.003.

[107] M. Zhang, X. Du, and K. Nygard, “Improving coverage performance in sensor networks by using mobile sensors,” *Proc. - IEEE Mil. Commun. Conf. MILCOM*, vol. 2005, 2005, doi: 10.1109/MILCOM.2005.1606170.

[108] Bahareh J. Farahani, Hossein Ghaffarian, and Mahmood Fathy, “A Fuzzy Based Priority Approach in Mobile Sensor Network Coverage,” *Int. J. Recent Trends Eng.*, vol. 2, no. 1, 2009, Accessed: Sep. 19, 2021. [Online]. Available: https://www.researchgate.net/publication/228802976_A_Fuzzy_Based_Priority_Approach_in_Mobile_Sensor_Network_Coverage

[109] R. Soleimanzadeh, B. J. Farahani, and M. Fathy, “PSO based Deployment

Algorithms in Hybrid Sensor Networks," *IJCSNS Int. J. Comput. Sci. Netw. Secur.*, vol. 10, no. 7, p. 167, 2010.

[110] R. Soleimanzadeh, B. J. Farahani, and M. Fathy, "Improved Dynamic K-Coverage Algorithms in Mobile Sensor Networks," *Wirel. Sens. Netw.*, vol. 02, no. 10, pp. 784–792, 2010, doi: 10.4236/WSN.2010.210094.

[111] M. Saravi and B. J. Farahani, "Distance Constrained Deployment (DCD) algorithm in mobile sensor networks," *NGMAST 2009 - 3rd Int. Conf. Next Gener. Mob. Appl. Serv. Technol.*, pp. 435–440, 2009, doi: 10.1109/NGMAST.2009.59.

[112] L. Da Xu, W. He, and S. Li, "Internet of things in industries: A survey," *IEEE Trans. Ind. Informatics*, vol. 10, no. 4, pp. 2233–2243, Nov. 2014, doi: 10.1109/TII.2014.2300753.

[113] E. Welbourne *et al.*, "Building the internet of things using RFID: The RFID ecosystem experience," *IEEE Internet Comput.*, vol. 13, no. 3, pp. 48–55, 2009, doi: 10.1109/MIC.2009.52.

[114] D. Miorandi, S. Sicari, F. De Pellegrini, and I. Chlamtac, "Internet of things: Vision, applications and research challenges," *Ad Hoc Networks*, vol. 10, no. 7, pp. 1497–1516, Sep. 2012, doi: 10.1016/J.ADHOC.2012.02.016.

[115] D. Bandyopadhyay and J. Sen, "Internet of Things: Applications and Challenges in Technology and Standardization," *Wirel. Pers. Commun. 2011 581*, vol. 58, no. 1, pp. 49–69, Apr. 2011, doi: 10.1007/S11277-011-0288-5.

[116] H. Sundmaeker, P. Guillemin, P. Friess, and S. Woelfflé, "Vision and Challenges for Realising the Internet of Things The meaning of things lies not in the things themselves, but in our attitude towards them. Antoine de Saint-Exupéry," 2010, Accessed: Sep. 19, 2021. [Online]. Available: http://europa.eu/information_society

[117] S. Haller, S. Karnouskos, and C. Schroth, "The Internet of Things in an Enterprise Context," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 5468, pp. 14–28, 2008, doi:

10.1007/978-3-642-00985-3_2.

[118] Z. Zheng, J. Zhu, and M. R. Lyu, “Service-generated big data and big data-as-a-service: An overview,” *Proc. - 2013 IEEE Int. Congr. Big Data, BigData 2013*, pp. 403–410, 2013, doi: 10.1109/BIGDATA.CONGRESS.2013.60.

[119] K. J. Keim Daniel and G. rey E. and F. Mansmann, “Mastering the Information Age Solving Problems with Visual Analytics,” *Mastering Inf. Age Solving Probl. with Vis. Anal.*, pp. 57–86, 2010, Accessed: Sep. 19, 2021. [Online]. Available: http://diglib.eg.org

[120] A. V. Dastjerdi, H. Gupta, R. N. Calheiros, S. K. Ghosh, and R. Buyya, “Fog Computing: principles, architectures, and applications,” *Internet Things Princ. Paradig.*, pp. 61–75, Jan. 2016, doi: 10.1016/B978-0-12-805395-9.00004-6.

[121] S. Delfin, N. P. Sivasanker, A. Anand, and N. Raj, “Fog computing: A new era of cloud computing,” *Proc. 3rd Int. Conf. Comput. Methodol. Commun. ICCMC 2019*, pp. 1106–1111, Mar. 2019, doi: 10.1109/ICCMC.2019.8819633.

[122] S. Sarkar and S. Misra, “Theoretical modelling of fog computing: A green computing paradigm to support IoT applications,” *IET Networks*, vol. 5, no. 2, pp. 23–29, Mar. 2016, doi: 10.1049/IET-NET.2015.0034.

[123] B. Negash, A. M. Rahmani, P. Liljeberg, and A. Jantsch, “Fog Computing Fundamentals in the Internet-of-Things,” *Fog Comput. Internet Things Intell. Edge*, pp. 3–13, May 2018, doi: 10.1007/978-3-319-57639-8_1.

[124] F. Bonomi, R. Milito, J. Zhu, and S. Addepalli, “Fog computing and its role in the internet of things,” 2012. doi: 10.1145/2342509.2342513.

[125] S. Sarkar, S. Chatterjee, and S. Misra, “Assessment of the Suitability of Fog Computing in the Context of Internet of Things,” *IEEE Trans. Cloud Comput.*, vol. 6, no. 1, pp. 46–59, Jan. 2018, doi: 10.1109/TCC.2015.2485206.

[126] C. Mouradian, D. Naboulsi, S. Yangui, R. H. Glitho, M. J. Morrow, and P. A. Polakos, “A Comprehensive Survey on Fog Computing: State-of-the-Art and Research Challenges,” *IEEE Commun. Surv. Tutorials*, vol. 20, no. 1, pp. 416–

464, Jan. 2018, doi: 10.1109/COMST.2017.2771153.

[127] "Fog Computing and the Internet of Things: Extend the Cloud to Where the Things Are What You Will Learn," 2015.

[128] S. Agarwal, S. Yadav, and A. K. Yadav, "An Efficient Architecture and Algorithm for Resource Provisioning in Fog Computing," *Int. J. Inf. Eng. Electron. Bus.*, vol. 8, no. 1, pp. 48–61, Jan. 2016, doi: 10.5815/IJIEEB.2016.01.06.

[129] S. Agarwal, S. Yadav, and A. Kumar Yadav, "Information Engineering and Electronic Business," *Inf. Eng. Electron. Bus.*, vol. 1, pp. 48–61, 2016, doi: 10.5815/ijieeb.2016.01.06.

[130] M. Hajibaba and S. Gorgin, "A Review on Modern Distributed Computing Paradigms: Cloud Computing, Jungle Computing and Fog Computing," *CIT. J. Comput. Inf. Technol.*, vol. 22, no. 2, pp. 69–84, Aug. 2014, doi: 10.2498/CIT.1002381.

[131] H. F. Atlam, M. O. Alassafi, A. Alenezi, R. J. Walters, and G. B. Wills, "XACML for building access control policies in internet of things," *IoTBDS 2018 - Proc. 3rd Int. Conf. Internet Things, Big Data Secur.*, vol. 2018-March, pp. 253–260, 2018, doi: 10.5220/0006725102530260.

[132] M. Ketel, "Fog-cloud services for IoT," *Proc. SouthEast Conf. ACMSE 2017*, pp. 262–264, Apr. 2017, doi: 10.1145/3077286.3077314.

[133] Z. Hao, E. Novak, S. Yi, and Q. Li, "Challenges and Software Architecture for Fog Computing," *IEEE Internet Comput.*, vol. 21, no. 2, pp. 44–53, Mar. 2017, doi: 10.1109/MIC.2017.26.

[134] O. Skarlat, S. Schulte, M. Borkowski, and P. Leitner, "Resource provisioning for IoT services in the fog," *Proc. - 2016 IEEE 9th Int. Conf. Serv. Comput. Appl. SOCA 2016*, pp. 32–39, Dec. 2016, doi: 10.1109/SOCA.2016.10.

[135] M. Chiang and T. Zhang, "Fog and IoT: An Overview of Research Opportunities," *IEEE Internet Things J.*, vol. 3, no. 6, pp. 854–864, Dec. 2016,

doi: 10.1109/JIOT.2016.2584538.

[136] K. P.Saharan and A. Kumar, “Fog in Comparison to Cloud: A Survey,” *Int. J. Comput. Appl.*, vol. 122, no. 3, pp. 10–12, Jul. 2015, doi: 10.5120/21679-4773.

[137] Y. Shi, G. Ding, H. Wang, H. Eduardo Roman, and S. Lu, “The fog computing service for healthcare,” *2015 2nd Int. Symp. Futur. Inf. Commun. Technol. Ubiquitous Heal. Ubi-HealthTech 2015*, pp. 70–74, Aug. 2015, doi: 10.1109/UBI-HEALTHTECH.2015.7203325.

[138] S. Yi, C. Li, and Q. Li, “A survey of fog computing: Concepts, applications and issues,” *Proc. Int. Symp. Mob. Ad Hoc Netw. Comput.*, vol. 2015-June, pp. 37–42, Jun. 2015, doi: 10.1145/2757384.2757397.

[139] Nisha Peter, “FOG Computing and Its Real Time Applications,” *Int. J. Emerg. Technol. Adv. Eng.*, vol. 5, no. 6, 2015, Accessed: Sep. 21, 2021. [Online]. Available: https://www.academia.edu/22876965/FOG_Computing_and_Its_Real_Time_Applications

[140] C. Puliafito, E. Mingozzi, and G. Anastasi, “Fog Computing for the Internet of Mobile Things: Issues and Challenges,” *2017 IEEE Int. Conf. Smart Comput. SMARTCOMP 2017*, Jun. 2017, doi: 10.1109/SMARTCOMP.2017.7947010.

[141] A. V. Dastjerdi, H. Gupta, R. N. Calheiros, S. K. Ghosh, and R. Buyya, “Fog Computing: Principles, Architectures, and Applications,” *Internet Things Princ. Paradig.*, pp. 61–75, Jan. 2016, Accessed: Sep. 21, 2021. [Online]. Available: https://arxiv.org/abs/1601.02752v2

[142] M. Suárez-Albela, T. M. Fernández-Caramés, P. Fraga-Lamas, and L. Castedo, “A Practical Evaluation of a High-Security Energy-Efficient Gateway for IoT Fog Computing Applications,” *Sensors 2017, Vol. 17, Page 1978*, vol. 17, no. 9, p. 1978, Aug. 2017, doi: 10.3390/S17091978.

[143] F. Bonomi, R. Milito, P. Natarajan, and J. Zhu, “Fog Computing: A Platform for Internet of Things and Analytics,” 2014, doi: 10.1007/978-3-319-05029-4_7.

[144] M. Aazam and E. N. Huh, “Fog computing micro datacenter based dynamic resource estimation and pricing model for IoT,” *Proc. - Int. Conf. Adv. Inf. Netw. Appl. AINA*, vol. 2015-April, pp. 687–694, Apr. 2015, doi: 10.1109/AINA.2015.254.

[145] S. S. Gill, P. Garraghan, and R. Buyya, “ROUTER: Fog enabled cloud based intelligent resource management approach for smart home IoT devices,” *J. Syst. Softw.*, vol. 154, pp. 125–138, Aug. 2019, doi: 10.1016/J.JSS.2019.04.058.

[146] M. Aazam, M. St-Hilaire, C. H. Lung, I. Lambadaris, and E. N. Huh, “IoT resource estimation challenges and modeling in fog,” *Fog Comput. Internet Things Intell. Edge*, pp. 17–31, May 2017, doi: 10.1007/978-3-319-57639-8_2.

[147] A. Alrawais, A. Alhothaily, C. Hu, and X. Cheng, “Fog Computing for the Internet of Things: Security and Privacy Issues,” *IEEE Internet Comput.*, vol. 21, no. 2, pp. 34–42, Mar. 2017, doi: 10.1109/MIC.2017.37.

[148] K. Lee, D. Kim, D. Ha, U. Rajput, and H. Oh, “On security and privacy issues of fog computing supported Internet of Things environment,” *2015 Int. Conf. Netw. Futur. NOF 2015*, Nov. 2015, doi: 10.1109/NOF.2015.7333287.

[149] S. Khan, S. Parkinson, and Y. Qin, “Fog computing security: a review of current applications and security solutions,” *J. Cloud Comput. 2017 61*, vol. 6, no. 1, pp. 1–22, Aug. 2017, doi: 10.1186/S13677-017-0090-3.

[150] I. Stojmenovic and S. Wen, “The Fog computing paradigm: Scenarios and security issues,” *2014 Fed. Conf. Comput. Sci. Inf. Syst. FedCSIS 2014*, pp. 1–8, Oct. 2014, doi: 10.15439/2014F503.

[151] R. Mahmud, R. Kotagiri, and R. Buyya, “Fog Computing: A Taxonomy, Survey and Future Directions,” *Internet of Things*, vol. 0, no. 9789811058608, pp. 103–130, 2018, doi: 10.1007/978-981-10-5861-5_5.

[152] Y. Nikoloudakis, E. Markakis, G. Mastorakis, E. Pallis, and C. Skianis, “An NFV-powered emergency system for smart enhanced living environments,” *2017 IEEE Conf. Netw. Funct. Virtualization Softw. Defin. Networks, NFV-SDN 2017*, vol. 2017-January, pp. 258–263, Dec. 2017, doi: 10.1109/NFV-

SDN.2017.8169872.

[153] A. V. Dastjerdi and R. Buyya, "Fog Computing: Helping the Internet of Things Realize Its Potential," *Computer (Long. Beach. Calif).*, vol. 49, no. 8, pp. 112–116, Aug. 2016, doi: 10.1109/MC.2016.245.

[154] R. Craciunescu, A. Mihovska, M. Mihaylov, S. Kyriazakos, R. Prasad, and S. Halunga, "Implementation of Fog computing for reliable E-health applications," *Conf. Rec. - Asilomar Conf. Signals, Syst. Comput.*, vol. 2016-February, pp. 459–463, Feb. 2016, doi: 10.1109/ACSSC.2015.7421170.

[155] S. K. Sood and I. Mahajan, "A Fog Assisted Cyber-Physical Framework for Identifying and Preventing Coronary Heart Disease," *Wirel. Pers. Commun. 2018 1011*, vol. 101, no. 1, pp. 143–165, Jun. 2018, doi: 10.1007/S11277-018-5680-Y.

[156] A. M. Rahmani *et al.*, "Exploiting smart e-Health gateways at the edge of healthcare Internet-of-Things: A fog computing approach," *Futur. Gener. Comput. Syst.*, vol. 78, pp. 641–658, Jan. 2018, doi: 10.1016/J.FUTURE.2017.02.014.

[157] T. M *et al.*, "Multiple risk factors during pregnancy in South Africa: the need for a horizontal approach to perinatal care," *Prev. Sci.*, vol. 15, no. 3, pp. 277–282, 2014, doi: 10.1007/S11121-013-0376-8.

[158] C. A. Lancaster, K. J. Gold, H. A. Flynn, H. Yoo, S. M. Marcus, and M. M. Davis, "Risk factors for depressive symptoms during pregnancy: a systematic review," *Am. J. Obstet. Gynecol.*, vol. 202, no. 1, pp. 5–14, Jan. 2010, doi: 10.1016/J.AJOG.2009.09.007.

[159] "Adolescent Pregnancy," *Dep. Child Adolesc. Heal. Dev. World Heal. Organ. Geneva*, 2004.

[160] "High-risk pregnancy and high-risk obstetrics," *UKHealthCare*.

[161] "What are some factors that make a pregnancy high risk? | NICHD - Eunice Kennedy Shriver National Institute of Child Health and Human Development."

https://www.nichd.nih.gov/health/topics/high-risk/conditioninfo/factors (accessed Aug. 24, 2021).

[162] “Maternal mortality.” https://www.who.int/news-room/fact-sheets/detail/maternal-mortality (accessed Aug. 24, 2021).

[163] “Bed Rest During Pregnancy.” https://my.clevelandclinic.org/health/articles/9757-pregnancy-bed-rest (accessed Aug. 24, 2021).

[164] “Sleeping During Pregnancy (for Parents) - Nemours Kidshealth.” https://kidshealth.org/en/parents/sleep-during-pregnancy.html (accessed Aug. 24, 2021).

[165] S. Gordon, K. Grimmer, and P. Trott, “Sleep Position, Age, Gender, Sleep Quality and Waking Cervico-Thoracic Symptoms,” *Internet J. Allied Heal. Sci. Pract.*, vol. 5, no. 1, p. 6, Jan. 2007, doi: 10.46743/1540-580X/2007.1134.

[166] S. Ganguly and A. Begum, “Rate of caesarean operation and complications in... - Google Scholar,” *Orion Med. J.*, vol. 27, pp. 463–466, 200AD, Accessed: Sep. 07, 2021. [Online]. Available: https://scholar.google.co.in/scholar?hl=en&as_sdt=0%2C5&q=Rate+of+caesarean+operation+and+complications+in+hypertensive+disorders+of+pregnancy&btnG=#d=gs_cit&u=%2Fscholar%3Fq%3Dinfo%3ACOTczkEsG4IJ%3Ascholar.google.com%2F%26output%3Dcite%26scirp%3D0%26hl%3Den

[167] A. M. Khedagi and N. A. Bello, “Hypertensive Disorders of Pregnancy,” *Cardiol. Clin.*, vol. 39, no. 1, pp. 77–90, Feb. 2021, doi: 10.1016/J.CCL.2020.09.005.

[168] “High Blood Pressure | NHLBI, NIH.” https://www.nhlbi.nih.gov/health-topics/high-blood-pressure (accessed Sep. 07, 2021).

[169] “Chronic hypertension in pregnancy: To treat or not to treat? | NHLBI, NIH.” https://www.nhlbi.nih.gov/news/2019/chronic-hypertension-pregnancy-treat-or-not-treat (accessed Sep. 22, 2021).

[170] “Preeclampsia and Eclampsia | NICHD - Eunice Kennedy Shriver National Institute of Child Health and Human Development.” https://www.nichd.nih.gov/health/topics/preeclampsia (accessed Sep. 22, 2021).

[171] H. CS, B. SA, C. MF, and G. JS, “Spectrum of hypertensive emergencies in pregnancy,” *Crit. Care Clin.*, vol. 20, no. 4, pp. 697–712, Oct. 2004, doi: 10.1016/J.CCC.2004.05.014.

[172] S. Khosravi *et al.*, “Study of the Prevalence of Hypertension and Complications of Hypertensive Disorders in Pregnancy,” *Open J. Prev. Med.*, vol. 4, no. 11, pp. 860–867, Nov. 2014, doi: 10.4236/OJPM.2014.411097.

[173] S. Ganesh Kumar, B. Unnikrishnan, K. Nagaraj, and S. Jayaram, “Determinants of pre-eclampsia: A case-control study in a district hospital in South India,” *Indian J. Community Med.*, vol. 35, no. 4, 2010, doi: 10.4103/0970-0218.74360.

[174] “Preeclampsia and Eclampsia | NICHD - Eunice Kennedy Shriver National Institute of Child Health and Human Development.” https://www.nichd.nih.gov/health/topics/preeclampsia (accessed Sep. 08, 2021).

[175] “Pre-eclampsia”, Accessed: Sep. 08, 2021. [Online]. Available: www.google.co.in/search?q=Pre-eclampsia

[176] G. SM, D. JGB, G. KM, and C. WS, “Maternal pre-eclampsia and long-term offspring health: Is there a shadow cast?,” *Pregnancy Hypertens.*, vol. 12, pp. 11–15, Apr. 2018, doi: 10.1016/J.PREGHY.2018.02.003.

[177] Kevin Ashton, “That ‘Internet of Things’ Thing | RFID JOURNAL,” 2009. https://www.rfidjournal.com/that-internet-of-things-thing (accessed Aug. 26, 2021).

[178] A. GhanyIsmaeel and E. Khadhm Jabar, “Effective System for Pregnant Women using Mobile GIS,” *Int. J. Comput. Appl.*, vol. 64, no. 11, pp. 1–7, Feb. 2013, doi: 10.5120/10675-5547.

[179] J. Maniam, C. K. Chin, and K. Chenapiah, “Mobile phone based pregnancy support system ,” 2007.

[180] O. Oti, I. Azimi, A. Anzanpour, A. M. Rahmani, A. Axelin, and P. Liljeberg, "Iot-based healthcare system for real-Time maternal stress monitoring," *Proc. - 2018 IEEE/ACM Int. Conf. Connect. Heal. Appl. Syst. Eng. Technol. CHASE 2018*, pp. 57–62, Feb. 2019, doi: 10.1145/3278576.3278596.

[181] V. Santhi, K. Ramya, A. Tarana, and G. Vinitha, "IOT Based Wearable Health Monitoring System for Pregnant Ladies Using CC3200," *Int. J. Adv. Res. Methodol. Eng. Technol.*, vol. 1, no. 3, 2017.

[182] F. Sarhaddi *et al.*, "Long-Term IoT-Based Maternal Monitoring: System Design and Evaluation," *Sensors 2021, Vol. 21, Page 2281*, vol. 21, no. 7, p. 2281, Mar. 2021, doi: 10.3390/S21072281.

[183] O. Oti, I. Azimi, A. Anzanpour, A. M. Rahmani, A. Axelin, and P. Liljeberg, "IoT-based Healthcare System for Real-time Maternal Stress Monitoring," *Proc. 2018 IEEE/ACM Int. Conf. Connect. Heal. Appl. Syst. Eng. Technol.*, 2018, doi: 10.1145/3278576.

[184] I. Azimi *et al.*, "Personalized maternal sleep quality assessment: An objective iot-based longitudinal study," *IEEE Access*, vol. 7, pp. 93433–93447, 2019, doi: 10.1109/ACCESS.2019.2927781.

[185] A. E. Munoz *et al.*, "Smart mobile computing in pregnancy care," *Proc. 34th Int. Conf. Comput. Their Appl. CATA 2019*, pp. 17–26, Mar. 2020, doi: 10.29007/8s9w.

[186] M. W. L. Moreira, J. J. P. C. Rodrigues, N. Kumar, K. Saleem, and I. V. Illin, "Postpartum depression prediction through pregnancy data analysis for emotion-aware smart systems," *Inf. Fusion*, vol. 47, pp. 23–31, May 2019, doi: 10.1016/J.INFFUS.2018.07.001.

[187] Y. Santur, S. G. Santur, and M. Karaköse, "Architecture and implementation of a smart-pregnancy monitoring system using web-based application," *Expert Syst.*, vol. 37, no. 1, p. e12379, Feb. 2020, doi: 10.1111/EXSY.12379.

[188] M. W. L. Moreira, J. J. P. C. Rodrigues, V. Furtado, N. Kumar, and V. V. Korotaev, "Averaged one-dependence estimators on edge devices for smart

pregnancy data analysis," *Comput. Electr. Eng.*, vol. 77, pp. 435–444, Jul. 2019, doi: 10.1016/J.COMPELECENG.2018.07.041.

[189] A. S. Sunge, Y. Heryadi, E. Abdurachman, and I. H. Kartowisatro, "Machine Learning Methods for Predicting the Necessity of Caesareans Section of Childbirth," *Proc. - 2021 IEEE 5th Int. Conf. Inf. Technol. Inf. Syst. Electr. Eng. Appl. Data Sci. Artif. Intell. Technol. Glob. Challenges Dur. Pandemic Era, ICITISEE 2021*, pp. 100–104, 2021, doi: 10.1109/ICITISEE53823.2021.9655949.

[190] M. W. L. Moreira, J. J. P. C. Rodrigues, A. M. B. Oliveira, and K. Saleem, "Smart mobile system for pregnancy care using body sensors," *2016 Int. Conf. Sel. Top. Mob. Wirel. Networking, MoWNeT 2016*, Jun. 2016, doi: 10.1109/MOWNET.2016.7496609.

[191] M. Y. Abegaz, H. A. Muche, and G. L. Aynalem, "Determinants of Pregnancy-Related Anxiety among Women Attending Antenatal Checkup at Public Health Institutions in Debre Markos Town, Ethiopia," *Depress. Res. Treat.*, vol. 2022, pp. 1–10, Aug. 2022, doi: 10.1155/2022/6935609.

[192] M. W. L. Moreira, J. J. P. C. Rodrigues, A. K. Sangaiah, J. Al-Muhtadi, and V. Korotaev, "Semantic interoperability and pattern classification for a service-oriented architecture in pregnancy care," *Futur. Gener. Comput. Syst.*, vol. 89, pp. 137–147, Dec. 2018, doi: 10.1016/J.FUTURE.2018.04.031.

[193] J. Penders, M. Altini, C. Van Hoof, and E. Dy, "Wearable Sensors for Healthier Pregnancies," *Proc. IEEE*, vol. 103, no. 2, pp. 179–191, Feb. 2015, doi: 10.1109/JPROC.2014.2387017.

[194] S. Usharani, P. M. Bala, R. Rajmohan, T. A. Kumar, and S. A. Selvi, "Pregnancy Women—Smart Care Intelligent Systems: Patient Condition Screening, Visualization and Monitoring with Multimedia Technology," *Intell. Interact. Multimed. Syst. e-Healthcare Appl.*, pp. 147–169, 2022, doi: 10.1007/978-981-16-6542-4_9.

[195] K. Grym *et al.*, "Feasibility of smart wristbands for continuous monitoring

during pregnancy and one month after birth 11 Medical and Health Sciences 1117 Public Health and Health Services," *BMC Pregnancy Childbirth*, vol. 19, no. 1, pp. 1–9, Jan. 2019, doi: 10.1186/S12884-019-2187-9/TABLES/3.

[196] S. Ghimire, S. Martinez, and M. Gerdes, "Self-imperative Care of Pregnancy using IoT Solutions," *Scand. Conf. Heal. Informatics*, vol. 187, pp. 64–68, Aug. 2022, doi: 10.3384/ECP187011.

[197] D. Bjelica, A. Bjelica, M. Despotović-Zrakić, B. Radenković, D. Barać, and M. Đogatović, "Designing an IT Ecosystem for Pregnancy Care Management Based on Pervasive Technologies," *Healthc. 2021, Vol. 9, Page 12*, vol. 9, no. 1, p. 12, Dec. 2020, doi: 10.3390/HEALTHCARE9010012.

[198] F. I. Ohana, N. Rahmina, F. Ahmed, and A. Basak, "IoT based health monitoring system for pregnant women & children," 2021, Accessed: Jan. 24, 2023. [Online]. Available: http://dspace.bracu.ac.bd/xmlui/handle/10361/15944

[199] manivannan j, K. P, and A. BM, "Design of H-IoT Based Pregnancy Monitoring Device in Free-living Environment," Jun. 2022, doi: 10.21203/RS.3.RS-1102515/V1.

[200] K. Song, J. De Jonckheere, X. Zeng, L. Koehl, X. Yuan, and X. Zhao, "Development of a data-based interactive medical expert system for supporting pregnancy consultations: general architecture and methodology," *IFAC-PapersOnLine*, vol. 52, no. 19, pp. 67–72, Jan. 2019, doi: 10.1016/J.IFACOL.2019.12.109.

[201] R. Ivanov, S. Yordanov, and D. Dinev, "Internet of Things-based pregnancy tracking and monitoring service," *Int. Conf. Autom. Informatics, ICAI 2022 - Proc.*, pp. 298–302, 2022, doi: 10.1109/ICAI55857.2022.9960012.

[202] B. BR, R. S, A. R, and H. D, "The effect of source credibility on consumers' perceptions of the quality of health information on the Internet," *Med. Inform. Internet Med.*, vol. 31, no. 1, pp. 45–52, Mar. 2006, doi: 10.1080/14639230600552601.

[203] M. R, M. J, and J. M, "Is primary care ready to embrace e-health? A qualitative

study of staff in a London primary care trust," *Inform. Prim. Care*, vol. 14, no. 2, pp. 121–131, 2006, doi: 10.14236/JHI.V14I2.622.

[204] B. BR, R. S, A. R, and H. D, "The effect of source credibility on consumers' perceptions of the quality of health information on the Internet," *Med. Inform. Internet Med.*, vol. 31, no. 1, pp. 45–52, Mar. 2006, doi: 10.1080/14639230600552601.

[205] B. W. T. Rohm and C. E. T. R. Jr., "A vision of the e-healthcare era," *Int. J. Healthc. Technol. Manag.*, vol. 4, no. 1/2, p. 87, 2002, doi: 10.1504/IJHTM.2002.001131.

[206] J. P. Harrison and A. Lee, "The role of e-Health in the changing health care environment," *Nurs. Econ.*, vol. 24, no. 6, pp. 283–290, Nov. 2006, Accessed: Aug. 24, 2021. [Online]. Available: https://go.gale.com/ps/i.do?p=AONE&sw=w&issn=07461739&v=2.1&it=r&id=GALE%7CA157034747&sid=googleScholar&linkaccess=fulltext

[207] "CN107137065A - A kind of pregnant baby's monitor system and method - Google Patents." https://patents.google.com/patent/CN107137065A/en?oq=CN107137065A (accessed Dec. 14, 2021).

[208] "CN204129448U - Pregnant woman's intelligent watch - Google Patents." https://patents.google.com/patent/CN204129448U/en?oq=CN204129448U (accessed Dec. 14, 2021).

[209] "CN204631461U - A kind of pregnant woman's intelligent watch - Google Patents." https://patents.google.com/patent/CN204631461U/en?oq=CN204631461U (accessed Dec. 15, 2021).

[210] "CN104523263A - Mobile internet based pregnant and lying-in woman health surveillance system - Google Patents." https://patents.google.com/patent/CN104523263A/en?oq=CN104523263A (accessed Dec. 15, 2021).

[211] "CN107242858A - A kind of personalized pregnant baby's monitoring method and system - Google Patents." https://patents.google.com/patent/CN107242858A/en?oq=CN107242858A+ (accessed Dec. 15, 2021).

[212] "CN106137127A - Critical pregnant and lying-in women's monitoring emergency system based on the Internet - Google Patents." https://patents.google.com/patent/CN106137127A/en?oq=CN106137127A (accessed Dec. 15, 2021).

[213] "KR20160046284A - Personal health device, smart device and pregnant-care service method using the personal health device and smart device - Google Patents." https://patents.google.com/patent/KR20160046284A/en?oq=KR20160046284 A (accessed Dec. 15, 2021).

[214] "KR20170067950A - System for pregnant women on parental care - Google Patents." https://patents.google.com/patent/KR20170067950A/en?oq=KR20170067950 A (accessed Dec. 15, 2021).

[215] A. Bin Queyam, R. Kumar Meena, S. Kumar Pahuja, and D. Singh, "An IoT Based Multi-Parameter Data Acquisition System for Efficient Bio-Telemonitoring of Pregnant Women at Home," *Proc. 8th Int. Conf. Conflu. 2018 Cloud Comput. Data Sci. Eng. Conflu. 2018*, pp. 618–624, Aug. 2018, doi: 10.1109/CONFLUENCE.2018.8442686.

[216] omesh reddy kurakula, V. M. LAGISETTY, and A. Pandian, "Healthcare Management for Pregnant Lady Using Iot," *SSRN Electron. J.*, Mar. 2020, doi: 10.2139/SSRN.3704643.

[217] O. Oti, I. Azimi, A. Anzanpour, A. M. Rahmani, A. Axelin, and P. Liljeberg, "Iot-based healthcare system for real-Time maternal stress monitoring," *Proc. - 2018 IEEE/ACM Int. Conf. Connect. Heal. Appl. Syst. Eng. Technol. CHASE 2018*, pp. 57–62, Feb. 2019, doi: 10.1145/3278576.3278596.

[218] A. Gholamy, V. Kreinovich, and O. Kosheleva, “Why 70/30 or 80/20 Relation Between Training and Testing Sets: A Pedagogical Explanation,” *Dep. Tech. Reports,* Feb. 2018, Accessed: Sep. 23, 2022. [Online]. Available: https://scholarworks.utep.edu/cs_techrep/1209

List of Publications

R. Beri and M. K. Dubey, “A utilitarian and Veracious EHealth Care System for Pregnant Women using Fog Devices.,” 2019.

R. Beri and M. K. Dubey, “MACHINE LEARNING FOR HEALTHCARE AND PHARMA,” *J. Gujarat Res. Soc.*, vol. 21, no. 6, pp. 500–504, 2019.

R. Beri, M. K. Dubey, A. Gehlot, and R. Singh, “A SMART HEALTHCARE SYSTEM FOR PREGNANCY MANAGEMENT,” 201911049368, 2019

R. Beri, M. K. Dubey, A. Gehlot, and R. Singh, *A Study of E-Healthcare System for Pregnant Women,* vol. 1206 CCIS. 2020. doi: 10.1007/978-981-15-4451-4_43.

R. Beri, M. K. Dubey, A. Gehlot, and R. RAJ, “Performance Assessment of Supervised Learning Techniques for Caesarean Rate Prediction,” *SSRN Electron. J.*, 2020.

R. Beri, M. K. Dubey, A. Gehlot, and R. Singh, “Health Assessment Model to Identify and Control Risk Associated with Preeclampsia using IoT,” 2020. doi: 10.1109/ICRITO48877.2020.9197786.

R. Beri, M. K. Dubey, A. Gehlot, and R. Singh, “COVID-19 ramifications during pregnancy,” in *Intelligent Circuits and Systems*, 2021, pp. 594–600.

R. Beri, M. K. Dubey, A. Gehlot, and R. Singh, “AN EFFECTIVE PREGNANCY E-HEALTHCARE SYSTEM INTEGRATED WITHREAL TIME MONITORING AND ATTENTIVENESS,” 201811030615, 2020

R. Beri, R. Singh, A. Gehlot, M. K. Dubey, and M. Gupta, “A SMART PREGNANT WOMEN MONITORING SYSTEM,” 202011040873, 2020

R. Beri, M. K. Dubey, A. Gehlot, and R. Singh, “Implementation of Smart Healthcare System to Predict Caesarean Chances,” *Desing Eng.*, vol. 2021, no. 7, pp. 3704–3712, 2021.

R. Beri, M. K. Dubey, A. Gehlot, R. Singh, M. Abd-Elnaby, and A. Singh, “A novel fog-computing-assisted architecture of E-healthcare system for pregnant women,” *J. Supercomput.*, vol. 78, no. 6, pp. 7591–7615, 2022.