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Smart Maternal and Child Health Monitoring System Using IoT and Machine Learning

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Abstract: ***Pregnancy is a critical period, and the timely detection of physiological changes helps in the early prevention of complications. Wearable sensors measure essential parameters like heart rate, temperature, and SpO_2, transmitting the data to the ThingSpeak cloud via Wi-Fi. It is analysed for the differentiation of normal and abnormal conditions via a Random Forest algorithm, which generates alerts in case of deviations. This allows for early intervention, reducing risks and enhancing maternal safety. It is low cost, compact, and user-friendly, thus allowing home-based monitoring without repeated visits to the hospital. It supports real-time visualization, record storage, and remote sharing of data with healthcare providers through cloud integration. Prototype testing confirms correct sensor readings and reliable ML predictions.***
Keywords: IoT, ML, Cloud, Maternal Health

I. INTRODUCTION

Maternal and child healthcare is a pivotal component of the contemporary healthcare systems, particularly in the case of pregnancy, as the constant monitoring should be conducted to make sure that both the mother and the baby are safe. A good number of complications arising during pregnancy are as a result of failure to undergo regular monitoring and prompt medical care especially in rural and remote regions whereby there is limited access to healthcare institutions. As the modern technology including the Internet of Things (IoT) and Machine Learning continues to evolve, one can create intelligent healthcare systems that could monitor patients remotely and assist them in time. The IoT technology can be used to connect biomedical sensors, microcontrollers, and cloud platforms to gather and transfer health information in real time.

This project suggests Smart Maternal and Child Health Monitoring System with the help of IoT and Machine Learning. The monitor constantly checks vital physiological parameters including heart rate, blood oxygen (SpO2) level, body temperature and movement of the fetus with the help of special sensors that are linked to a microcontroller.The information gathered is sent to the cloud which is analysed using machine learning algorithms to identify potential health risks. The proposed system can be used to enhance the health services offered to pregnant women and minimise the number of complications by offering realtime monitoring, early risk detection, and remote access to healthcare. This system finds special application in the rural settings where medical supervision may not always be available.

II. SCOPE AND OBJECTIVE

1) To examine various algorithms of Machine Learning that can be applied to assess maternal health risks.
2) To create an IoT-based system of constant tracking of physiological data in mothers.
3) To enhance the predictability of risks through the use of LSTM model and produce early warning notifications.

III. LITERATURE REVIEW

Ahmed and Kashem [1] introduced the IoT-based prediction model of the degree of risk in order to enhance maternal health and this was mostly used in developing nations where continuous monitoring is inaccessible. The paper pays attention to the issue of the maternal health challenge, including the lack of awareness, the delaying diagnosis, and the inappropriacy of seeking healthcare services and facilities, particularly, in the rural regions. The authors also highlight the significance of continuous monitoring of the expectant mother to help in maintaining the safety of the mother and the fetus since the traditional healthcare systems which depend on the periodic checkups are normally inadequate due to the failure to detect complications at an early stage [1].

The idea of smart healthcare systems was put forward by Mittal et al. [5] in an attempt to mitigate the growing threat of the contemporary healthcare industry that is witnessed by the alarming rate of chronic illness and the escalating need of effective healthcare services.

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This paper points out that conventional healthcare models have various shortcomings that include the shortage of medical personnel, ignorance, late diagnosis, inadequate patient care experience and data management. The mentioned issues are a major contributor to the quality and accessibility of healthcare services that requires the development of one of the most innovative technological solutions that would enhance efficiency and decrease the pressure on healthcare infrastructure.

Warbhe and Karmore [6] have carried out a detailed survey on wearable healthcare monitoring systems, their significance in enhancing healthcare services, particularly in distant and rural facilities. According to the study, the conservative healthcare method may be characterized by manual documents record-keeping and intermittent medical check-ups thus creating delays in diagnosis and resulting in higher risk in cases of emergency. In most of the rural areas, healthcare delivery is further complicated by the inability of people to have direct access to physicians. To address these shortcomings, the authors present wearable systems, which will allow constant monitoring of physiological parameters and allow patients and healthcare providers to be in constant contact.

Abdiakhmetova et al. [7] suggested the implementation of an intelligent healthcare monitoring system using ATmega microcontrollers to enhance patient monitoring and alleviate stress by monitoring them constantly and responding to medical aid on time. It focuses on the increased significance of the Internet of Medical Things (IoMT) in the sphere of contemporary healthcare as real-time monitoring and patient-centric systems are the key enablers in improving healthcare quality. The authors emphasize that the existing healthcare systems do not always offer obsessive monitoring that can result into late diagnosis and higher risks to the patients especially in remote locations where such patients have limited access to healthcare facilities. In the suggested construction, the hardware and the software are combined to track the patient health parameters by attaching sensors to an ATmega328 microcontroller. This microcontroller forms the processing power of this system since it collects, processes and transmits physiological information like temperature, pulse rate, and pressure. The sensor interface will contain the sensor devices such as the temperature sensor (LM35), pulse sensor, and pressure sensor which will constantly transmit patient information [7]. These sensors are gated to the microcontroller that reads the analog signals and transforms into digital signals to continue with further processing and analysis.

Robinsha and Amutha [8] provided an extensive survey of the changing nature of the healthcare systems in the context of the Internet of Things (IoT) as this technology allows development of smart, connected, and efficient healthcare architecture. The article is dedicated to the application of IoT technologies in healthcare facilities to enhance patient monitoring, diagnosis, and individual treatment. It emphasizes the fact that most traditional healthcare systems are simply ineffective in terms of real-time monitoring and effective utilization of information, but the IoT-based systems form a screen of interconnected gadgets that gather and transfer patient data continuously. The change enables healthcare providers to follow up with the patients even when they are not able to reach out to them directly and to conduct rapid response to any abnormalities that would result in better patient outcomes and healthcare delivery in general.

The research of Islam et al. [9] is a mobile health (mHealth) technology that would evaluate and treat maternal depression and stress in pregnancy, especially in countries with low incomes and middle-income where the access to mental healthcare is few. In the study, the maternal mental health complications causing depression, stress and anxiety are noted as important public health concerns, as these health complications relate to the interests of the mother and child. It underlines that the percentage of pregnant women with psychological distress is quite high, and it may result in negative consequences in maternal wellness and child development [9]. To help resolve this problem the authors present a mobile-based intervention which helps provide continuous monitoring and intervention with the help of smartphone applications and community healthcare system. The device of the proposed system is a mobile app called the Depression Evaluation and Educational Application (DEEA), where the diagnosis of mental state and individual interventions are provided. The system gathers information with the help of the structured questionnaires that are culturally biased to the target population [9]. This information is then compared through the application of Machine Learning to measure the extent of depression and stress among pregnant women. According to the analysis, the system offers personalized psycho-educational content in the form of text and videos, whereby, one understands their condition and performs the right actions.

Godi et al. [11] introduced an E-Healthcare Monitoring System (EHMS) using the Internet of Things (IoT) and Machine Learning methods to offer continuous monitoring of health and make intelligent decisions in healthcare settings. The research highlights the increased burdens of keeping human health because of present lifestyle trends including unbalanced nutrition, stress, and exercise, and environmental factors. These lead to different health conditions, and it is necessary to come up with mechanisms that are capable of tracking the health of patients at all times.

In the traditional healthcare systems, there is the tendency of not offering real-time monitoring services and diagnoses because a doctor is not able to monitor the patients all the time. In order to address these shortcomings, the authors suggest an automated system that is a combination of IoT and Machine Learning to be used in efficient healthcare monitoring [11].

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The suggested EHMS architecture will gather physiological information in real time and via the application of the IoT wearables [11]. These gadgets have sensors like the temperature sensors, heart rate sensors, blood pressure sensors, and diabetes monitoring sensors. The sensors constantly record the information in the body of the patient and relay it to a central system via wireless communication technologies [11]. The system has the ability to track patients under various conditions such as hospitals, homes and workplaces so that constant eye is on the patient irrespective of the location.

Ettiyan and Geetha [12] conducted a thorough survey of healthcare monitoring systems of maternity women with the use of Internet of Things (IoT) technology and the relevance of improving maternal and fetal health monitoring with the help of smart and connected systems. The paper emphasizes the fact that the IoT has come out as a strong technology that can fill the gap between physical and digital health systems, as it allows the communication between devices, sensors, and healthcare platforms [12]. It underlines the idea that the IoT systems can greatly benefit the monitoring of pregnant women with both the real-time physiological data tracking and prompt alert and decision support. Another important issue that the authors advise is confidentiality and accuracy in monitoring pregnancy as confirmation and management of pregnancy are vital elements of maternal healthcare.

Priyanka et al. [14] proposed an IoT-based system for monitoring the health status of pregnant women's to offer better prenatal care, especially for rural areas, where access to healthcare facilities is limited. The flow diagram of IoT based health monitoring the study raises the issue that lack of regular checkups and awareness result in greater maternal and fetal risks [14]. To deal with the latter, the authors created a system that allows continuous surveillance of vital health parameters through IoT technology [14].

IV. PROBLEM STATEMENT

The issue of maternal and child healthcare continues to pose considerable challenge, the greatest challenge being the rural and low-resource regions where the accessibility of medical institutions and constant check-up is minimal. Health checkups that are conducted periodically by pregnant women in hospitals might not be sufficient to ascertain any sudden development in their physiological status. Due to this, most pregnancy complications like abnormal heart rate, temperature fluctuations, low oxygen levels in the blood or slow fetal movements may be overlooked until they develop into severe complications. Conventional monitoring systems cannot offer the real-time monitoring of the parameters of maternal health and doctors may fail to get access to the latest information regarding the condition of the patient. Moreover, current systems, which operate with simplistic machine learning algorithms, do not pay off well in the analysis of continuous health data, which results in inaccurate forecasts and slow notifications. Thus, it is necessary to have a smart, stable and cheap monitoring system capable of constantly monitoring the health parameters of the mother and intelligently analysing the results to give early alerts in the case of abnormal conditions. Such a system will be able to assist a healthcare professional to act in time and to enhance the safety of both mother and child.

V. PROPOSED METHODOLOGY

The proposed system will measure critical health parameters, and it is comprised of sensor-based data acquisition, microcontroller processing and cloud communication. Physiological information that includes heart rate and temperature is gathered by the system with sensors being linked to an Arduino microcontroller. The gathered information is calculated by the microcontroller and shown on a local screen in the form of an LCD display and also sent to a cloud platform to monitor remotely. A based in built alert system with a buzzer is introduced as a control measure in case of abnormal readings. Combining IoT and smart data analysis methods with each other, the system offers an effective solution to the real-time health monitoring and early warning of possible health dangers. The Figure 5.1 represents the block diagram of maternal and child health monitoring system. The system starts with the data gathering phase which involves the use of different sensors to measure different physiological parameters which include temperature, pulse rate, galvanic skin response (GSR), blood oxygen saturation (SpO2) and fetal movement. The sensors constantly scan the physiological signs of the user and translate it into electrical messages that can be interpreted in the microcontroller.

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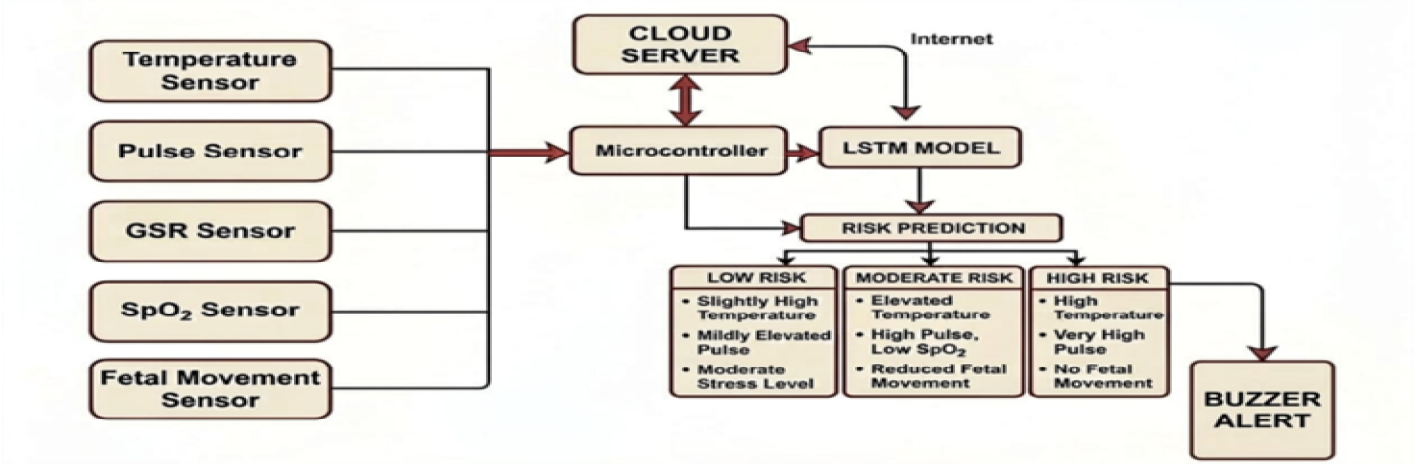


Figure 5.1: The block diagram of maternal and child health monitoring system

The sensor data obtained are sent to the microcontroller which is the central processing unit of the system. The sensor values are read and the microcontroller processes them and prepares to get the further analysis. The information is processed and sent to a cloud server using an internet connection. The data gathered is stored in the cloud platform under which remote monitoring and analysis of the health parameters are possible. After the data is present on the cloud platform, it is perceived with the help of a Long Short-Term memory (LSTM) model, which is the method of deep learning that is aimed at analyzing the sequential data. The LSTM model takes historical and real-time physiological data and types patterns and identifies abnormal states. On the analysis, the system is used to predict risk based on the risk levels using three levels, such as Low Risk, Moderate Risk and High Risk, based on the health condition. In case the system notices some abnormal physiological states, which show increased-risk level, an alarm system is triggered. An alert buzzer is triggered in the high-risk condition to alert the caregivers or medical staff right away. This will assist in raising the early warnings and also allow an immediate medical treatment.

A. Working of the System

The health monitoring system proposed is realized on the principle of constant gathering of physiological measurements of the user, the processing of the obtained measurements by a microcontroller and the transfer of information to a cloud platform, risk forecasting through the work of a deep learning model. The general working methodology is a combination of sensor-based monitoring, IoT communication, and intelligent analysis of data in order to deliver real-time health tracking and early risk identification. The system starts with the data acquisition stage in which several sensors are employed to check the vital physiological parameters. The temperature sensor, pulse sensor, galvanic skin response (GSR) sensor, blood oxygen saturation (SpO2) sensor, and fetal movement detection sensor are the sensors which constantly record signals of the user. These sensors detect the physiological activities and convert them into electrical signals that may be understood by the microcontroller.

The sensor signals that are collected are then sent to the microcontroller in the next stage which is the central processing unit of the system. The sensor signals are measured by the microcontroller which then processes the data to get meaningful values which include temperatures measurements, beats per minute heart rate, oxygen saturation and movement measurements. The microcontroller takes care of the communication between the sensors and the cloud as well.

The sensor data can be dealt with then the system sends the information collected to a cloud server by the use of the internet. The cloud platform is significant in maintaining and storing the physiological data of the system. With the help of cloud-based uploading of the data, one can remotely monitor the state of the patient regarding the conditions of his or her health. The data can also be obtained in real-time by a provider of care or healthcare provider and can be viewed at any location to reveal the health condition of a patient.

After the data has been stored in the cloud server, it is fed through a Long Short-Term Memory (LSTM) model that is a deep learning technique and is used to analyze sequential data. LSTM model involves the examination of past and current physiological data to discover patterns and unhealthy conditions. The model will be able to forecast any possible threats to the user health through the examination of the trends in the gathered information and determine the health status of the user.

According to the results of the analysis, the system does risk prediction as well as classifies the health condition in three levels Low Risk, Moderate Risk and High Risk. All these risk levels are also associated with particular physiological conditions, including slightly high temperature, abnormal pulse rate, low oxygen levels, or absence of fetal movement. In case the system records a high-risk condition, an automatic notification system is brought into effect to alert the user, or the caregivers instantly. The system produces an audible alarmed with the help of buzzer alert to show that urgent action is necessary. It is an alert system that can serve in assuring prompt action and mitigate the possibility of severe health complications.

VI. RESULTS AND DISCUSSIONS

The proposed health monitoring system can be experimented by combining hardware features, cloud interaction with machine learning algorithms to track physiological variables and anticipate possible threats to health. The system records the real time information of several sensors and processes the information with the help of a microcontroller sending the information to a cloud platform to analyze and predict further. The hardware system includes the following sensors namely: temperature sensor, pulse sensor, galvanic skin response (GSR) sensor, blood oxygen saturation (SpO2) sensor, and a fetal movement detection sensor. These sensors are linked to an Arduino that is the central processing unit of the system. After the sensor data is processed it is sent to a cloud server via an internet connection. The physiological data is collected and stored by the cloud platform by which it is managed. This will enable one to monitor the health parameters of the user remotely and access past data to process further.

The data needed in this analysis is physiological parameters that were taken by the sensors attached to the health monitoring system. Among various parameters gathered in the system are temperature, pulse rate, galvanic skin response (GSR), blood oxygen saturation (SpO2) and fetal movement. Monitoring of these parameters is performed continuously with the help of the sensor modules attached to the microcontroller. All sensors record a certain physiological signal and translate it into digital values that can be handled and stored to be analysed further. Sensor values are sent to the cloud system where the information is stored and arranged in an orderly manner. Every line in the dataset is the collection of physiological measurements at some moment in time. The dataset covers several samples comprising of the sensor values that are recorded coupled with the label of the health condition applied to determine risk. The information contains real-time sensor data, as well as historical data stored into the cloud platform. This makes the combination of real-time and historical data in the system analyzing sequential trends in physiological parameters possible.

A. Performance Metrics

The metrics are used to identify the accuracy of the model in classifying the health status of the user into various levels of risks. Accuracy is one of the most frequently employed measures of evaluation. Accuracy is the percentage of correct model predictions made against the number of predictions made. It gives an overall idea of the success in using the model to classify the health risk levels according to the input physiological parameters. The model performance is shown in Figure 6.1.

Precision is another significant measure. Precision is a measure of the percentage of the correct positive predictions made among all of the positive predictions made. When applied to health monitoring, precision assists in understanding the accuracy of cases that are deemed to be a part of a particular risk category to the system.

The F1-score, which is used to evaluate the trade-off between the precision and the recall. It offers an integrated value of both measures and comes in handy where the dataset has uneven classes. The F1-score is used to measure the effectiveness of the prediction model in general.

Besides these, one of which is a confusion matrix to visualize model classification performance shown in Figure6.2. The confusion matrix reveals the count of accurate and wrong predictions that the model did concerning the various risk types, which are low risk, moderate risk and high risk. This is useful in determining the ability of the model in distinguishing various health conditions.

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Dataset Preview:

Age	SystolicBP	DiastolicBP	BS	BodyTemp	HeartRate	RiskLevel
25	130	80	15	98	86	{'high risk'}
35	140	90	13	98	70	{'high risk'}
29	90	70	8	100	80	{'high risk'}
30	140	85	7	98	70	{'high risk'}
35	120	60	6.1	98	76	{'low risk' }
23	140	80	7.01	98	70	{'high risk'}
23	130	70	7.01	98	78	{'mid risk' }
35	85	60	11	102	86	{'high risk'}

Model Accuracy: 86.14%
Performance Metrics:

precision	recall	f1score
0.87037	1	0.93069
0.85185	0.87342	0.8625
0.86567	0.76316	0.81119

Average Precision: 0.86
Average Recall: 0.88
Average F1 Score: 0.87
Predicted Maternal Risk Level:
High Risk

Figure 6.1: Performance Evaluation of the model

With the help of such evaluation metrics, the functioning of the machine learning and deep learning models can be thoroughly considered so that the suggested health monitoring system can be capable of offering certain valid and reliable risk prediction results.

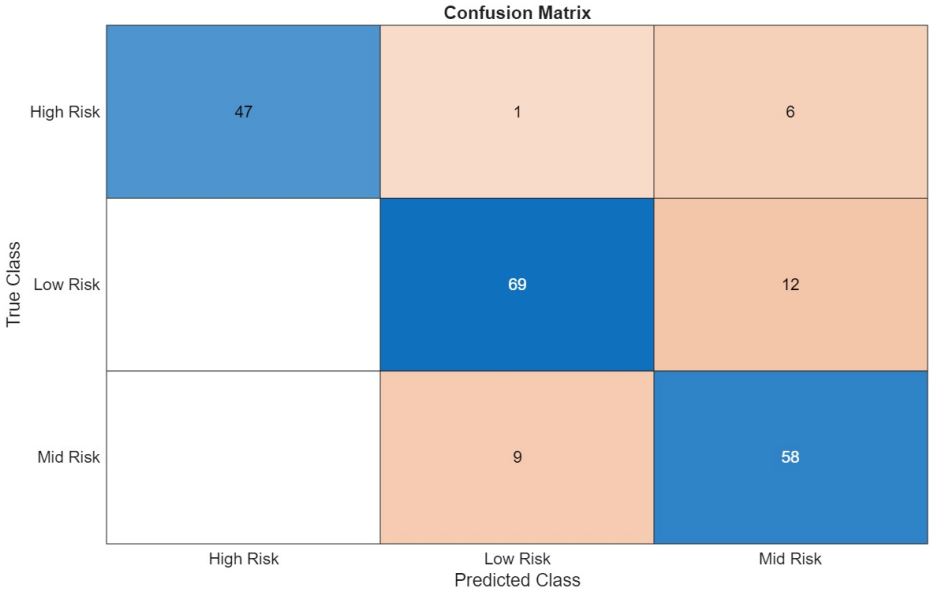


Figure 6.2: Confusion Matrix

The risk prediction analysis is done and the health condition of the user is determined by examining the physiological parameters that are recorded by the sensors. The developed machine learning and deep learning models process the input data and categorize the health status into various categories of risks. The results of the prediction are used to determine the possibility of health problem and assist in the early medical intervention. The Figure 6.3 represents the accuracy and loss graphs per an epoch.

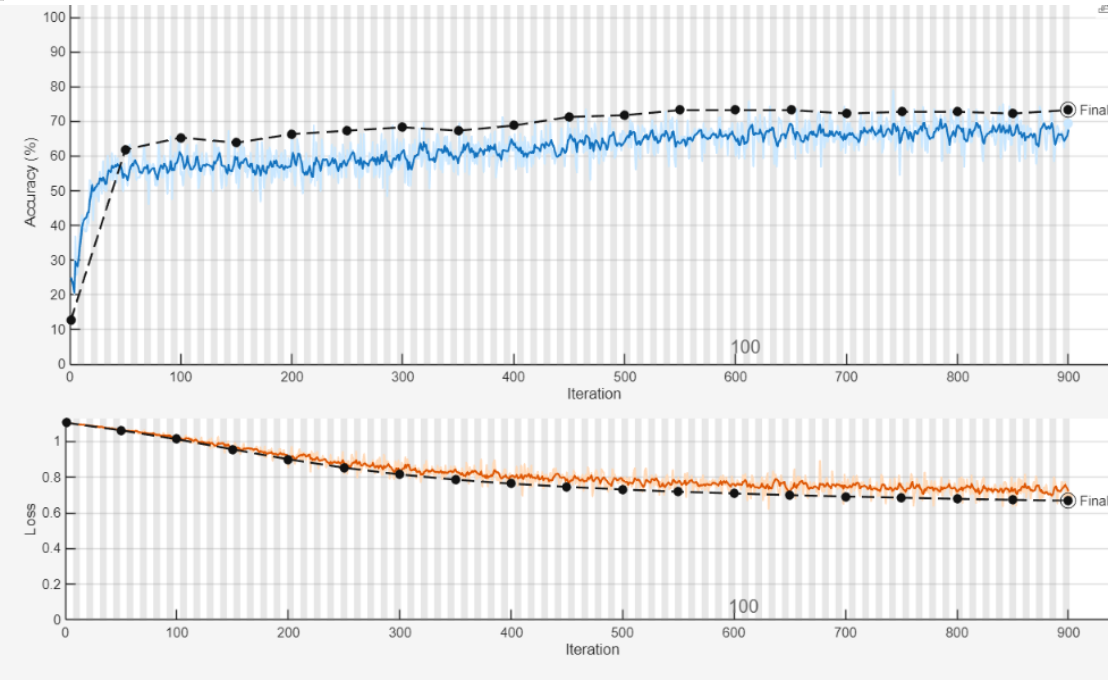


Figure 6.3: Accuracy and Loss Graphs

The machine learning and deep learning approaches are applied in this research to process the sensor data and infer the health condition to various risk levels. The analysis assists in determining the performance and predictability of the prediction models employed in the system. The physiological dataset is going to be analysed with the help of different machine learning and deep learning models. Risk prediction in this system is accomplished with the help of such models as Random Forest and Long Short-Term Memory (LSTM). The risk level ranges are shown in Table 1.

TABLE I : RANGES OF RISK LEVEL CLASSIFICATION PARAMETER	LOWRISK	MODERATE RISK	HIGH RISK
GSR	70-109	110-120	<70 OR >120
TEMPERATURE	80-89	90-100	<80 OR >100
SPO2	60-99	100-120	<60 OR >120
PULSE RATE	60-139	140-160	<60 OR >160
KICK COUNT(12 HRS)	1-3	5-10	0 OR >10

The comparison of the results of the various models is made in order to establish the model that works better in the health risk prediction activity. Depending on the results of the evaluation, the models may be further optimized with the help of changing the parameters or training to increase the accuracy of prediction. By evaluating in this way, the proposed system will ensure that the chosen machine learning and deep learning models would make suitable and accurate predictions to monitor health risks.

VII. CONCLUSION

The suggested health monitoring system is a successful strategy of constant monitoring and forecast of health risks based on the combination of sensor technology, Internet of Things (IoT) communication, and machine learning methods.

The system will be programmed to measure vital physiological values like the temperature, pulse rate, galvanic skin response (GSR), blood oxygen saturation (SpO2), and fetal movement by measuring sensor modules which will be attached to a microcontroller. These parameters are important indicators of the health condition of a person and are useful in monitoring and analysis.

The microcontroller processes the gathered physiological data and sends it to a cloud platform where health information and remote monitoring can be monitored and stored. The cloud connectivity will enable healthcare providers and caretakers to get the data anywhere, which will be a guarantee of the uninterrupted observation of the health status of the person using it. This ability to monitor remotely enhances accessibility and assists in offering timely medical care in case abnormal conditions are realized.

The obtained results of the experimental assessment prove that the proposed system can be used to monitor physiological parameters effectively and predict the risk of health issues with a high degree of accuracy. However, by combining IoT technology with machine learning algorithms, the system will be able to analyze health data in real time and offer credible risk classification. The system also considers a warning mechanism which alerts the user or caregiver in case of abnormal conditions by providing a quick response to any emergencies in relation to health conditions.

In general, the suggested health monitoring system offers a valid and effective solution of real-time health monitoring and predictive healthcare. The system will help enhance the healthcare management and enable the prompt detection of the health risks by integrating sensor-based monitoring with cloud communication and intelligent data analysis. The deployment of this type of systems may be of great value in improving the monitoring of patients and the ability to come up with smarter healthcare solutions.

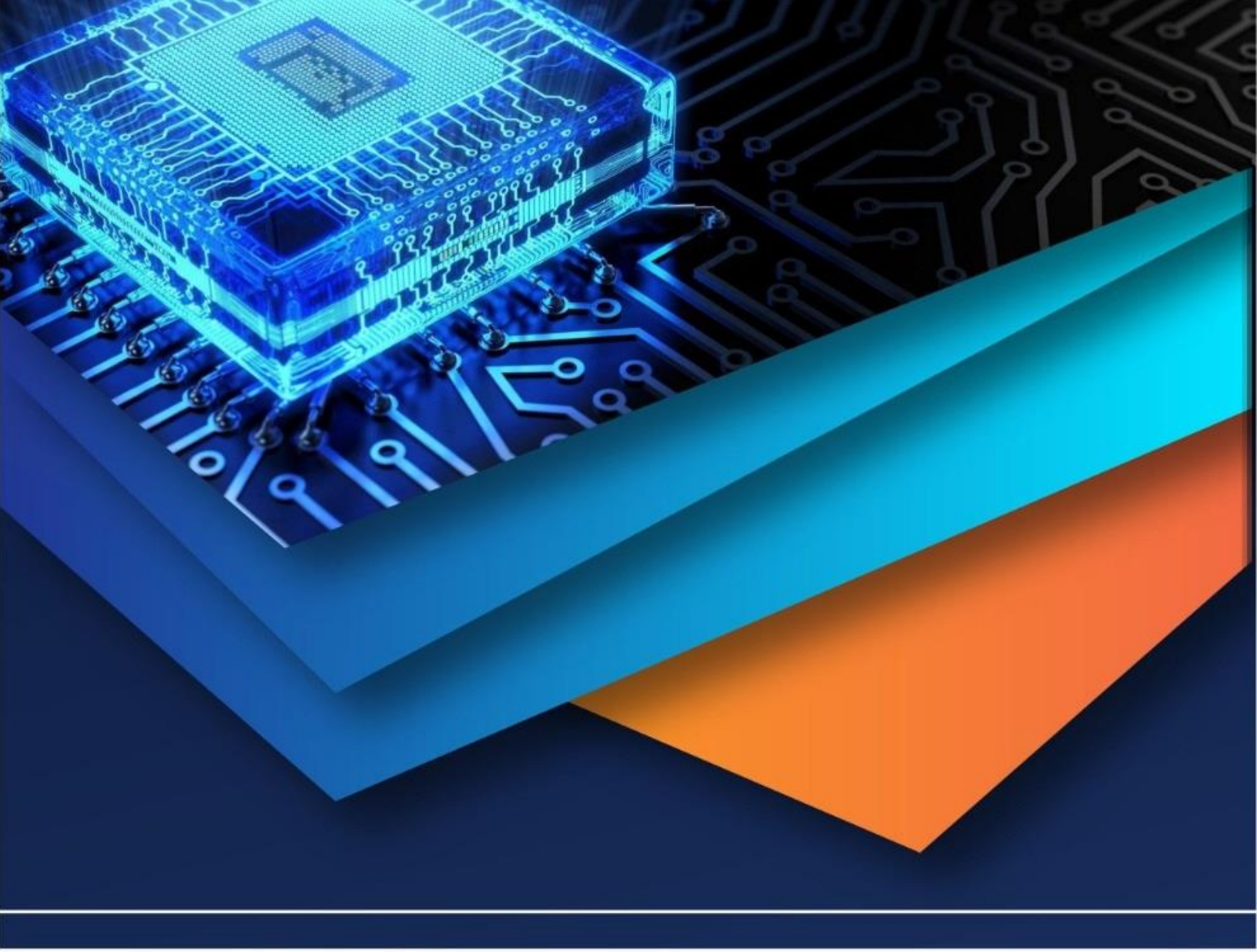
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