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Decision Tree-Based Approach to Early Detection of Preeclampsia in Healthcare

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ABSTRACT: Preeclampsia is a pregnancy complication marked by high blood pressure and organ dysfunction, posing serious risks to maternal and fetal health if left undetected. This project introduces a smart, AI-driven system for realtime preeclampsia detection, integrating machine learning with IoT-based health monitoring. Utilizing a Raspberry Pi Pico W microcontroller, the system collects physiological data from biomedical sensors—measuring heart rate, oxygen saturation (SpO₂), body temperature, and blood pressure—continuously monitoring for abnormalities.

A trained machine learning model processes this data, classifying readings as normal or indicative of preeclampsia. Upon detecting abnormalities, the system promptly alerts the patient via a buzzer while simultaneously sending emergency notifications to caregivers or healthcare professionals through an automated messaging system. An LCD display provides real-time health insights for immediate reference.

By leveraging AI-based analysis and IoT-enabled remote monitoring, this low-cost, portable solution enhances early detection, ensuring timely medical intervention and improving prenatal care accessibility, particularly in underserved regions. The project demonstrates the potential of AI-assisted healthcare in reducing pregnancy-related complications and advancing maternal health safety.

I. INTRODUCTION

Pregnancy is a transformative journey, yet it comes with potential health risks that demand vigilant monitoring. Among these risks, preeclampsia stands out as a serious condition characterized by elevated blood pressure and potential organ damage, posing threats to both the mother and the unborn child. Traditional diagnostic methods rely on periodic clinical assessments, but these can be limited in accessibility, especially in rural or underserved areas where frequent medical checkups are impractical.

Advancements in Artificial Intelligence (AI) and Machine Learning (ML) have revolutionized healthcare, enabling predictive diagnostics that enhance early detection and intervention strategies. When integrated with Internet of Things (IoT) technology, real-time monitoring systems can significantly improve maternal healthcare by providing continuous tracking of vital signs.

This project presents an innovative AI-driven preeclampsia detection system, leveraging biomedical sensors and machine learning algorithms to analyze physiological data for early risk identification. The system utilizes a Raspberry Pi Pico W microcontroller to collect and process data from sensors measuring heart rate, oxygen saturation, body temperature, and blood pressure. When irregularities indicative of preeclampsia are detected, alerts are instantly triggered, notifying both the patient and caregivers.

By combining AI-based medical analysis with IoT-enabled remote monitoring, this solution aims to bridge the gap between patients and healthcare providers, offering a cost-effective, accessible, and efficient tool for maternal health management. The proposed system enhances prenatal care by facilitating early diagnosis, reducing complications, and empowering expectant mothers with real-time health insights.





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II. PRELIMINARIES

The development of AI-powered preeclampsia detection systems relies on several foundational concepts spanning healthcare, embedded systems, and machine learning. Before diving into the specifics of this project, it is essential to outline key technical and medical aspects that form the basis of this work.

A. Preeclampsia: A Medical Overview

Preeclampsia is a pregnancy complication characterized by elevated blood pressure and signs of organ damage, particularly affecting the liver and kidneys. It is considered one of the leading causes of maternal and fetal health risks worldwide. Early detection and monitoring of physiological indicators such as blood pressure, heart rate, and oxygen saturation levels play a crucial role in preventing severe complications like eclampsia, premature birth, or maternal mortality.

B. IoT in Healthcare

The integration of Internet of Things (IoT) technology in medical monitoring has revolutionized patient care, allowing real-time data collection and remote health management. By embedding biomedical sensors into wearable or portable devices, health parameters can be continuously monitored and transmitted for analysis. This system utilizes IoT principles to track vital signs, process physiological data, and generate automated alerts when abnormalities indicative of preeclampsia are detected.

C. Machine Learning for Health Monitoring

Machine learning (ML) plays a critical role in predictive healthcare by analyzing large datasets and recognizing patterns that may not be immediately apparent through manual assessments. By training ML models on preeclampsia-related medical data, the system can effectively classify vital sign readings as normal or abnormal, triggering alerts in the case of high-risk conditions. The integration of ML ensures increased accuracy in early detection, contributing to better maternal healthcare outcomes.

D. Embedded Systems and Raspberry Pi Pico W

Embedded systems enable seamless automation in health monitoring by integrating low-power microcontrollers with sensors and communication modules. The Raspberry Pi Pico W, chosen for its compact size and wireless connectivity, serves as the core processing unit of this project, collecting data from biomedical sensors and running ML models for classification.

E. Importance of Remote Alerts and Accessibility

Early intervention is crucial in managing preeclampsia risk, and real-time alerts—delivered via an LCD display, buzzer, and SMS notifications—enhance patient awareness and caregiver responsiveness. The proposed system is designed for accessibility, ensuring that pregnant women, particularly those in rural or underserved areas, receive timely health alerts for immediate medical attention.

III. RELATED WORKS

Several studies have explored AI-driven solutions for detecting and managing preeclampsia, leveraging machine learning and biomedical data analysis to enhance early diagnosis and intervention. This section reviews notable research efforts in the field, highlighting different methodologies and their contributions to preeclampsia detection.

Soft Voting-Based Ensemble for Preeclampsia Prediction

OknalitaSimbolon et al. (IEEE, 2020) proposed a mobile application that integrates machine learning for preeclampsia risk prediction. The model employs a soft voting ensemble approach, combining classifiers such as k-Nearest





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Neighbors, Support Vector Machines, and Multi-Layer Perceptron to enhance accuracy. Their system achieved an impressive 98.51% accuracy, demonstrating the effectiveness of ensemble learning in medical predictions.

Preterm Preeclampsia Risk Modeling Using Biophysical Markers

Bryn C. Loftness et al. (IEEE, 2023) explored the potential of identifying preeclampsia risk prior to conception by analyzing biomarkers derived from hemodynamic, biochemical, and biophysical measurements. Their study trained machine learning models on data from 80 women, yielding a promising detection rate of 88% using a support vector machine (SVM). This research emphasizes the importance of early risk assessment for preventive care.

Feature Selection Algorithms for Preeclampsia Prediction

Jose F. Carreño et al. (IEEE, 2021) conducted a comparative analysis of feature selection methods to predict preeclampsia based on proteomics data. Their study applied dimension reduction techniques such as the Imperialist Competitive Algorithm and Sample Progression Discovery for efficient data processing. Results showed an accuracy of approximately 90%, reinforcing the significance of feature selection in refining predictive models.

Platelet Distribution Width and Plateletcrit in Nonthrombocytopenic Preeclampsia

Padmaja A. Havle et al. (IEEE, 2024) investigated platelet indices as markers for evaluating the severity of preeclampsia. Their study analyzed variations in platelet distribution width (PDW) and plateletcrit to assess disease progression. Findings suggested that monitoring platelet indices provides a valuable metric for predicting the severity of preeclampsia, aiding in timely intervention.

Hyperparameter-Tuned KNN for Preeclampsia Detection

S. Maheswari et al. (IEEE, 2024) proposed a machine learning-based approach using a hyperparameter-optimized K-Nearest Neighbors (KNN) classification model. Their system processed clinical parameters such as blood pressure, BMI, uterine artery pulsatility index, and ultrasound imaging data to improve diagnostic accuracy. The model incorporated advanced optimization techniques to fine-tune performance, ensuring reliability in real-time predictions.

IV. PROPOSED MODULES

The development of the AI and IoT-based preeclampsia detection system is structured into several functional modules, each responsible for a specific aspect of the system's operation. These modules work together to ensure seamless data acquisition, processing, analysis, and alert generation.

1. Sensor Data Acquisition Module

This module is responsible for collecting real-time physiological data from biomedical sensors integrated into the system. The key sensors used include:

- Heartbeat Sensor Monitors the heart rate to detect abnormal patterns.
- SpO₂ Sensor Measures oxygen saturation levels to identify potential hypoxia.
- Body Temperature Sensor (LM35) Tracks body temperature variations.
- Blood Pressure Sensor Captures systolic and diastolic pressure readings.

All sensor readings are transmitted to the Raspberry Pi Pico W for processing and analysis.

2. Preprocessing and Data Normalization Module

Raw sensor data often contains noise and inconsistencies due to environmental or physiological variations. This module performs essential preprocessing tasks, including:





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- Signal filtering to remove noise.
- Normalization of sensor data to ensure consistent scale.
- Handling missing or erroneous values to maintain data integrity.

3. Machine Learning-Based Diagnosis Module

This module processes the sensor data using a trained machine learning model to classify readings as either normal or indicative of preeclampsia. The key steps include:

- Feature extraction from collected physiological data.
- Running predictive analysis using classification algorithms.
- Decision-making based on predefined thresholds and learned patterns.

The AI model has been trained using a dataset of preeclampsia-related cases to ensure accurate predictions.

4. Alert and Notification Module

Upon detecting an abnormal condition, this module triggers immediate responses:

- Buzzer Activation Emits an audible alert to notify the user of a critical health issue.
- LCD Display Notification Displays real-time sensor readings and warning messages.
- SMS Alert System Sends emergency notifications to registered caregivers or healthcare professionals for timely intervention.

This module ensures that abnormal health conditions do not go unnoticed, facilitating quick medical response.

5. IoT Communication Module

This module enables remote monitoring and data transmission through wireless connectivity. The Raspberry Pi Pico W facilitates:

- Sending sensor data to a cloud-based platform for storage and further analysis.
- Enabling caregivers and healthcare providers to access live health data.
- Integrating additional communication methods such as GSM or Wi-Fi-based alerts for enhanced accessibility.

6. User Interface Module

Designed for user-friendly interaction, this module provides:

- An LCD display for real-time parameter tracking.
- Simple navigation controls for adjusting settings or configuring alerts.
- Compatibility with mobile applications or web interfaces for extended usability.

7. System Power and Hardware Management Module

Since portability and efficiency are key aspects of the design, this module ensures:

- Optimal power consumption for prolonged battery life.
- Management of hardware resources to prevent overheating or failures.
- Compatibility with multiple power sources, including battery-operated setups for remote use.





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V. BLOCK DIAGRAM

OVERALL VIEW



Fig-3: Overall View of the AI and IoT-Based Preeclampsia Detection System

The proposed AI and IoT-based preeclampsia detection system is designed to provide continuous health monitoring for pregnant women by integrating biomedical sensors, machine learning, and real-time alert mechanisms. The system offers an intelligent, cost-effective, and accessible solution for early detection of preeclampsia, ensuring timely intervention and improved maternal healthcare outcomes.

VI. EXPERIMENTAL RESULTS AND DISCUSSION

The implementation of the proposed AI and IoT-based preeclampsia detection system successfully demonstrated the ability to monitor, analyze, and classify physiological data in real time. The final prototype was tested using simulated and real-time sensor inputs to validate the functionality and effectiveness of the hardware and machine learning integration.

Key health parameters, including heart rate, oxygen saturation (SpO₂), body temperature, and blood pressure, were continuously monitored using respective sensors connected to the **Raspberry Pi Pico W** microcontroller. The system displayed the readings on the LCD screen while simultaneously transmitting the collected data to an onboard machine learning model for analysis.

The machine learning model, trained on pre-classified datasets of normal and abnormal vital sign patterns, performed binary classification to detect abnormalities indicative of preeclampsia. During testing, the model exhibited **high accuracy in identifying abnormal cases**, especially when blood pressure levels exceeded **140/90 mmHg**, heart rate fluctuated beyond **100 bpm**, or SpO₂ levels dropped below **92%**. These findings confirm the model's robustness in detecting preeclampsia-related risks.

Upon detecting a critical abnormality, the system triggered an immediate response:

- **Buzzer activation** to alert the user.
- **Real-time notifications** displayed on the LCD screen.
- Automated SMS alerts sent to registered caregivers or healthcare professionals.





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VII. PERFORMANCE ANALYSIS

During testing, various combinations of sensor inputs were fed into the system to assess its responsiveness and accuracy:

- The buzzer's response time was found to be instantaneous, ensuring immediate awareness.
- The SMS alert transmission was completed within a few seconds, depending on the network connectivity.
- **Continuous monitoring capability** proved valuable for detecting subtle deviations in health parameters that might otherwise go unnoticed in periodic medical checkups.

VIII. LIMITATIONS AND CHALLENGES

While the system showcased excellent performance, some challenges were identified:

- Sensor placement sensitivity Blood pressure readings depended on correct sensor positioning, requiring user training or calibration for accurate results.
- Dependency on internet connectivity SMS alerts rely on consistent network access, which could be a limitation in rural or remote areas.
- **Hardware constraints** The Raspberry Pi Pico W, while efficient, has limited computational power for advanced AI models, restricting potential upgrades without external processing units.

IX. FUTURE ENHANCEMENTS

To address these limitations, **potential improvements** include:

- Incorporating a GSM module for SMS alerts independent of internet access.
- Enhancing AI model sophistication to improve prediction accuracy.
- **Optimizing hardware efficiency** by integrating additional edge-computing capabilities.

X. CONCLUSION AND FUTURE WORK:

CONCLUSION

The development of the AI and IoT-based preeclampsia detection system highlights the potential of intelligent health monitoring solutions in maternal healthcare. By integrating biomedical sensors, real-time data processing, and machine learning algorithms, this system provides an accessible, cost-effective, and proactive approach to detecting preeclampsia symptoms at an early stage.

The successful **implementation and testing** of the prototype demonstrate its ability to **continuously monitor vital signs**, process sensor data through AI classification, and trigger timely **alerts for early intervention**. The incorporation of **a buzzer**, **LCD display**, **and SMS notifications** ensures that abnormalities are promptly detected, facilitating faster medical response and reducing the risk of complications.

One of the key advantages of this system is its suitability for remote and non-clinical environments, particularly in rural or underserved areas where traditional healthcare infrastructure may be limited. The low-power design, portability, and affordability of the Raspberry Pi Pico W make it an ideal microcontroller for implementing smart maternal health solutions.

Overall, this project lays the foundation for technology-driven improvements in prenatal care, enabling early diagnosis, reducing hospital dependencies, and enhancing maternal safety. With continued research and development, the system can evolve into a comprehensive healthcare tool for pregnancy-related monitoring, contributing to better health outcomes for both mothers and infants.





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FUTURE WORK

While the current implementation has successfully met its objectives, several areas for **enhancement and expansion** remain:

Enhanced AI Model Accuracy – The machine learning classification can be further optimized using **larger datasets** and **advanced predictive algorithms** to improve diagnostic precision.

Integration with Cloud-Based Healthcare Platforms – Expanding the system to support **cloud connectivity** would enable healthcare professionals to remotely access patient health data, offering **real-time intervention capabilities**.

GSM-Based Alert System – To overcome challenges related to **internet dependency**, a GSM-based module can be integrated for **offline emergency notifications**, ensuring caregivers receive alerts even in **network-constrained** regions.

Wearable Device Adaptation – Miniaturizing the system into a wearable form factor, such as a smart bracelet or patch, could provide continuous health tracking with minimal user intervention.

Expanded Application for Other Pregnancy Complications – The core framework can be adapted for **monitoring additional pregnancy-related conditions**, such as **gestational diabetes**, **anemia**, **and fetal distress**, broadening its scope within maternal healthcare.

User-Friendly Mobile Application Interface – Developing a smartphone app to complement the system would allow users to visualize sensor data, receive alerts, and consult healthcare professionals seamlessly.

Final Outlook

By addressing these **future improvements**, the proposed **AI-powered maternal health monitoring system** could evolve into a **robust**, **scalable healthcare solution**, capable of **enhancing prenatal care**, **reducing maternal mortality rates**, and **improving overall pregnancy safety**.

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