An Intelligent Machine Learning Framework for Maternal Risk Assessment and Preeclampsia Prediction

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Abstract: Pre-eclampsia is a critical pregnancy complication that generally occurs after 20 weeks of gestation and is characterized by elevated blood pressure and potential damage to vital organs, posing significant risks to both maternal and fetal health. Early detection of pre-eclampsia is essential for effective clinical management and prevention of severe complications. With the growing availability of healthcare data, machine learning approaches have become valuable tools for predictive analysis in maternal healthcare. This study focuses on the prediction of pre-eclampsia and identification of high-risk pregnancies using clinical and perinatal demographic data. The dataset includes key maternal health parameters such as age, blood pressure measurements, and other relevant clinical indicators. The existing approach utilizes Logistic Regression for prediction, while the proposed method employs a Deep Neural Network to capture complex relationships within the dataset and improve predictive capability. The developed models are trained and evaluated to support early risk identification and assist healthcare professionals in making informed decisions for timely medical intervention. The proposed framework highlights the potential of machine learning techniques in enhancing early detection and improving maternal healthcare outcomes.

Key Words: Pre-eclampsia Prediction, Maternal Healthcare, Deep Neural Network (DNN), Machine Learning, High-Risk Pregnancy, Clinical Data Analysis, Predictive Modelling, Healthcare Analytics

1.Introduction

Pregnancy is a critical phase in a woman's life that requires continuous monitoring and medical care to ensure the well-being of both the mother and the developing fetus. Although advancements in healthcare have significantly reduced maternal and neonatal mortality rates, pregnancy-related complications continue to pose serious challenges worldwide. Among these complications, pre-eclampsia is one of the most dangerous and life-threatening disorders affecting pregnant women. It is characterized by elevated blood pressure and signs of damage to vital organs, particularly the liver and kidneys, usually occurring after the 20th week of gestation. If left untreated, pre-eclampsia can progress to severe conditions such as eclampsia, stroke, organ failure, premature birth, and

even maternal or fetal death. Therefore, early detection and appropriate clinical intervention are essential for reducing the risks associated with this condition.

Pre-eclampsia affects a significant percentage of pregnancies globally and remains one of the leading causes of maternal and neonatal morbidity and mortality. The exact cause of pre-eclampsia is not fully understood; however, several risk factors have been identified, including maternal age, obesity, hypertension, diabetes, multiple pregnancies, genetic predisposition, and previous history of pregnancy-related complications. Healthcare professionals traditionally diagnose pre-eclampsia through regular prenatal examinations that monitor blood pressure levels, proteinuria, and other clinical symptoms. While these methods are effective for diagnosis, they often identify the condition only after symptoms become evident. As a result, opportunities for preventive treatment and early intervention may be limited.

The rapid growth of healthcare data and advances in computational technologies have created new opportunities for improving disease prediction and risk assessment. In recent years, machine learning has emerged as a powerful tool in the healthcare sector, enabling the analysis of large and complex datasets to uncover hidden patterns and relationships. The integration of machine learning and deep learning techniques enhances diagnostic accuracy, supports clinical decision-making, and contributes to safer pregnancies and improved maternal and fetal health outcomes.

2. Literature Survey

Several studies have explored the use of machine learning techniques for predicting pre-eclampsia and assessing maternal health risks. Traditional algorithms such as Logistic Regression, Decision Trees, Random Forest, and Support Vector Machines have shown promising results in analyzing clinical and demographic data for early risk identification.

Bosschieter et al. (2022) developed interpretable machine learning models for predicting maternal and fetal health outcomes, including preeclampsia. Using Explainable Boosting Machines (EBM), the study achieved accurate predictions while maintaining transparency, helping healthcare professionals understand key risk factors such as maternal age and blood pressure.

Ranjbar et al. (2022) conducted a systematic review of machine learning models for preeclampsia prediction. The study found that algorithms such as Random Forest, Gradient Boosting, and XG Boost achieved high predictive performance, demonstrating the potential of

AI-based systems for early risk detection and improved maternal healthcare management.

3. Proposed System

The proposed system utilizes a Deep Neural Network (DNN) model for early prediction of maternal health risks, including pre-eclampsia and high-risk pregnancies. Clinical parameters such as age, systolic blood pressure, diastolic blood pressure, blood sugar level, body temperature, and heart rate are used as input features. The dataset is pre-processed through missing value handling, feature scaling, and label encoding to improve data quality. SMOTE is applied to balance the dataset and enhance model performance on minority risk classes. The DNN architecture consists of multiple hidden layers, batch normalization, and dropout layers to learn complex patterns and prevent overfitting. The model is trained using the Adam optimizer and categorical cross-entropy loss function. It classifies pregnancies into low-risk, mid-risk, and high-risk categories with high accuracy. The proposed system supports early risk identification, enabling healthcare professionals to provide timely intervention and improve maternal and fetal health outcomes.

4. System Architecture

The Maternal Risk Prediction system integrates a web-based interface with a Deep Neural Network (DNN) model for early detection of pre-eclampsia and pregnancy-related risks. Users register, log in, and enter maternal health parameters through a Flask-based web application, while user information is stored in Tiny DB.

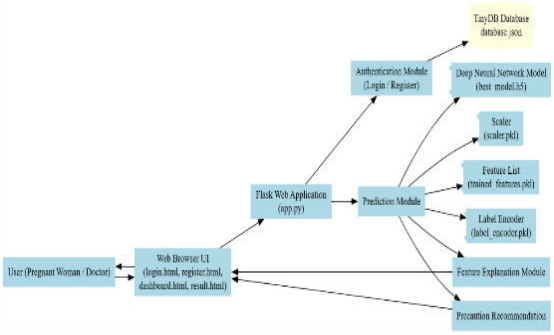


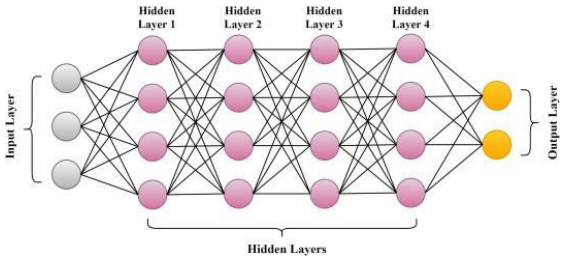
Fig 4.1: System Architecture

The input data is pre-processed using a trained scaler and then passed to the DNN model for risk prediction. The predicted result is converted into risk categories using a label encoder and displayed along with precautionary recommendations. This architecture enables accurate, efficient, and user-friendly maternal risk assessment to support timely healthcare decisions.

5. Methodology

The proposed system employs a Deep Neural Network (DNN) to analyze maternal health parameters and predict pregnancy risk levels. The input features are first normalized and then passed through multiple hidden layers with ReLU activation functions to learn complex relationships among health indicators. Batch normalization and dropout layers are

used to improve training stability and prevent overfitting.



The network learns significant patterns associated with maternal risks such as pre-eclampsia from the training data. Finally, a soft max output layer classifies the pregnancy into low-risk, mid-risk, or high-risk categories, enabling accurate early risk prediction and timely medical intervention. The evaluation process uses metrics such as accuracy to determine the percentage of correctly classified risk levels. Stratified K-Fold cross validation is used to ensure that the model performs consistently across different subsets of the dataset and avoids bias caused by uneven class distribution.

6. Design and construction

The Maternal Risk Prediction system is designed as a web-based application that integrates a Flask framework with a Deep Neural Network (DNN) model for risk assessment. The system collects maternal health parameters, preprocesses the data, and uses the trained DNN model to predict risk levels. The application is constructed with user authentication, data storage, and prediction modules to provide accurate and user-friendly maternal healthcare support.

The performance of the proposed Deep DNN model is evaluated using various evaluation techniques to measure its effectiveness in predicting maternal risk levels. After training the model on the training dataset, predictions are generated on the testing dataset to evaluate its accuracy and reliability

i) Data Collection Module: Collects maternal health data such as age, blood pressure, blood sugar, body temperature, and heart rate from healthcare datasets for analysis and prediction.

ii) Data Pre-processing Module: Cleans the dataset by handling missing values, removing inconsistencies, and scaling features to prepare the data for model training.

iii) Feature Selection Module Identifies the most important maternal health parameters that significantly contribute to pre-eclampsia and maternal risk prediction.

iv) Model Development Module: Implements Logistic Regression as the existing model and Deep Neural Network (DNN) as the proposed model for risk classification.

v) Model Training and Evaluation Module: Trains the models using the prepared dataset and evaluates their performance using accuracy and other validation metrics.

vi) Risk Prediction Module: Processes new maternal health data and predicts the

pregnancy risk level (Low Risk, Mid Risk, or High Risk) to support early medical intervention.

The model also uses validation data during training to monitor performance and prevent overfitting. Techniques such as early stopping automatically stop the training process when the validation performance stops improving.

7. Results and Discussions

The model provided moderate performance in predicting maternal risk and pre-eclampsia due to its limitations in capturing complex feature relationships. The proposed Deep Neural Network (DNN) model achieved better predictive accuracy by learning nonlinear patterns from maternal health data. Experimental results indicate that the DNN model is more effective in identifying high-risk pregnancies, supporting early diagnosis and timely medical intervention.

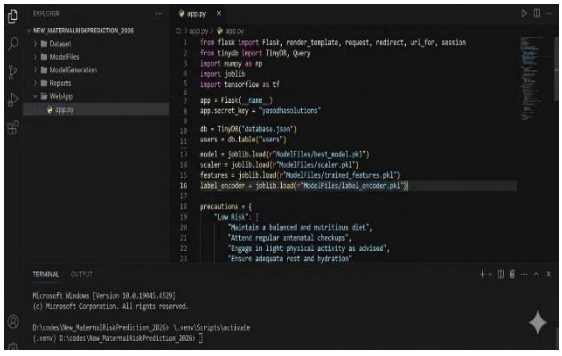


Fig 7.1: Implementation Environment of the System

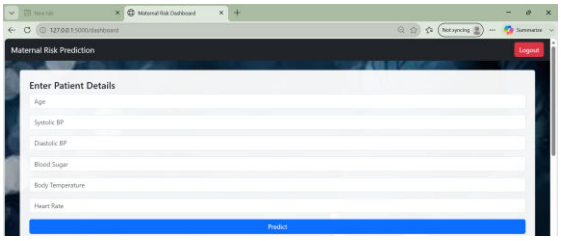


Fig 7.2: Maternal Risk Prediction Input Interface

Fig 7.2 illustrates the patient data entry interface of the Maternal Risk Prediction System, where healthcare professionals or users provide essential clinical parameters required for maternal health risk assessment. The interface includes input fields for Age, Systolic Blood Pressure, Diastolic Blood Pressure, Blood Sugar, Body Temperature, and Heart Rate, which are key physiological indicators associated with maternal health.

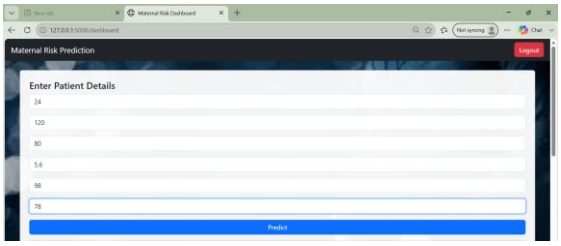


Fig 7.3: Patient Details Entry for Maternal Risk Prediction

Fig 7.3 shows the patient data entry interface where users provide clinical parameters such as age, blood pressure, blood sugar, body temperature, and heart rate for risk assessment. The entered data is processed by the trained machine learning model to generate maternal health risk predictions accurately.

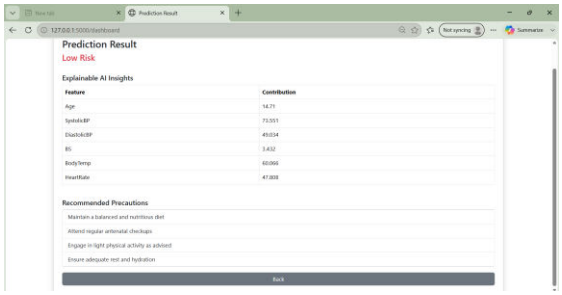


Fig 7.4. Maternal Health Risk Prediction Result with Explainable AI Insights

Fig 7.4 displays the maternal health risk prediction result, where the system classifies the patient as Low Risk based on the entered clinical parameters. The page also provides Explainable AI (XAI) insights and precautionary recommendations to help users understand the prediction and support healthy pregnancy management.

Algorithm	Accuracy
Logistic Regression	0.602589865
SVM	0.699214749
KNN	0.686372726
Naive Bayes	0.616378091
Decision Tree	0.8412525
Random Forest	0.848158806
ANN	0.72189436
Deep DNN	0.702165532

The accuracy comparison shows that Random Forest achieved the highest accuracy of 84.82%, followed by Decision Tree with 84.13%, making them the most effective models for maternal health risk prediction. ANN, Deep DNN, SVM, and KNN demonstrated moderate performance, while Logistic Regression and Naïve Bayes achieved comparatively lower accuracies.

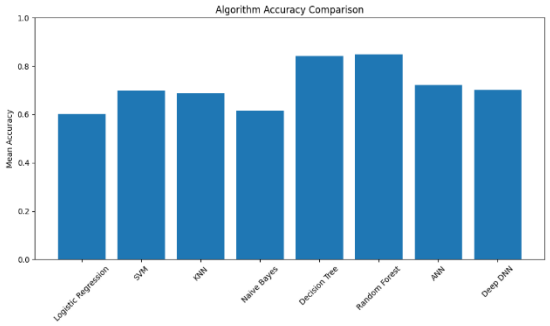


Fig 7.5. Comparison of Classification Algorithm Accuracy

Fig 7.5 compares the mean prediction accuracy of various machine learning and deep learning models for maternal health risk prediction. Random Forest achieves the highest accuracy, followed by Decision Tree, demonstrating the effectiveness of tree-based models in identifying maternal health risks. Other models such as ANN, Deep DNN, SVM, and KNN show moderate performance, while Logistic Regression and Naïve Bayes achieve lower accuracy.

8.Conclusion and Future Scope

Early prediction of pre-eclampsia is essential to reduce maternal and fetal complications during pregnancy. In this study, machine learning techniques were applied to analyze clinical and perinatal demographic data for identifying high-risk pregnancies. The existing approach used Logistic Regression, while the proposed method implemented a Deep Neural Network to better capture complex

relationships within the data. Experimental results indicate that the proposed model provides improved prediction capability compared to the traditional approach. The developed system can assist healthcare professionals in early risk assessment and support timely medical intervention. In the future, the model can be further enhanced by incorporating larger datasets and additional clinical parameters to improve reliability and applicability in real-world healthcare settings.

Future Scope: The proposed maternal risk prediction system can be enhanced by incorporating larger and more diverse healthcare datasets to improve prediction accuracy and generalization. Future work may integrate real-time patient monitoring through wearable devices and advanced deep learning techniques to enable continuous risk assessment and early detection of pregnancy complications.

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