Fetal Health Classification Using Machine Learning

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***Abstract*—The development of machine learning algorithms has completely changed the healthcare industry and has enormous potential to improve prenatal care and fetal health outcomes. This research describes a novel method for categorizing fetal health using a variety of machine learning approaches. The goal is to create a dependable and accurate system that helps medical practitioners identify and forecast fetal health issues early on the basis of pertinent clinical data.**

A comprehensive dataset with a variety of fetal health markers, such as pertinent maternal and fetal physiological measurements, will be created using the suggested methodology. These inputs are subjected to feature extraction techniques in order to extract discriminative information and ensure the best possible representation for subsequent classification tasks. To train prediction models based on the collected characteristics, a number of cutting-edge machine learning methods are used, including support vector machines (SVM), and random forests (RF).

Utilizing a sizable dataset generated from clinical records, substantial experimentation is carried out to assess the performance of the suggested approach. The dataset has been preprocessed in a way that takes into account missing values, outliers, and class imbalance. The trained models are rigorously tested and evaluated using various performance metrics, including accuracy, precision, recall, and F1-score, to assess their effectiveness in accurately classifying fetal health conditions.

The outcomes show the potential of machine learning algorithms for categorizing fetal health. The suggested method possesses high accuracy and strong predictive capabilities, allowing for the early identification and classification of fetal distress, typical symptoms, and other potential health concerns. The comparative examination of several algorithms reveals their relative strengths and shortcomings and sheds light on the best methods for categorizing fetal health.

This research provides a viable path toward improving prenatal care and lowering the frequency of unfavorable outcomes pertaining to fetal health by utilizing the capabilities of machine learning algorithms.

***Index Terms*—Fetal health classification, machine learning algorithms, prenatal care, feature extraction, support vector machines, random forests, predictive modeling, healthcare.**

I. Introduction

Fetal Health Classification using Machine Learning aims to develop a predictive model that can accurately classify the health status of a fetus based on certain features and variables. Detecting fetal health issues can be challenging, and traditional methods such as fetal monitoring can be time-consuming and subjective. Thus, this project involves training multiple ML models on a dataset of fetal health indicators and outcomes, such as fetal heart rate, uterine contractions, and fetal movements, as well as maternal health factors, such as age, weight, and medical history.

The goal of this project is to develop a model that can accurately predict the health status of a fetus, such as whether it is healthy, at risk, or in distress, based on these indicators. This can be useful in identifying potential health issues early on, allowing for timely intervention and potentially reducing the risk of complications or adverse outcomes. This project involves various techniques, such as ***logistic regression, decision trees, k-nearest neighbors, naive bayes*** etc.

The accuracy and reliability of the model will depend on the quality and quantity of the data used for training and the choice of the appropriate machine learning algorithms. Hence, different models are used to compare and contrast.

Overall, a Fetal Health Classification Machine Learning project has the potential to improve the ***monitoring*** and ***management*** of fetal health during pregnancy, leading to better health outcomes for both the mother and the child.

II. Related Work

Several studies have been conducted to explore the application of machine learning techniques in fetal health classification based on cardiotocographic (CTG) data. In [1], they proposed a fetal health classification model using machine learning. They employed various features extracted from CTG data and achieved promising results in accurately predicting the fetal health status.

In [2] different efficient machine learning methods were evaluated for fetal health classification. The study aimed to identify the most effective algorithm for accurate classification. Their findings provided valuable insights into the performance of various machine learning techniques in fetal health classification.

In [3], they investigated the use of machine learning in fetal cardiology. Their study explored the potential applications and expectations of machine learning techniques in analyzing fetal heart data. The authors discussed the challenges and future directions of machine learning in this domain.

In [4], they introduced DeepFHR, an intelligent prediction model for fetal acidemia based on fetal heart rate (FHR) signals using a convolutional neural network. Their work

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demonstrated the potential of deep learning techniques in predicting fetal acidemia accurately, which is crucial for timely intervention and prevention of adverse outcomes.

In [5], they proposed an AutoML and explainable artificial intelligence (XAI) approach for classifying fetal health status using cardiotocography measurements. Their study focused on diagnosing the major contributing factors in fetal health classification. The integration of AutoML and XAI techniques allowed for interpretable and accurate predictions.

In [6], machine learning techniques were applied to predict fetal health status based on maternal clinical history. The authors utilized various machine learning algorithms and maternal clinical information to develop a predictive model. The findings highlighted the potential of utilizing maternal clinical data for fetal health assessment.

Overall, these studies demonstrate the growing interest in applying machine learning techniques to fetal health classification using different approaches, including feature-based models, deep learning architectures, comparative analyses, and the integration of AutoML and XAI. These works contribute to the understanding of the capabilities and limitations of machine learning in this field and pave the way for further advancements in fetal health assessment.

III. Methodologies

A. Data Collection

The dataset used in this study was obtained from Kaggle, a popular online platform for data science and machine learning. It was specifically collected for the purpose of analyzing and classifying Cardiotocogram (CTG) exams, which play a crucial role in assessing fetal health during pregnancy. The dataset consists of 2126 records, each representing a CTG exam. These records contain 22 quantitative features extracted from the CTG exams, providing valuable information about the fetal heart rate (FHR), fetal movements, uterine contractions, and other relevant parameters. The features were obtained by analyzing the ultrasound pulses and their corresponding responses during the exams.

The objective of this study is to classify the CTG exams into three distinct classes: Normal, Suspect, and Pathological. The classification task is a critical step in identifying potential risks to fetal health and enabling healthcare professionals to take appropriate actions to prevent child and maternal mortality. The class labels in the dataset are discrete, with values of 1.0, 2.0, and 3.0 representing Normal, Suspect, and Pathological classes, respectively. To ensure the accuracy of the dataset labels, three expert obstetricians independently classified each CTG exam into one of the three classes mentioned above. Their assessments were based on their extensive knowledge and experience in the field of obstetrics and gynecology. This multi-expert approach helps minimize potential biases and provides robust classifications for further analysis and research.

The dataset comprises a total of 2126 data points or instances, each representing a unique CTG exam. The 22 quantitative features extracted from each exam provide comprehensive information about various aspects of fetal well-being. These features include measurements related to FHR, fetal movements, uterine contractions, and other relevant parameters, offering valuable insights into the health status of the fetus.

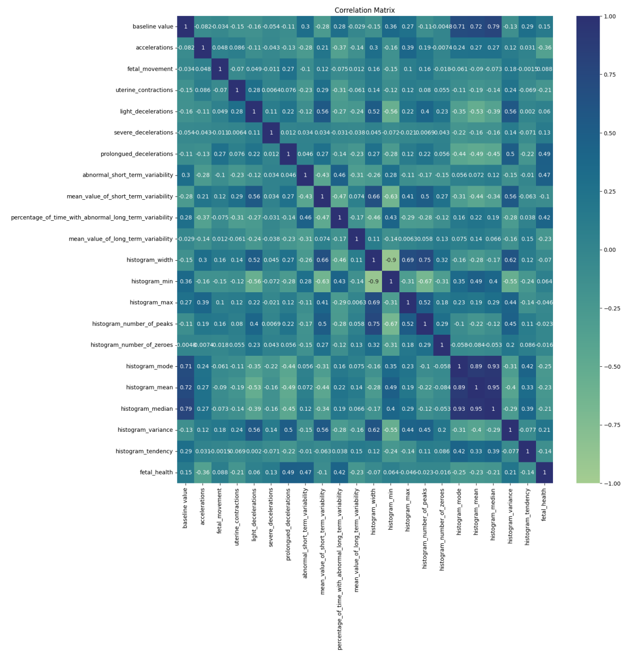

Fig. 1. Correlation Matrix

B. Imbalanced Dataset

The distribution of instances across the output feature reveals that the unique classes, namely Normal, Suspect, and Pathological, are not evenly represented in the dataset.

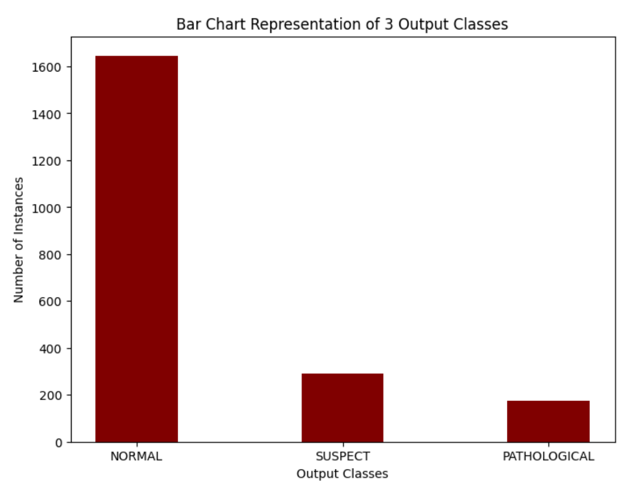

Fig. 2. Bar Chart Representation of 3 Classes

C. Data Preprocessing

In fetal health classification, data preprocessing is crucial for accurate and reliable results.

Imputation is done in the dataset as there were ***missing*** values. It helps fill missing data points.

There were also some ***categorical*** values which needs to be converted to numerical in order to do modelling. ***Label Encoding*** converts categorical data into numeric values that machine learning algorithms can process.

Duplicate values were observed thus, those were dropped to ensure each observation in the dataset is unique, avoiding bias. The instances or values can be removed by dropping a row in our data frame using pandas. The same method is also used to rid the dataset of ***NULL*** values.

By implementing these techniques, accurate non-biased predictions can be made to improve fetal and maternal health outcomes.

D. Feature Scaling

We need to scale our dataset because one particular feature might dominate other features, making the estimator unable to learn from the latter. In mathematical terms, more importance is given to the features with a higher magnitude of variance, thus to prevent that from occuring in our models, a scaler is needed. StandardScaler is used from Scikit-Learn to standardize the values of our dataset. It is influenced by outliers but our dataset does not contain any outliers thus, the estimation is more accurate. It uses a feature value, along with standard deviation and mean to scale each feature to unit variance

$$z = \frac{x - \mu}{\sigma}$$

Fig. 3. Standardization Formula using Standard Scaler

MinMaxScaler & ***RobustScaler*** are not used as aforementioned ***StandardScaler*** results in comparatively higher prediction accuracies for our models.

E. Data Splitting

The dataset is ***split*** using train_test_split from Scikit-Learn with 70% for training and 30% for testing.

The ***random state*** is set to 0, so that we get the same training and testing sets when executing different models. This way, we can compare the prediction accuracies based on identical datasets.

Another parameter, ***stratify***, is set to y so that the training and testing sets have the same proportions of class labels as the input dataset.

IV. Model Training & Testing

A. Logistic Regression

Logistic Regression is a binary classification algorithm in Machine Learning that models the relationship between input variables and a binary output. It estimates the probability of an event occurring by applying a sigmoid function to a linear combination of the input variables

B. K-Nearest Neighbor

K-Nearest Neighbors is a classification and regression algorithm in Machine Learning that finds the k closest training set to a test set and predicts its output based on the majority class or average value of the k nearest neighbors. It uses a distance metric to measure similarity between examples.

C. Naive Bayes Classifier

Naive Bayes is a probabilistic classification algorithm in Machine Learning that estimates the probability of an instance belonging to a particular class based on the Bayes theorem and assumes the input variables are independent of each other. It uses prior knowledge of class distribution and likelihood estimation from training data

D. Decision Tree

Decision Tree is a classification and regression algorithm in Machine Learning that builds a tree-like model of decisions and their possible consequences. It partitions the feature space into rectangular regions and predicts the output based on the majority class or average value of the training examples in each leaf node. The decision tree of our model is plotted in code and is shown with a max optimal depth of 6.

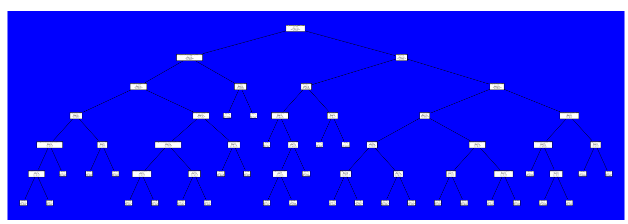

Fig. 4. Decision Tree

E. Neural Network/MLP

Neural Network is a versatile algorithm in Machine Learning that models complex relationships between input variables and output variables using interconnected layers of nodes (neurons). It uses forward propagation to compute outputs and backward propagation to adjust weights through back propagation, using gradient descent to minimize error.

F. Support Vector Machine

Support Vector Machine is a classification algorithm in Machine Learning that finds the hyperplane that maximizes the margin between classes in a feature space. It transforms the input data using a kernel function and computes the decision boundary using a subset of support vectors. It minimizes classification error and generalizes efficiently.

V. Comparison Analysis

A. Prediction Accuracy

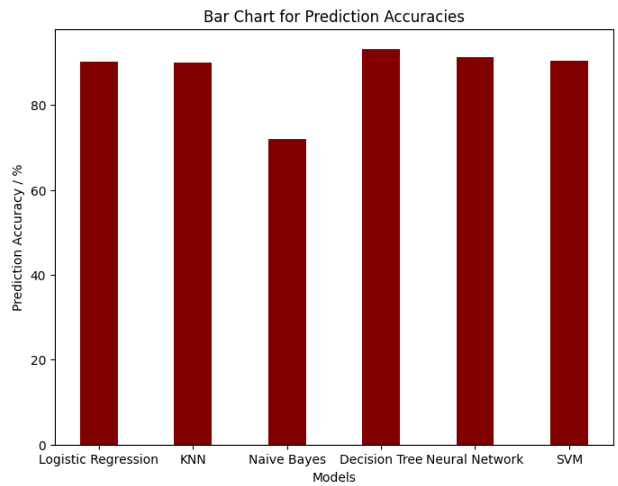

Fig. 5. Bar Chart for Prediction Accuracy (%)

B. Preicision & Recall

Models	Precision(%)	Recall (%)
Logistic Regression	82.72	79.12
K-Nearest Neighbor	85.40	77.07
Naive Bayes	66.56	74.39
Decision Tree	89.69	87.69
Neural Network	83.41	82.20
Support Vector Machine	82.43	79.19

Fig. 6. Precision & Recall for Each Model (%)

C. Confusion Matrix

The following confusion matrices have the best and worst accuracy on the tested dataset:

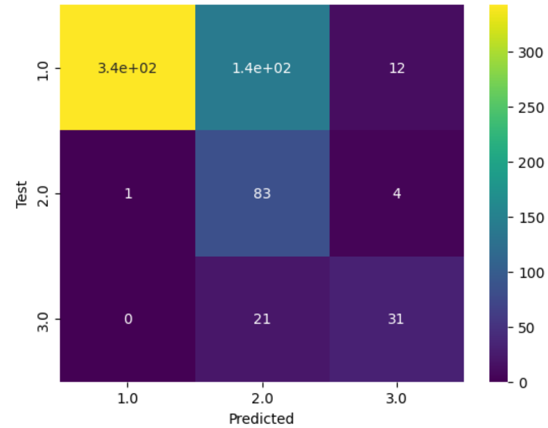

Fig. 7. Naive Bayes Confusion Matrix

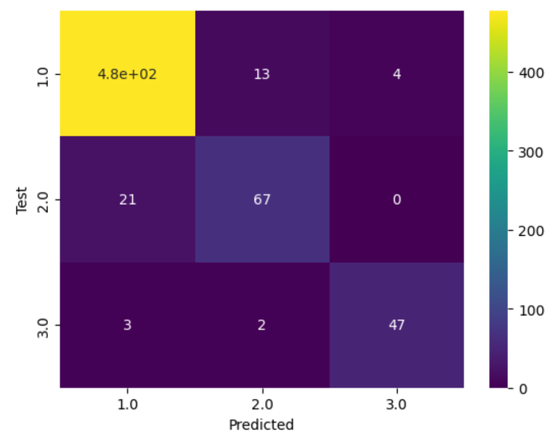

Fig. 8. Decision Tree Confusion Matrix

VI. Conclusion

After applying 6 different machine learning models to figure out which model suits our problem description the most, it is observed that ***Decision Trees*** are the most relevant machine learning model to appropriately classify fetal health at early stages of pregnancy, according to this dataset.

Due to its high rate of accuracy, precision and recall in comparison to other model counterparts, it will provide more trustworthy classifications results, consequently saving a lot of lives by identifying early stage fetal issues before it gets fatal.

In our paper, we have established the need for classification models like the Decision Tree in medical diagnosis based on predictions.

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