Fetal Health Classification

Abstract

Fetal mortality, which has been a rising concern over the years, has accounted for over 200,000 deaths, 94% in which could have been prevented. Medical professionals have gained interest in this issue and are looking into preventive measures to reduce mortality. A data set of ultrasound measurements collected from cardiotocography (CTG) examinations was analysed in order to understand the features playing a prominent role in fetal health classification. Our goal was to determine which model could be used to accurately determine characteristics that can help implement preventative measures to detect fetal abnormalities. Finding more affordable preventive measures could help to effectively care for those who live in a low-income setting. The Random Forest Classifier and Gradient Boosting algorithms are determined to have the best accuracy in analyzing the three classes and determining which CTG measurements were important. It was found that baseline fetal heart rate, accelerations and decelerations were important in the classification and should be used to help implement preventative measures.

Introduction

Child and maternal mortality has been a rising concern over the years. As of 2017, it has accounted for over 295,000 deaths, in which 94% could have been prevented. The United Nations (UN) wants to implement preventative measures in hopes to decrease child and maternal mortality. The UN expects that by 2030, countries will end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce under-5 mortality to at least as low as 25 per 1,000 live births.

Cardiotocogram (CTG) is a simple and cost accessible option to assess fetal health, allowing healthcare professionals to take action in order to prevent child and maternal mortality. The equipment itself works by sending ultrasound pulses and reading its response, thus providing important information such as fetal heart rate (FHR), fetal movements, uterine contractions and more.

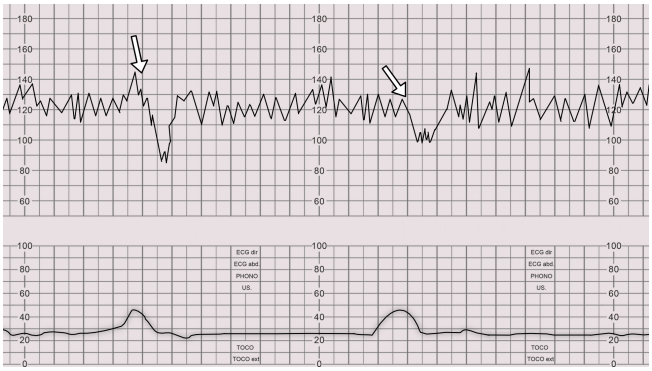

Figure 1: Sample of CTG data collected from a cardiotocograph

Using the measurements generated from CTG exams, professional obstetricians haved classified each fetal examination into three groups: Normal, Suspect, and Pathological. Normal is defined as an average and healthy fetus having a stable and normal heart condition. Suspect is defined as an infant who has an unsteady heart rate which should be closely monitored. Pathological classification is defined as an abnormal heart rate that can lead to mortality.

According to The Royal Women's Hospital, the Normal classification can be distinguished by the following conditions: having a baseline FHR of 110-160 bpm, frequent accelerations, and decelerations that last for a short amount of time. Baseline FHR is the heart rate taken at stable conditions within a 10 minute window. Accelerations are sudden increases in the baseline FHR of greater than 15 bpm for more than 15 seconds and should be present along with uterine contractions within a healthy fetus. Decelerations are sudden decreases in the baseline FHR of greater than 15 bpm for greater than 15 seconds. This feature is important because a reduction in heart rate aids preserving oxygenation. Prolonged and late decelerations are deviations from this and can result in fetal complications.

The goal of this analysis is to determine which model(s) can be used to accurately assess fetal health classification and detect fetal abnormalities early on in order to prevent mortality. This analysis can aid in discovering more affordable preventive measures that effectively care for those who live in a low-income setting.

Exploratory Data Analysis (EDA)

The data set was taken from an assessment in testing a new cardiotocogram and was retrieved from CTG examinations of different fetuses. Null values were not present in the data, therefore, minimal modifications were needed and no data was removed. Boxplots were created to compare the other features in respect to the fetal classification. Even though boxplots show that outliers were present, outliers were not taken into consideration or removed for analysis. This ensures that all data values and information were used during the analysis. There is a possibility that outliers present for one class might be associated with another class or could be defined differently by other obstetricians. Initial findings showed that the fetal classification data was imbalanced. The data contained 2126 collections and of those, 1655 were classified as normal, 195 were considered as suspect and 176 were classified as Pathological.

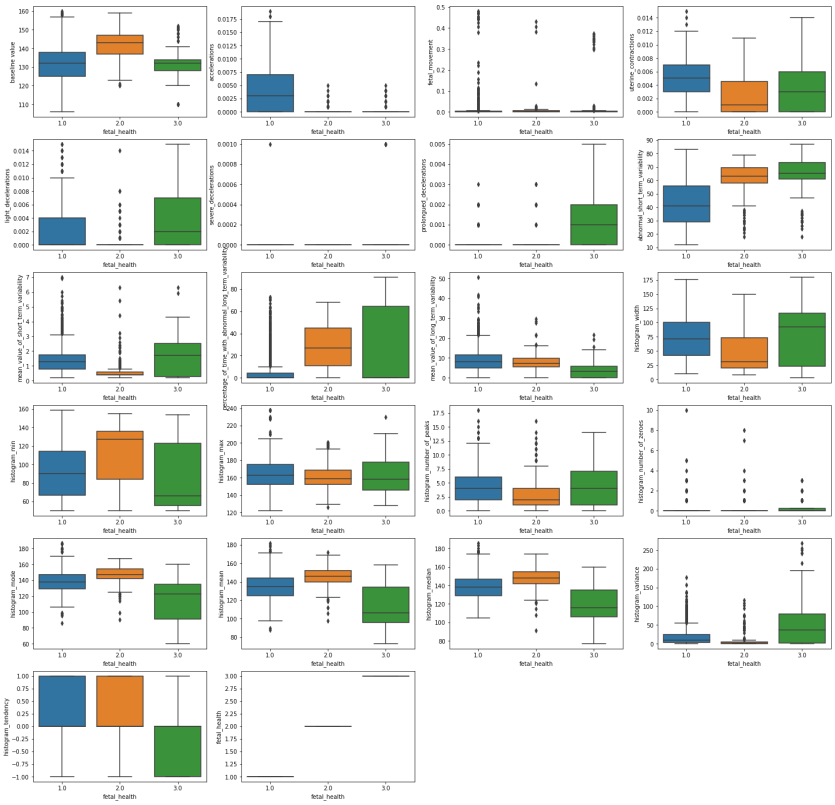

Figure 2: Boxplot of different each feature with respect to the fetal classification

The data also showed certain features had certain characteristics and trends specific to a fetal class. For example, those who are classified as pathological showed a relatively low acceleration whereas normal fetuses had frequent acceleration in their heart rate. This feature was predicted to be important in determining if a fetus was healthy. Prolonged decelerations also showed a correlation with fetal health. The longer the decelerations were, the more detrimental it is for the fetal health. The minimum and maximum baseline FHR examined was 106 bpm and 160 bpm respectively. Majority of the data falls within the range, however; seven of those had a heart rate out of range. These fetuses, however, were classified as Normal and did not have an impact on classification. Data showed that on average, normal fetuses have more uterine contractions.

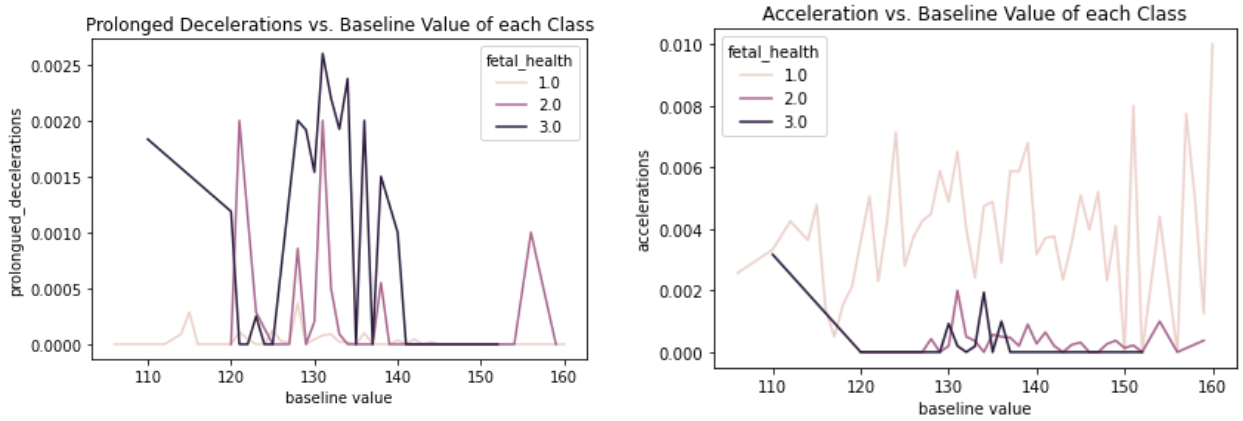

Figure 3: Prolonged Deceleration (L) and Accelerations (R) with respect to baseline FHR of each fetal classification

Preprocessing

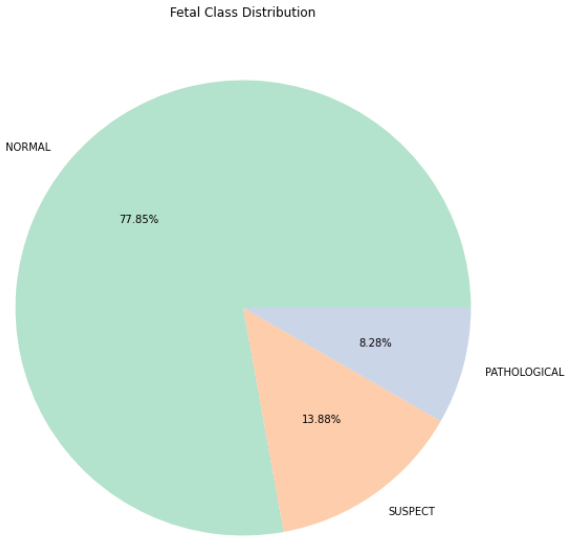

Figure 4: Breakdown of fetal classification presented in the dataset

Since the data was imbalanced, analysis was first done on an oversampled dataset and another on an undersampled dataset. The oversampled data was analyzed with respect to the fetal health, while the undersampled data was analysed with respect to each fetal class. One hot encoding was used to separate the fetal health by their class. A correlation map was generated to see which factors had a strong correlation with respect to the fetal classification. Those features were used in different algorithms by splitting into a test and train dataset. Information value (IV) was also used to determine the significance of each feature and see if they fall within the range of 0.02-0.80. Variance Inflation Factor (VIF) was performed to understand the effectiveness of the predictor variables. A VIF score greater than five was removed to decrease multicollinearity. Abnormal short term variability had a high correlation, however, it had a VIF factor greater than 5. Because of this, it was considered to not be an important feature. The correlation map showed that accelerations and prolonged deceleration have a high correlation with fetal health in both of the resampled data. Acceleration had a value of -0.494 and prolonged deceleration had a value of -0.498 in both of the resampled data.

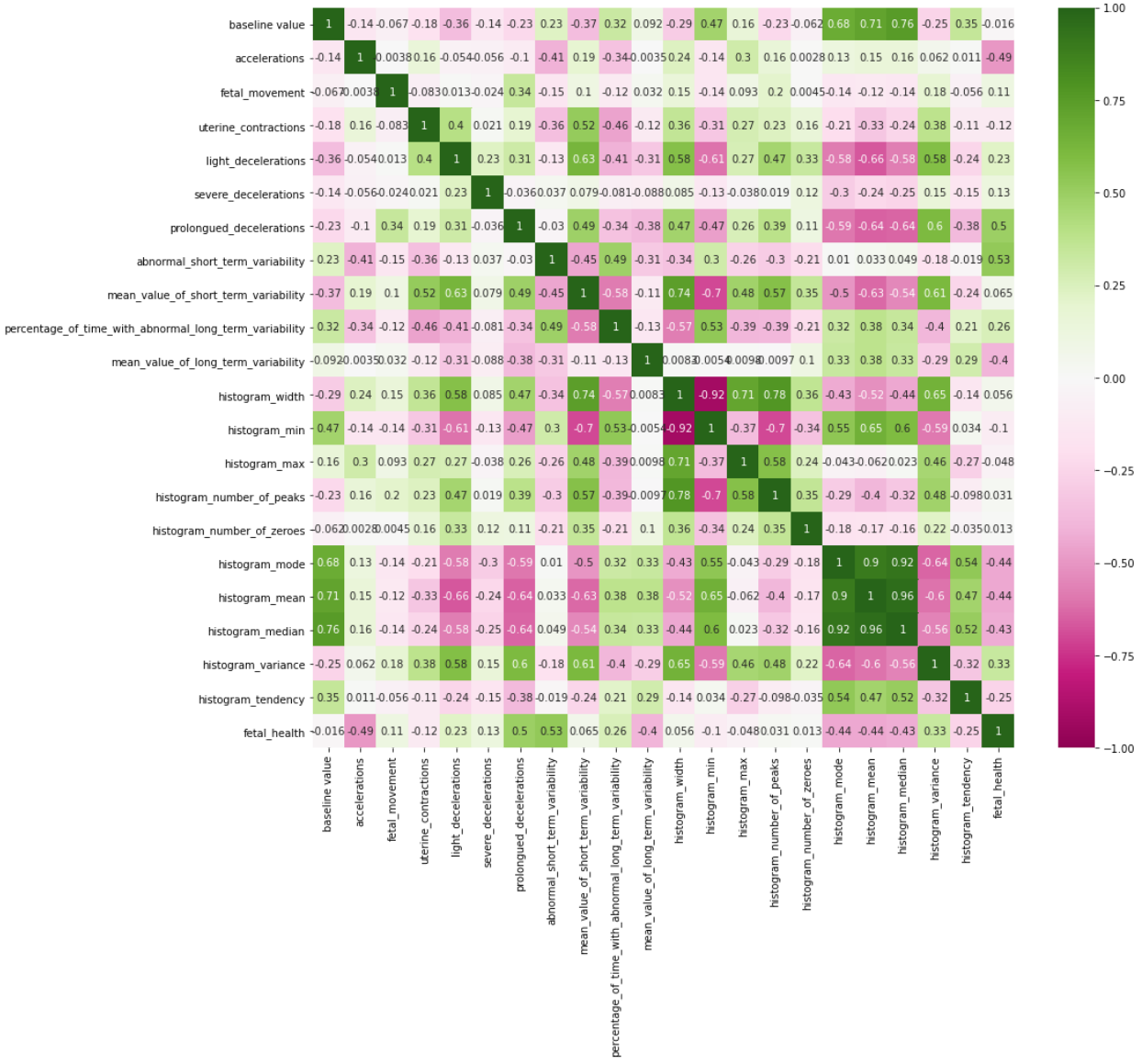

Figure 5: Correlation map of the oversampled data set

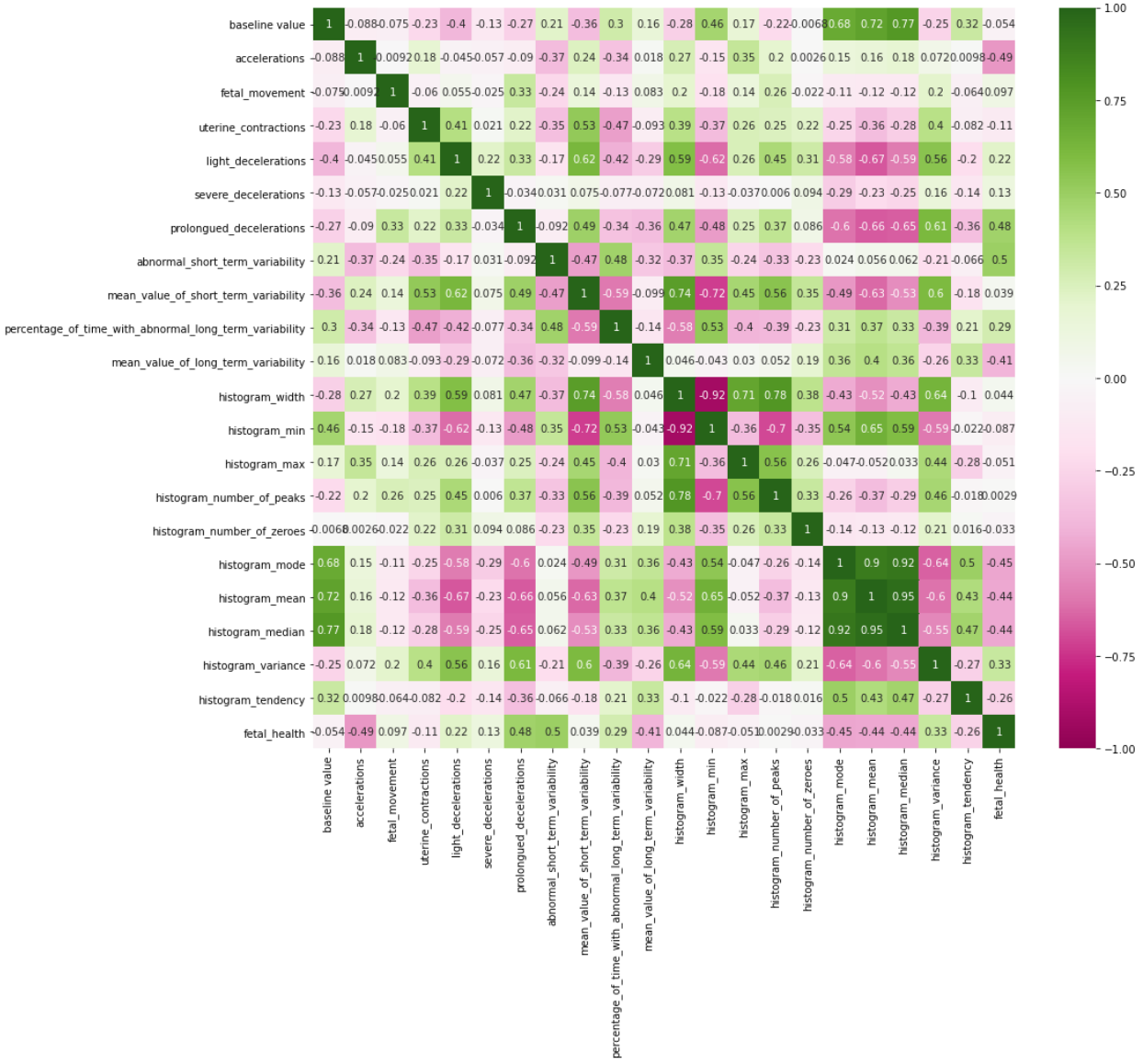

Figure 6: Correlation map of the undersampled data set

Modeling

Logistic regression, random forest classifier and gradient boosting algorithms were used to model for this analysis. The over sampled data with respect to the fetal health as a whole showed that the gradient boosting algorithm had the most accuracy. The undersampled data showed that the normal class worked better with the random forest classifier and pathological classification worked better with gradient boosting. Both of these algorithms worked in the suspect classification.

Shapley Additive Explanations (SHAP) Analysis was performed for each feature to see the change in the expected model prediction. Looking at the SHAP analysis, accelerations and percentage of long term abnormal variability had a strong importance in its feature, as seen in the original data. In the

undersampled data however, the histogram mean, which is the average baseline FHR, shows to have a strong feature in respect to each fetal class.

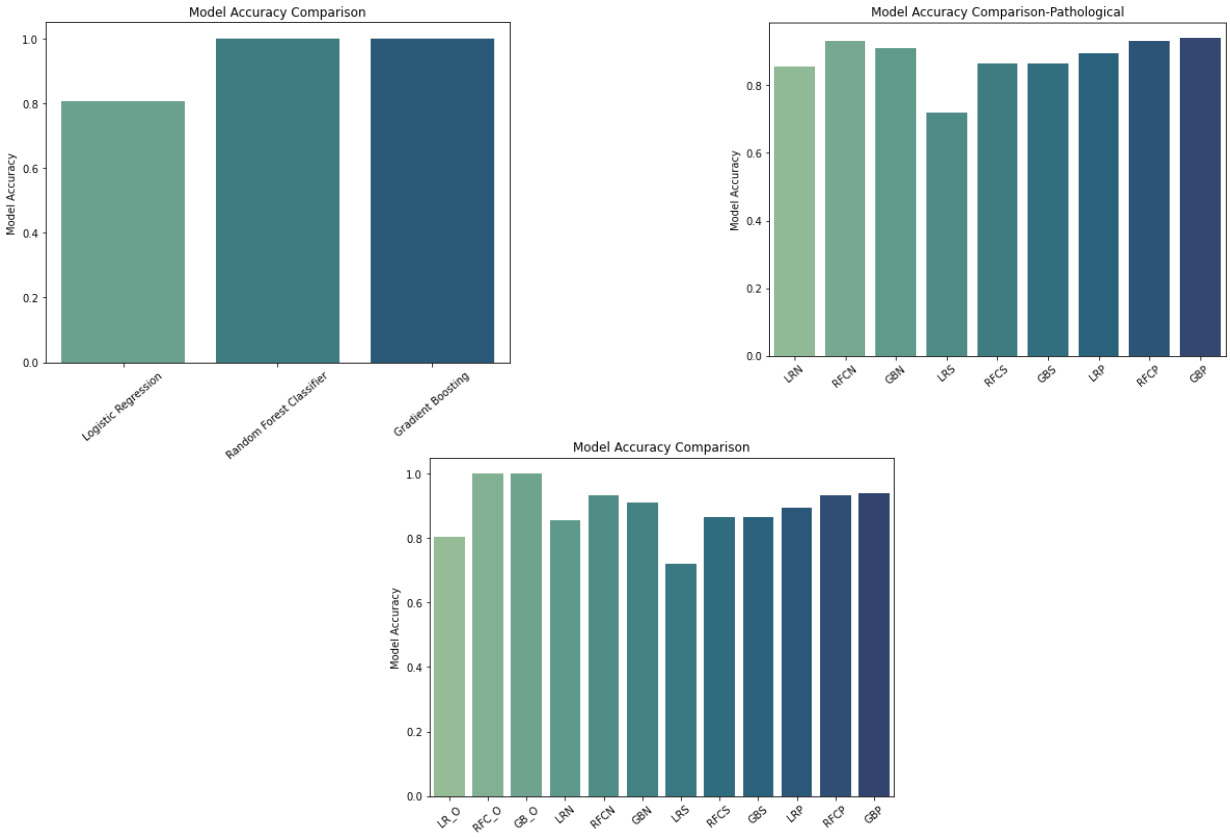

Figure 6: Model Accuracy of the oversampled data (Top L) and the undersampled data (Top R) and combined resampled data (midde)

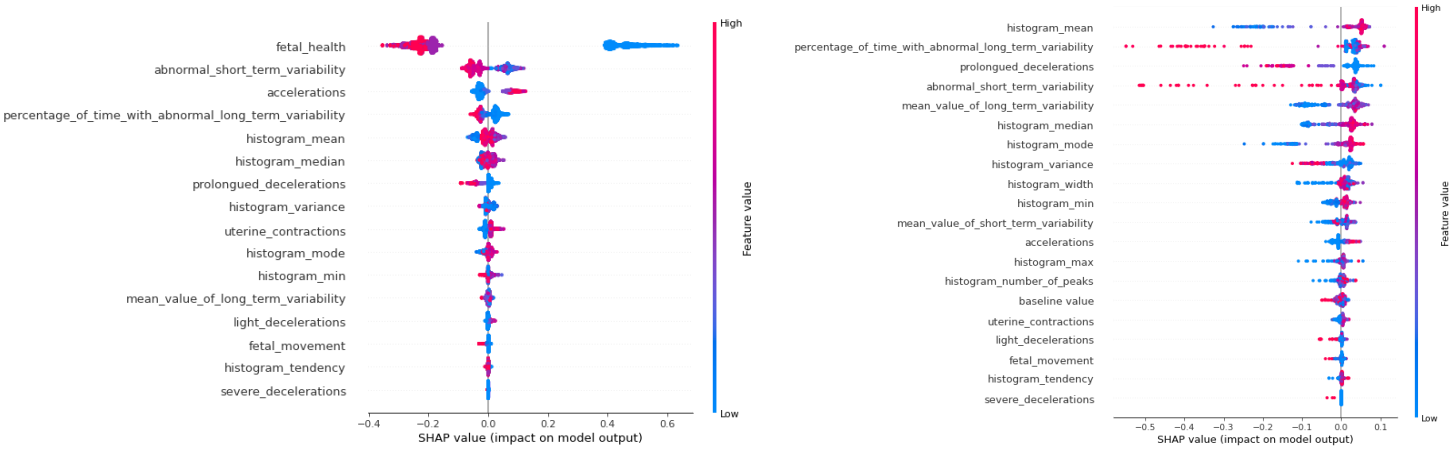

Figure 7:Shap Analysis of the oversampled data (L) and the undersampled data (R)

Findings

Findings show that when reading a CTG, obstetricians should use the accelerations, length of the decelerations, and baseline FHR to determine if a fetus is healthy or at a risk of death. If fetal baseline FHR is outside of the average range with accelerations not being present and deceleration being longer than usual, then obstetricians should take measures in bringing their heart rate back to normal. Detecting these minute changes in the heart rate can help determine fetal health problems and can help lead to preventative measures for the baby.

Recommendations

It is recommended that the physicians take CTG examinations frequently of the fetal to actively assess the heart of the fetus. If accelerations are low, not frequent or not existent, preventive measures should be taken since the fetal will be considered at a higher risk of mortality. If decelerations are longer than normal, this indicates that fetal heart rates are not accelerating. Similar to the acceleration feature, if decelerations are longer than anticipated then preventive measures should be considered. Hospitals should provide a systematic procedure in taking care of high risk fetuses to ensure care is properly given.

Future Scope

In the future, maternal demographics and socioeconomics can be recorded and used to analyze the type of healthcare these expecting mothers have access to. One can also look into to see how prominent environmental and genetic factors play a role in fetal heart and see if it has a strong association with mortality.

Resources

-Ayres de Campos et al. (2000) SisPorto 2.0 A Program for Automated Analysis of Cardiotocograms. J Matern Fetal Med 5:311-318 (link)
-https://thewomens.r.worldssl.net/images/uploads/downloadable-records/clinical-guidelines/ctg-interpretation-and-response_280720.pdf