Predictive Analysis of common risk factors in Neonates using Machine Learning

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Abstract: To identify the clinical–demographic risk factors contributing to birth asphyxia ongoing pregnancies and to suggest preventive measures. The proposed methodology is used to identify the risk factor associated with birth asphyxia such as-maternal risk factors, type of deliveries, educational status of mothers, the age distribution of mothers, gestation period, birth weight, etc. A hospital-based prospective observational study was carried out on 220 participants. After obtaining the consent of either of the parents, the detailed maternal data and history were taken in a structured questionnaire designed for the study purpose. The statistical evaluation of model performance is evaluated using these standard metrics.In this research, three types of machine learning classification algorithms which are Two class Neural networks, Two-Class Boosted Decision Tree, Multi-Class Decision Jungle were used to build the Birth asphyxia model to identify the overall risk factors associated with birth asphyxia. The findings showed that the Two-Class Boosted Decision Tree achieved the highest accuracy at 94.5%

Keywords: Birth Asphyxia, Azure Microsoft Machine Learning, Two-Class Boosted Decision Tree, Multi-Class Decision Jungle, Two-Class Neural Network

1. Introduction

Despite clinical advances, the rate of newborn morbidity and mortality remains high globally, with more than 6 million losses per year. It has been observed during the critical study that many countries in the world have seen no decrease in the death rate of Neonates. Neonate refers to a newborn child who is a week old or younger. Birth asphyxia is one of the major causes of newborn deaths worldwide. It is one such emerging global health issue and its early detection can be very helpful. Every year three million babies are stillborn and 3.6 million die in the first month of life which is considered the neonatal period [1]. The highest proportion of perinatal fatalities (99 percent) occurs in low and middle-income regions [2]. The number of newborn deaths in the first 7 days comprises the highest overall death rate in neonates. At present 1/3rd part of all neonates' death enrolled globally occurs in India [3]. The major disease in neonatal period were Birth Asphyxia with (32%), fetal malnutrition (26%) , other respiratory condition(27%), infection(8 %) , Diarrhoea(1%), anaemia (1%) and septicaemia(5%)[1]. Among the above disease, birth asphyxia is a serious concern and also a major contributing factor for the cesarean section during the delivery of the child. In severe situations, it may lead to the death of newborn babies.

The shortfall of oxygen at the delivery time or insufficient oxygen supply that can cause serious brain injury (also called intrapartum asphyxia) in infants is a major factor that plays in birth asphyxia. Despite that, birth asphyxia may not always be the cause of prenatal and postnatal death, but its percentage of infant mortality is still quite high.

It is evident from the literature that the disease is analyzed after the infant has suffered significant damage, thus motivated the researcher to identified the overall risk factors in term pregnancies and if identified and managed in time, can reduce the neonatal mortality rate at minimal cost, which will make it easier for the caregiver to adopt the technique to ensure the well-being of new-born. Unfortunately, in many middle and low-income areas, the opportunity to identify and provide corrective measures to new-born is limited due to the cost of the existing diagnostic system.

The implementation of computer technology is a ray of light that has become an expendable tool in modern business management to eradicate the darkness and is being explored in the study by numerous researchers, institutes, and industries in the field of health care. The growth of data and complexity in health care has motivated the use of artificial intelligence and other related technologies for progressive, effective, and efficient results. Statistical pattern recognition and machine learning have been the subject of great interest in the medical profession since these methodologies keep promising to enhance the sensitivity and/or specificity of disease detection and diagnosis. The upcoming section elaborates on machine learning and its classification in detail to lay the foundation of the work being carried out to analyze the risk of birth asphyxia.

1.1 Defining Birth Asphyxia

According to a report by MCCD_report_2018[1], Birth Asphyxia is the fifth primary leading cause of death in India. The newborn death rate and maternal death rate are the indices of the effective delivery of health care services in a given state. Infant mortality contributes to about 28 per 1000 live births globally and 34 per 1000 live births in India. If the state of H.P is compared with the rest of India, the infant mortality is 25 per 1000 live births , which is better, as compared to the Indian and the global average[1]. The infant mortality rate has been controlled due to effective preventive strategies against diseases like diarrhea, pneumonia, and vaccine-preventable diseases but is still high due to the high neonatal mortality rate (25 per 1000 live births).

The major contributory factors for neonatal mortality rate are prematurity, infections, Birth Asphyxia, and congenital malformations each of which accounts for 35%, 33%, 20%, and 9% respectively [3]. According to WHO[2], 4 million prenatal deaths took place every year due to Birth Asphyxia. A total of 109704 infants are born per year and a total of 2742 neonates die each year, out of which 548 babies die of Birth Asphyxia per year, 959 dies of prematurity, 904 dies of sepsis and 246 dies of congenital malformations. If we leave aside congenital malformations, prematurity, and sepsis, and considering timely intervention in 2/3rd cases of Birth Asphyxia, the neonatal mortality rate can be reduced from 25 per 1000 to 21.6 per 1000 live births i.e. total neonatal mortality may be reduced from 2742 infant deaths to 2377 infant deaths per year.

India's National Neonatology Forum has suggested that "Gasping and inadequate breathing or lack of breathing at 1 minute" should still be known as Birth Asphyxia[3] consistent with the definition given by WHO [2] as "Failure to start and continue breathing at birth"[2]. The National Neonatal Perinatal Database (NNPD) in 2000[3] used a similar definition for Perinatal Asphyxia. Birth Asphyxia affects nearly all organs such as the pulmonary system, brain, and spinal cord system, cardiovascular system, kidney failure, gastrointestinal tract, skin, hematopoietic system, etc. Among these are the most dangerous neuro abnormalities while the child does not completely recover and there's little chance of developing long-term complications including down syndrome, learning disabilities, and, in some cases, paralyzing disability which causes a huge burden both for the family and community.

Asphyxiation is currently overcome by multiple forms of diagnostic imaging including MRI, CT scan, radiology, ultrasound, endoscopy, and medical photography. However, these tests are not enough to detect the symptoms as the child should go through more tests so that one can detect the presence of prenatal asphyxia.

1.2 Causes of Birth Asphyxia

Birth asphyxia can always be induced by activities that have their root either in postpartum, the intrapartum, or the antepartum or combinations era. A recent survey shows that asphyxia tends to be predominantly antepartum of origin in 50% of situations, intrapartum in 40%, and postpartum in the remaining 10% of cases [3] as shown in Fig.2. The causative factors for birth asphyxia can be mainly divided into Antepartum like maternal age, poor outreach of health care facilities, Pre-eclampsia, gestational diabetes, and high intake of drugs cases and Intrapartum causes such as maternal fever, breech presentation, prelabour rupture of bones, and less amniotic fluid and postpartum causes such as fetal distress, malformed fetus, blood loss, birth weight, and prematurity.

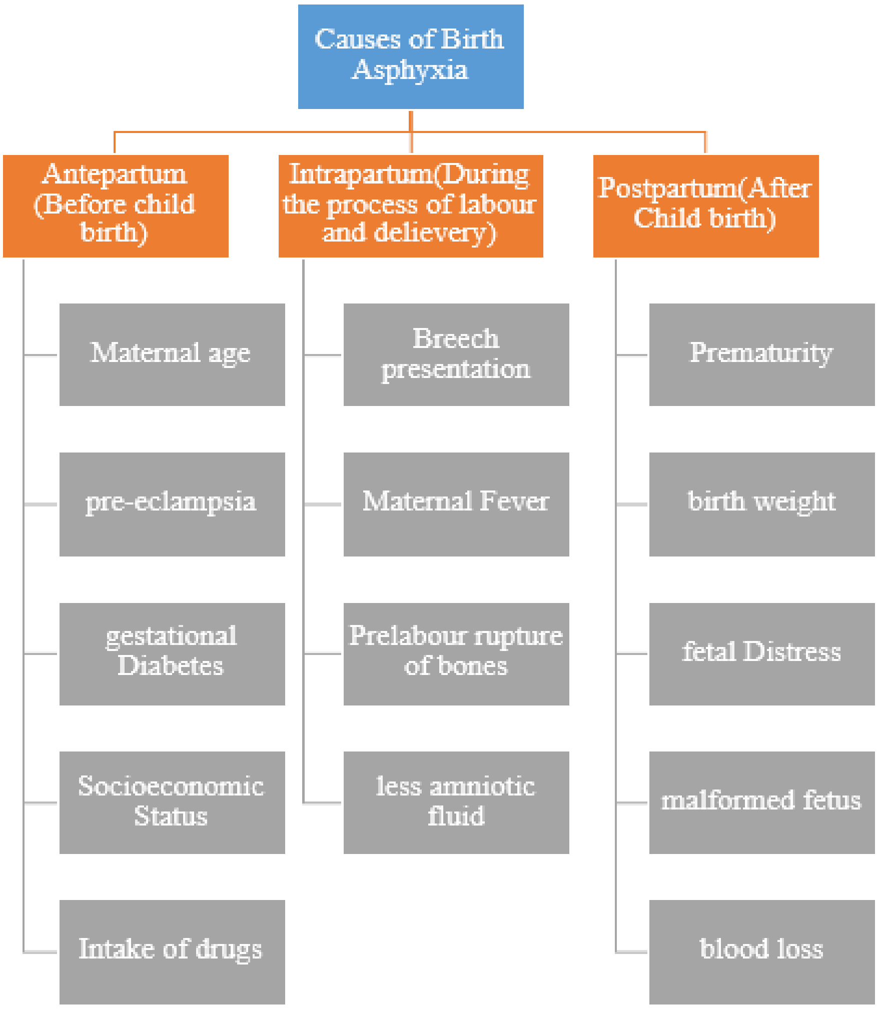

Figure. 2 Causes of Birth Asphyxia

The causes of birth asphyxia are heterogeneous and most occur before or during labor and delivery. Perinatal mortality, morbidity, and long-term sequelae have not only been related to maternal risk factors such as age, maternal illness, smoking, and socioeconomic status but also obstetric risk factors, i.e. factors related to the management of labor and fetal abnormalities such as malformations and intrauterine, growth retardation. These risk factors can be broadly classified into modifiable and non-modifiable risk factors as shown below in Table 1.

Table 1: Risk Factors of Birth Asphyxia

Modifiable risk factors	**Non-modifiable risk factors**
Hypertension	Educational status
Preeclampsia	Parity status of the mother
Gestational diabetes	Maternal age
Antepartum haemorrhage	Distance from health facility
Eclampsia	Fetal presentation
Mode of delivery	Prematurity
Premature rupture of membrane	
Means of transport	
Thyroid disorders	

It is evident from various previous literature and studies that, there is an overall difference in incidence and etiological profile of birth asphyxia in developed countries and developing countries like India, Bangladesh, Nepal, Pakistan due to differences in their health status, per capita income, literacy rate, birth rate and prevailing maternal and fetal morbidities and health facilities and nutritional status of mothers and availability of early diagnosis and intervention in high-risk pregnancies.

2. Related Work

Birth asphyxia leads to various short-term as well as long-term sequelae in a child. In the acute presentation, asphyxia could lead to multi-organ dysfunction or even death, whereas in the chronic sequelae, childhood survivors of neonatal hypoxic-ischemic encephalopathy might develop cerebral palsy, developmental delay, visual, hearing, and intellectual impairment, epilepsy, and learning and behavioral problems. Unfortunately, in developing countries accurate epidemiological data is scarce, and the exact burden of severe neurological disability due to birth asphyxia is unknown.

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In another study done by Sittikom et al[4] in July 2014 at Vajira Hospital, Navamindradhiraj University, Bangkok, Thailand, it was found that low 1-minute APGAR score was significantly associated with antenatal care, meconium-stained amniotic fluid, operative obstetric deliveries, and low birth weight. In this study, total 13 600 newborns were enrolled and four antepartum and intrapartum variables were identified as independent factors associated with low 1-minute APGAR score. These included antenatal care, meconium-stained amniotic fluid, mode of delivery and low birth weight.

Nath and Dipangkar (2016)[5] in India conducted a study at the Neonatal Intensive Care Unit, Guwahati Medical College and Hospital, Assam in which the authors concluded that there were lots of potentially preventable factors associated with birth asphyxia, which can be prevented if there is proper antenatal care including prevention of anemia and pregnancy-induced complications and proper management during the early neonatal period. Among 150 babies, they found a significant association between birth asphyxia and factors like poor antenatal check-up (48%), MSAF (38.7%), maternal anemia (78%), PIH (20.7%), eclampsia (15.3%), prolonged labor (28%), antepartum fetal distress (14.7%); 24% cases were in HIE stage I, 32% in stage II and 44% in stage III. Multi-organ involvement was seen with renal (9.3%), hematological (3.3%) abnormalities.

A similar study was conducted in Pakistan by[6] in 2011 at Civil Hospital Karachi. Demographics of both the mothers and neonates were noted and Questions regarding possible risk factors were asked from mothers. A total of 240 newborns were enrolled in the study. Significant antepartum risk factors were maternal age of 20–25, booking status, pre-eclampsia, and primigravida. Significant intrapartum risk factors were breech presentation, home delivery, and maternal fever. Significant fetal risk factors were resuscitation of a child, pre-term babies, fetal distress, and baby weight.

Kumar et al. [7] conducted a descriptive cross-sectional study in 2014 in the departments of Pediatrics, and Gynecology/Obstetrics LUH Hyderabad (India). The Authors concluded that birth asphyxia in their community was due to a lack of proper perinatal care, late recognition, and late referral of high-risk pregnancy. Most risk factors associated with birth asphyxia could be prevented by timely and accurate diagnosis and proper management. In this study, 300 asphyxiated babies were evaluated for risk factors of birth asphyxia. Risk factors in birth asphyxia found in decreasing frequency of distribution were irregular antenatal visits (46%), prolonged rupture of membrane (PROM) (40%), prolonged labor (40), anemia (24%), pre-eclampsia (17%), and antepartum hemorrhage (13%).

Another Indian study done in 2015 by Srivastava et al. [8] found that amongst 4714 live births, there were 171 cases of birth asphyxia, providing an incidence of 36 per 1000 live births. Risk factors significantly associated and having the most strong association with perinatal asphyxia was observed in eclampsia followed in decreasing frequency by prematurity, meconium staining of amniotic fluid, antepartum hemorrhage, gestational diabetes mellitus, breech presentation, oligohydramnios, PROM, PIH. Asphyxia-related mortality was 10.6 per 1000 live births. The authors further concluded that there is a need to strengthen intrapartum management and early identification of mothers with high-risk pregnancies to reduce asphyxia mortality and morbidity.

In 2010–2011, authors in [9] conducted a case-control study on “risk factors associated with the development of perinatal asphyxia in neonates” at the Hospital Universitario del Valle, Cali, Colombia. Fifty-six cases and 168 controls were examined. Premature placental abruption, labor with a prolonged expulsive phase, lack of oxytocin use, and mothers without a partner were risk factors for the development of perinatal asphyxia in the study population. The authors concluded that proper control and monitoring of labor, development of a thorough partograph, and active searches are recommended to reduce the frequency and negative impact of perinatal asphyxia.

To conclude, the overall review of the literature depicts that in developed countries the risk factors responsible for birth asphyxia are maternal morbidities like PIH, anemia, placental abruption, placenta previa, breech delivery, abnormal uterine contractions, prolonged labor, fetal gestation, fetal weight, and operative vaginal deliveries. Whereas in developing countries the major risk factors responsible for birth asphyxia were antenatal care (50% cases), home delivery (40% cases), fetal hypoxia (25% cases), maternal anemia (10% cases), prolonged labor (21.6% cases), antepartum hemorrhage (13.3% cases), eclampsia (8.3% cases) and poor monitoring of labor process. This paper provides a thorough analysis of risk factors and problem parameters of Birth Asphyxia. So there is a need for a model which can analyze the risk factor of perinatal asphyxia during the antepartum stage to minimize the effect of damage to the baby and reduce the number of neonates death. Many machine learning models are used for the prediction and the performance of their model is compared and analyzed using per class metrics, micro and macro averages.

3. Proposed Methodology

As is noted in the previous section that there is a need to design a novel system that can analyze various risk factors in the antepartum stage. To achieve this objective a model is proposed. The proposed model is based on input factors such as age and parity of mothers, gestation period, maternal education, etc. and then applying different machine learning techniques to quickly analyze the risk factor of Birth Asphyxia during the antepartum stage to minimize the effect of damage to the baby and reduce the number of neonates morbidity. The block diagram of the proposed model is shown in fig. 3.

The steps involved in the proposed work methodology is as follows:

1) **Data Collection**- After obtaining the consent of either of the parents, the detailed maternal data and history were taken in a structured questionnaire designed for the study purpose. This included socio-demographic details of the mother, antenatal history, h/o maternal illnesses, and any prior treatment history. All the newborns of these mothers underwent detail clinical examination and APGAR/Levene's scoring at birth.

2) **Data Transformation** - The collected data was subsequently transformed and new attributes were derived to convert the data into a single format and then undesired attributes such as relation, age-desc have been removed. After data transformation, data is cleaned up to delete noisy data. Next, the selected attributes are used and they are divided so that they are used for testing the modules. To test the modules, we use the Two-Class Neural Network, Two-Class Boosted Decision Tree, and Multi-Class Decision Jungle Algorithms.

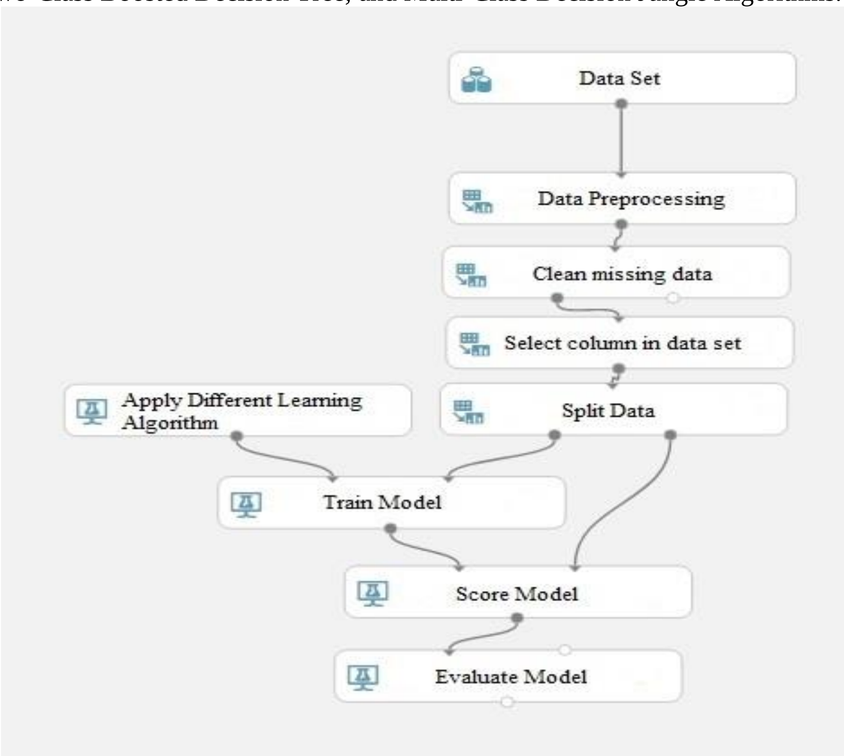


Figure 3 . A perspective view of the Proposed Model

Rating model or scoring model assesses data to predict birth asphyxia from the scale (values 1, 2, and 3) and absence (value 0).

3) **Prediction Model**- Once the data is divided into the training and testing part. The ML is applied for predicting the traits of Birth Asphyxia. For this purpose, three different classification algorithm was applied and accuracy was calculated.

I. Two-Class Neural Network

The *Two-Class Neural Network* is one of the most commonly used classification algorithms using neural networks. To calculate the network output for a specific input, a value is calculated at each node in the masked layers and the output layer. First, we look at Evaluation in the two-class for Classification in Azure Machine Learning[10]. There are three additional columns that are included in the output to classify in Azure Machine Learning. These additional columns provided the probabilities for each category. Scored labels will be those with the highest probability.

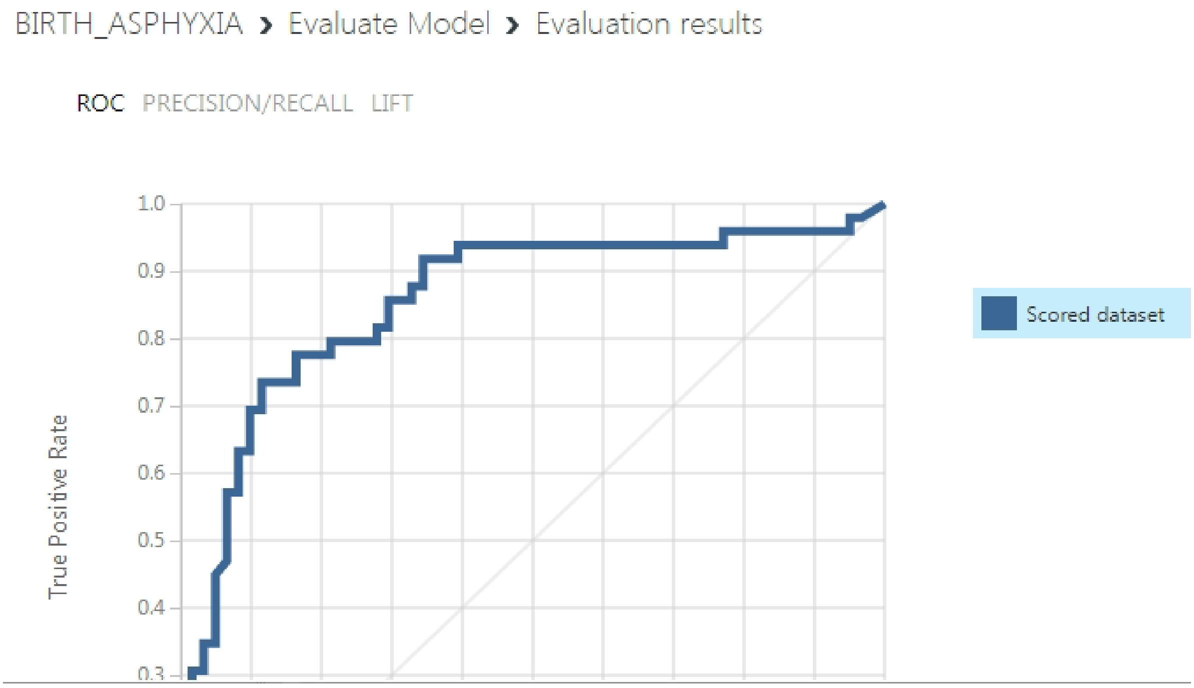


Figure 4 . ROC graph of the Two-Class Neural Network

Also, there are three charts to assess the two-class classification in Azure Machine Learning[10].ROC or Receiver Operation Curve is a visual tool for finding pattern accuracy. This model calculates quantities like “Accuracy”, “Precision”, “Recall”, and “AUC”, and produces a plot of the ROC curve as shown in fig.4. As you see below, the ROC curve is higher than the standard normal curve.

II. Two-Class Boosted Decision Tree

It is an ensemble learning method used in Azure Machine Learning Studio to develop a learning model. The predictions are based upon the set of trees together which makes the prediction. This algorithm reverted to an untrained class. Next, a particular model is formed using a Train model or a Tune Model Hyper Parameters on a labeled training data set. Later, the model created serves to make predictions.

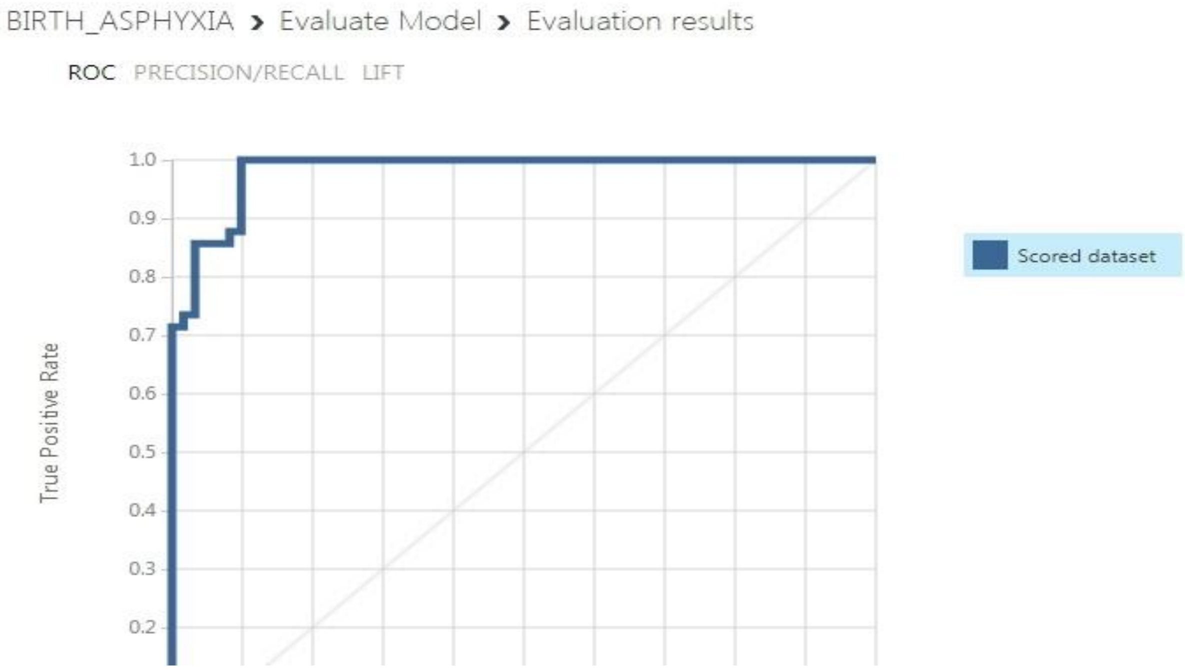
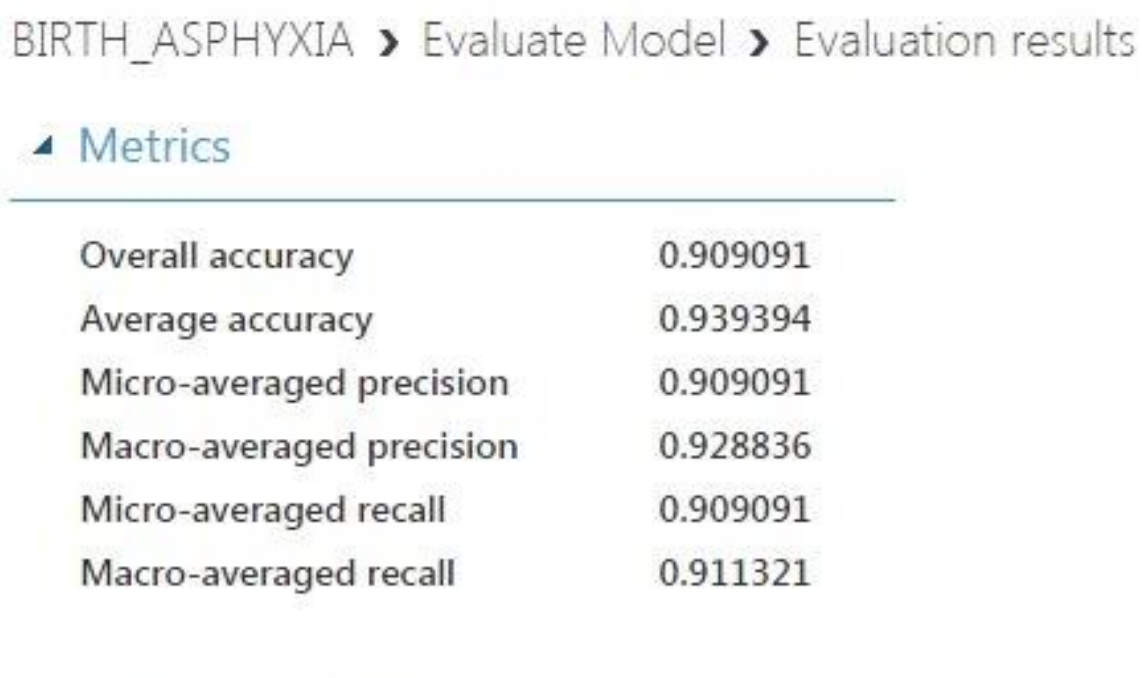


Figure 5 . ROC graph of the Two-Class Boosted Decision Tree

This model proceeds by using the same pattern and parameters as described in the two-class neural network and the results of the ROC as shown in fig.5.

III. Multi-Class Decision Jungle

The Multi-Class Decision Jungle algorithm is used in Azure Machine Learning Studio to develop a model that is dependent on the machine learning algorithm known as the decision jungle. They are non-parametric models. Once a model and its parameters have been defined, the subsequent connection to a marked data set is used to form the model using one of the training modules. Next, the trained pattern is used to analyze and predict a target with multiple values. Following is the confusion matrix and other accuracy parameters such as Accuracy, Precision and Recall as shown in fig.6 and fig.7.


BIRTH_ASPHYXIA › Evaluate Model › Evaluation results

Metrics

Overall accuracy	0.909091
Average accuracy	0.939394
Micro-averaged precision	0.909091
Macro-averaged precision	0.928836
Micro-averaged recall	0.909091
Macro-averaged recall	0.911321

Figure 6. Metrics of Multi-Class Decision Jungle algorithm

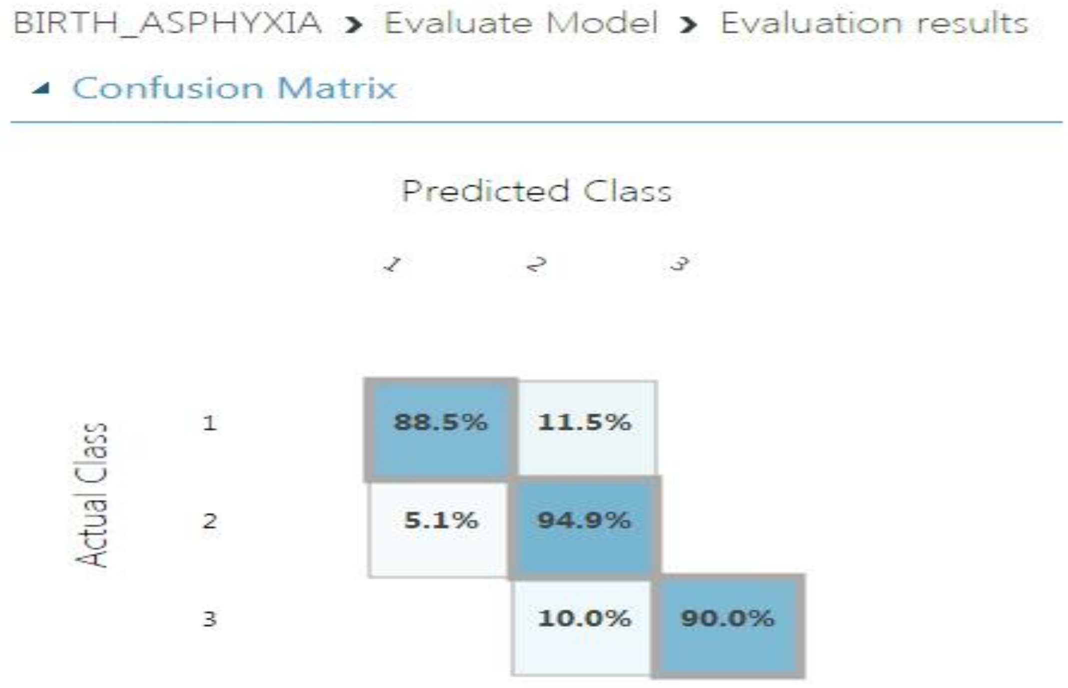


Figure 7. Confusion matrix of Multi-Class Decision Jungle algorithm

4. Results And Discussion

After the model has been evaluated, the overall accuracy, precision, and recall of the algorithms can be compared. The Two-class Neural Network has 75.5%, 69%, and 0.816, Two-Class Boosted Decision Tree has 94.5%,89.1%, and 1.000 and Multi-Class Decision Jungle has 90.91%,90.9%, and 0.911. Based on the results, the Two-Class Boosted Decision Tree is proved to be the best for predicting the risk factor associated with Birth Asphyxia.

Looking at table 2 below, we can see that the Two-Class Boosted Decision Tree has better accuracy for this data set. However, Multi-Class Decision Jungle has slightly higher precision than the Two-Class Boosted Decision Tree.

Table 2 . Predictive Parameters

Techniques	**Accuracy**	**Precision**	**Recall**
Two-class Neural Network	75.5%	69%	0.816
Two-Class Boosted Decision Tree	94.5%	89.1%	1.000
Multi-Class Decision Jungle	90.91%	90.9%	0.911

5. Conclusion And Future Work

In our study, risk factors for birth asphyxia that were statistically significant were: prolonged labor (82.7% cases); prolonged Ist stage – 14.5% cases, IInd stage – 68.18% cases, gestational age (postdate pregnancies), maternal literacy, delayed referrals, indirect or inappropriate referral, time taken, and distance traveled to reach an appropriate health facility.

Hence it is suggested:

• To increase awareness regarding the availability of free ambulance services in remote and less connected areas of the state.

• Early detection of high-risk cases and their follow-up and delivery at appropriate institutes containing facilities for necessary interventions as required.

• Timely and appropriate referral services from the primary and secondary health care centers.

• Effective inter-facility communication services to ensure the availability of obstetricians, pediatricians, blood bank facility, and availability of the required intervention before referring a high-risk pregnancy to a higher center.

• Regular intra-institutional audits should be conducted at the state level in all tertiary care centers to identify causes and suggest remedy in all the cases of severe birth asphyxia, stillbirths, and neonatal mortalities

The future study includes an in-depth analysis, which would be more useful for researchers working in the field of birth asphyxia and other associated diseases to understand the potential scope and to refine the methodology to increase its accuracy..

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