DRLPARTO: A Machine Learning Based Partograph for Fetal Monitoring System

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Abstract: The review focuses on predicting the mode of delivery using machine learning techniques. Our approach involves developing a machine learning model that evaluates partograph data to anticipate possible complications or the necessity for medical interventions. Although various perspectives exist on the application of partographs, a comprehensive understanding of their implementation remains unclear. The proposed model assesses multiple parameters, considering the mother's health status, fetal condition, and the ongoing labor progression. The primary goal is to identify the most effective algorithms for predicting delivery outcomes, specifically distinguishing the types of delivery i.e, normal or cesarean deliveries using machine learning techniques. Supervised learning algorithms such as Decision Trees, Random Forest, and Logistic Regression were employed with the proposed method DRLPARTO achieving 93% accuracy and consistently high precision, recall, and F1 score (92-93%), demonstrating its robustness and effectiveness in the given task.

1 INTRODUCTION

A partograph is a tool used to track labor progress and monitor the health of both the mother and baby. It records data in a graphical format, helping doctors make decisions if complications arise during childbirth. To predict delivery outcomes, we develop machine learning models using parto- graph data. According to the Government of India, around 1.3 million Indian women have died during childbirth in the past two decades due to various reasons. The partograph plays a crucial role in understanding the health of the mother and baby, identifying complications early, and making labor safer. It also helps healthcare workers better understand labor patterns.

Partographs have been the subject of extensive research, but because of a lack of standardized implementation, their practical application is still restricted. The goal is to close the gap between data-driven insights and practical clinical decision-making by incorporating machine learning into partograph analysis. The results demonstrate artificial intelligence's potential.

If we can predict the type of delivery (normal or C-section), we can prevent unnecessary medical complications, ensuring the safety of both the mother and baby. This also reduces risks during childbirth and helps lower death rates. The World Health Organization (WHO) supports monitoring active labor and encourages new approaches during this phase. The main goal of this project is to analyze health conditions during labor and predict the delivery type using machine learning. To understand why partographs are important, we must look at their history. The idea of recording labor progress in a graph started in 1952 when Dr. Emanuel Friedman couldn't be present for his first child's birth due to work. He contacted the hospital frequently and recorded his wife's cervical dilation on a graph. He continued observing all women in the maternity ward throughout the night. Though contraction frequency wasn't very informative, he noticed that cervical dilation followed an S-shaped curve, now called the "sigmoid curve." Since his first recording happened on the day his child was born, the concept of the curve is believed to have started in 1952.

Friedman later decided to divide labor into two phases: latent and active, published a study analyzing 100 women, recording cervical dilation and contractions per centimeter. This graph became known as the "Friedman Curve" or "cardiograph". In

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1955, this study expanded to 500 women and published another research paper. Figure 1 shows Phases of Labour representation.

Friedman divided labor into four phases based on cervical dilation as in Figure 1:

- Latent phase - Slow dilation (up to 2.5 cm).
- Acceleration phase - Rapid dilation with a change in speed.
- Maximum slope - The cervix dilates steadily in a straight- line pattern.
- Deceleration phase - The cervix is fully dilated, and the rate of dilation slows down. Later, Dr. Philpott developed a partograph based on Friedman's curve. He introduced two lines:

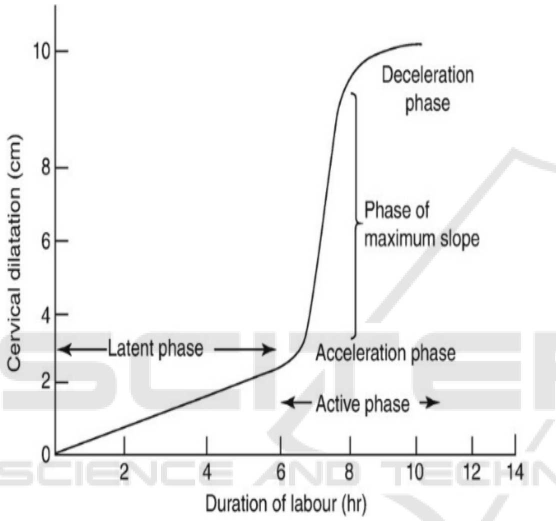

Figure 1: Phases of labor representation.

The alert line, which acts as a warning. The action line, which signals the need for medical intervention if crossed. This system was later introduced in England, where British gynecologist John Studd made modifications. He replaced the alert and action lines with a nomogram that used cervical dilation at the time of admission as a reference.

In 1994, the World Health Organization (WHO) officially approved the partograph. They recommended its use in all labor wards to ensure safer deliveries. This recommendation was based on a study involving over 35,000 women. The use of partographs significantly reduced maternal and infant deaths and lowered the risks of prolonged labor. The WHO also introduced an updated version called the labor scale, which helps study labor conditions in more detail. This is how the partograph has evolved and developed over the years, becoming a vital tool in maternal healthcare.

Section 2 provides an overview of related work, while Section 3 outlines the proposed methodology. The results and findings are discussed in Section 4, and the conclusion is presented in Section 5.

2 RELATED WORKS

Khali et al. (2022) evaluated a digital version of the partograph for labor management. The goal was to enhance labor quality and prevent complications by ensuring accurate monitoring. The study, which involved 800 women, found that the average delivery duration was 3.5 hours for first-time mothers and 3.3 hours for those who had given birth before. The average participant age was 25.6 years, with an average parity of 2. The findings showed that the digital partograph effectively improved labor management and newborn health outcomes.

Ashour E.S. et al. (2023) conducted a study in Egypt to compare digital and paper-based partographs. They found that digital partographs improved maternity nurses' performance, ensuring better documentation and timely interventions. Additionally, digital tools led to better maternal and neonatal outcomes, reducing cesarean sections and newborn intensive care admissions. The study suggested that adopting digital partographs in labor wards could enhance maternal and newborn health in other regions.

Bedwell et al. (2017) analyzed the effectiveness of the partograph in labor monitoring. Their review followed five steps: defining the research scope, gathering evidence, evaluating primary studies, synthesizing findings, and sharing results. They reviewed 95 sources, including research papers, policies, audits, and expert opinions. The findings showed that while the partograph is useful for tracking labor, its effectiveness depends on factors like healthcare worker competency and acceptance.

GJ Hofmeyr et al. (2021) introduced a new approach to labor monitoring called the next-generation partograph. This tool aims to offer personalized care, focusing on respectful maternity services. Key features include considering individual differences in labor progression and setting intervention triggers based on the health of the mother and baby. The model promotes better communication between healthcare providers and laboring women. The study argues that adopting this advanced partograph could improve health outcomes and patient satisfaction.

Melese et al. (2020) studied the use of the partograph in Southern Ethiopia. The research assessed healthcare workers' knowledge, attitudes, and usage of the tool in obstetric care. While most participants were aware of the partograph, their willingness to use it was inconsistent. The study found that factors such as equipment availability, workload, and training influenced its use. The authors emphasized the need to promote partograph use in healthcare facilities to improve childbirth outcomes.

Lavender T et al. (2020) examined the role of the partograph in labor management. Their study discussed the history of the partograph, its challenges, and its effectiveness in improving childbirth outcomes. They explored different versions of the partograph and the factors that affect its success. The paper also suggested best practices and future research directions to enhance labor monitoring tools. The authors supported their conclusions with references to multiple studies.

Xiaoqing He et al. (2023) reviewed 62 studies to gain new insights into labor patterns. Their research challenged traditional labor curves and definitions of abnormal labor. The review emphasized that recent studies suggest abnormal labor cannot always be determined based on a standard labor curve. This has significant implications for global childbirth care practices.

Yeliz Dog˘an Merih et al. (2023) developed the Electronic Touch and Partograph Device, an innovation that combines vaginal examination with digital labor monitoring. This device can track up to 50 patients simultaneously, ensuring real-time data collection. Developed between 2016 and 2020, the device underwent extensive research and ethical reviews. It improves safety for both healthcare workers and pregnant women, offering a promising advancement in labor monitoring technology.

Singh et al. (2022) conducted a quality improvement initiative to increase the use of the modified WHO partograph in labor rooms. The aim was to improve maternal and neonatal outcomes by ensuring regular labor monitoring. The team identified reasons for low partograph usage and introduced solutions such as allocating triage rooms, training staff, involving interns and nurses, setting clear policies, and designating supervisory roles. As a result, partograph usage increased from 25 Percent to 95 Percent. Despite challenges like printer malfunctions and misplaced documents, the initiative successfully improved labor care quality.

Shivani Sharma et al. (2022) focused on improving maternal health through a new partograph model. The study aimed to reduce preventable maternal deaths by identifying abnormal labor early and providing timely interventions. Researchers developed and validated a reliable partograph, which proved effective in improving childbirth outcomes. The study recommended widespread adoption of partographs in labor monitoring to enhance maternal and newborn safety.

3 PROPOSED SYSTEM

The traditional approach to labor monitoring primarily relies on manual partograph recording to track the progress of labor and ensure maternal and fetal well-being. A partograph is a standardized tool used by healthcare providers to document key parameters such as cervical dilation, fetal heart rate, uterine contractions, and maternal vital signs at regular intervals. In conventional systems, paper-based partographs are widely used in hospitals and maternity wards. Healthcare professionals manually record observations and assess labor progression based on predefined thresholds. If abnormal labor patterns are detected, appropriate clinical interventions are initiated. However, this manual process is prone to human errors, inconsistencies in data recording, and delays in decision making. Despite its importance, the adoption and effective utilization of partographs remain limited due to several challenges. These include insufficient training, high workload on healthcare staff, and a lack of standardized monitoring protocols. Additionally, paper-based partographs lack real-time analysis and do not provide predictive insights that could help anticipate complications in labor.

Furthermore, while some digital partograph solutions have been introduced, their adoption is still in early stages. Many healthcare facilities continue to rely on traditional manual methods, which may not provide the level of efficiency required for modern obstetric care. Thus, the existing labor monitoring system heavily depends on manual data entry and fixed threshold-based decision making, making it less adaptable to variations in labor progression and real time clinical needs. There is a growing necessity for intelligent, automated, and predictive solutions that can enhance the accuracy and efficiency of labor monitoring, ultimately improving maternal and neonatal outcomes.

The primary objective of this work is to develop a machine learning model that analyzes partograph data to predict potential complications during labor and determine the need for medical interventions. The model evaluates various maternal and fetal parameters, including maternal status, fetal condition, and labor progression, to classify the delivery type as either normal or cesarean. To achieve this, the study leverages advanced machine learning techniques to process and interpret partograph data effectively. The system is designed to identify crucial patterns that indicate deviations from normal labor, enabling timely medical decisions. Various machine learning algorithms are assessed to determine the most accurate model for delivery type prediction.

This research aims to bridge the gap between theoretical understanding and practical implementation of partographs in clinical settings. By integrating machine learning into obstetric care, the system enhances decision-making, improves maternal and fetal health outcomes, and reduces risks associated with labor. Through extensive experimentation and validation, this study contributes to the advancement of intelligent healthcare solutions for maternity care.

3.1 Methodology

Upon analyzing the reviewed research papers, it is evident that multiple methodologies and techniques have been applied to understand and implement the partograph. However, despite numerous studies and recorded data, the actual implementation remains limited. To improve the effectiveness and accuracy of labor monitoring, certain machine learning models have been identified as optimal solutions. The algorithms employed in this study include Decision Trees, Random Forest, and Logistic Regression. These models fall under the category of supervised machine learning algorithms, which are utilized to make accurate predictions based on historical data. The functioning of each algorithm is elaborated below:

3.1.1 Supervised Machine Learning Algorithms

Supervised learning is a branch of machine learning where models are trained on labeled datasets, meaning the input data is associated with known output values. By leveraging these pre-labeled examples, the model learns patterns and makes predictions when new, unseen data is introduced.

3.1.2 Decision Tree Classifier

A decision tree is a rule-based model that facilitates decision-making by structuring the data into a hierarchical tree format. It consists of decision nodes and leaf nodes, where decision nodes represent different choices based on feature values, and leaf nodes signify the final output. This algorithm effectively categorizes data through a sequence of binary decisions, ultimately arriving at a conclusion based on conditions such as yes/no or true/false responses.

3.1.3 Random Forest

Random Forest is an ensemble learning technique that enhances the performance of individual decision trees by generating multiple trees and aggregating their predictions. Each tree is built using a subset of the training data, and the final prediction is obtained by averaging (for regression) or voting (for classification) among all trees. This method improves accuracy, reduces overfitting, and ensures robust predictions, making it highly effective in labor monitoring applications.

3.1.4 Logistic Regression

Logistic regression is a statistical model used for classification tasks, where the output is a discrete value (such as 0 or 1, yes or no, or true or false). It applies a sigmoid function to transform input values into probability scores, determining the likelihood of an event occurring. When the probability surpasses a certain threshold, the outcome is classified as 1 (positive class); otherwise, it is classified as 0 (negative class). This algorithm is particularly useful for predicting binary outcomes in medical and healthcare applications.

By integrating these algorithms, we can achieve reliable and efficient labor monitoring solutions, overcoming some of the challenges and limitations identified in prior research.

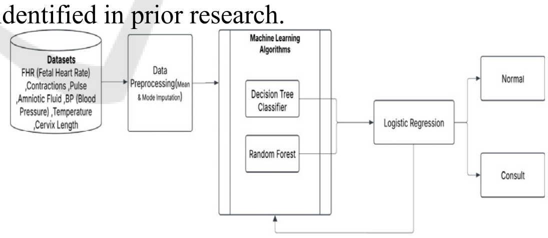

Figure 2: DRLPARTO: A partogragh tracer architecture.

The figure 2 shows the workflow of the machine learning-based classification system. The process starts with collecting datasets containing FHR, contractions, pulse, amniotic fluid, BP, temperature, and cervix length. The data undergoes processing and cleaning to remove inconsistencies. The cleaned data is then split into training data and testing data. The training data is used to train machine learning algorithms, including Decision Tree Classifier, Random Forest, and Logistic Regression. After training, a classification model is generated, which is then used to make predictions based on new input data.

4 RESULTS AND DISCUSSION

Figure 3 indicates that the cervix length increases sharply at the beginning and then stabilizes over time. This suggests that initial changes occur rapidly, but further progression is minimal or steady.

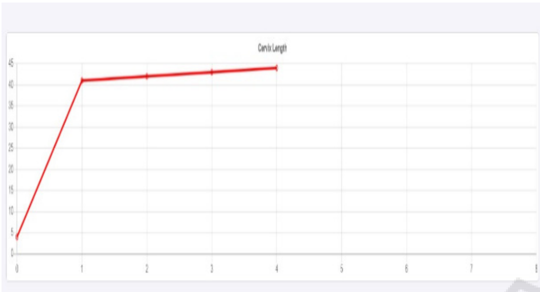

Figure 3: Cervix dilation.

Phase-wise analysis of a process, where each phase is categorized as either "Normal" or requiring "Consult" as shown in figure 4. While most phases are marked as "Normal," Phase 4 and Phase 7 indicate" Consult," suggesting potential concerns in those stages. However, the final result is marked as "Normal," implying that despite some irregularities, the overall outcome is within acceptable limits.

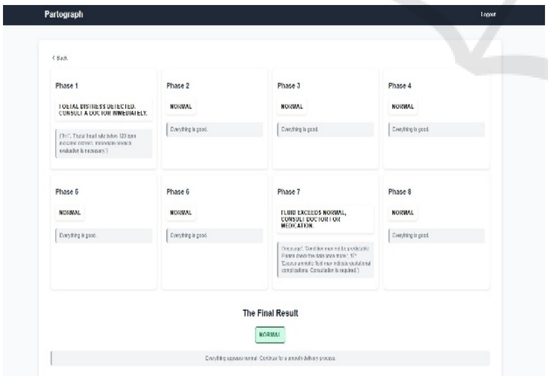

Figure 4: Delivery prediction.

Figure 5: Comparison of the proposed model with individual models.

The table 1 presents a comparative analysis of different machine learning algorithms based on four key performance metrics: accuracy, precision, recall, and F1 score. It is also shown graphically in figure 5. The Decision Tree model achieved 85% accuracy, with balanced precision, recall, and F1 scores around 83-84%. Random Forest performed better, attaining 89% accuracy and an F1 score of 91%, indicating improved overall performance. Logistic Regression showed similar effectiveness with 88% accuracy and slightly lower recall. The proposed method outperformed all models, achieving 93% accuracy and consistently high precision, recall, and F1 score (92-93%), demonstrating its robustness and effectiveness in the given task.

Table 1: State of art comparison.

algorithm	accuracy	precision	recall	f1 score
decision tree	85	83	84	83
random forest	89	90	87	91
logistic regression	88	87	86	86
proposed method	93	92	92	93

5 CONCLUSION AND FUTURE WORK

Predicting the type of delivery a few hours before labor begins can help ensure a safe childbirth. Whether a woman delivers vaginally or through a cesarean section can impact both her health and the baby's well-being. Therefore, making the right decision is crucial. This can be done using a partograph, a tool that is widely recognized and recommended by the World Health Organization (WHO), highlighting its importance in labor management. From our review of various studies, we found that machine learning and artificial intelligence can be used to implement this prediction system. Many researchers have explored different ways to apply these technologies to improve labor monitoring. In our approach, we focus on supervised machine learning algorithms such as decision trees, random forests, and logistic regression. Using these methods can help predict delivery outcomes with high accuracy, ultimately improving maternal and newborn care. The partograph plays a crucial role in monitoring health conditions during labor. Since its introduction, it has undergone several modifications to improve its effectiveness. Various factors help assess the mother's health and the environment necessary for a safe delivery, and these have been refined over time. As seen from the analysis of different studies, the partograph is highly beneficial for healthcare providers, mothers, and newborns. While many researchers have explored its theoretical aspects and case studies, only a few have discussed using machine learning algorithms for predicting delivery outcomes. Some studies have highlighted important parameters for labor monitoring, but practical implementation is still lacking.In the future, further advancements can be made by integrating machine learning techniques and improving implementation strategies. Through continuous research, experimentation, and technological innovation, the medical field can enhance labor monitoring and improve maternal and neonatal health outcomes.

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