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Predictive System for Fetal Health and Pregnancy Risk

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Abstract

Health assessment of the fetus and monitoring the possible risks in the pregnancy are crucial for safety of the mothers and lowering complications. Methods based on CTG and ultrasound use human interpretation that might cause mistakes due to insufficient resources. This research proposed using an artificial intelligence model to increase accuracy and time-efficient classification of fetal health and pregnancy risks.

The machine learning model classifies risk into low, average and high according to the data about the mother's and baby's health for taking necessary measures. The following models will be applied in this research – SVM, K-Nearest Neighbors, Decision Tree, Random Forest, ANN, AdaBoost, Gradient boosting, XGBoost and Multilayer Perceptron due to their ability to classify the data.

The result of the tests proves that ensemble methods and neural networks and more accurate and reliable. AdaBoost and multilayer perceptron showed better performance compared to other methods.

Key Words: Fetal health Monitoring, Pregnancy Risk Prediction, Artificial Intelligence, Machine Learning, AdaBoost

I.INTRODUCTION

The assessment of fetal health and identification of the potential risk during pregnancy is a critical aspect in maternal healthcare. Pregnancy complications may have severe adverse implications for both the pregnant woman and her fetus and the child who will be born. Early detection of high-risk pregnancies caused by anomalies of the physiological indicators or pre-existing disorders in the patient can help prevent possible negative health effects in babies once born. Unfortunately, however, such approaches as cardiotocography (CTG) or ultrasound imaging can result in significant diagnostic errors due to the necessity for clinicians to interpret obtained data manually.

Thanks to recent advancements in AI and machine learning (ML), researchers and practitioners managed to significantly increase their predictive abilities when making diagnosis-related decisions. ML algorithms can analyze huge datasets related to different parameters of the patient's health condition (e.g., age, blood pressure, glucose, heart rate, and FHR patterns) and identify risks associated with pregnancy. Numerous studies prove that MLP and other machine learning algorithms outperform traditional approaches in predicting high-risk pregnancies.

Motivated by theses developments, the proposed research attempts to create an integrated solution that would help classify the state of fetal health and detect pregnancy risks.

II. Related Work

A. Current Approaches

Machine learning techniques have become relevant to prediction of fetal health and pregnancy risks. Some common models include K-nearest Neighbors (KNN), Random Forest and XGBoost algorithms. These approaches are applied in combination with CTG and maternal features to provide classification results with accuracy above 90%. Neural networks work successfully

because of their ability to capture complex nonlinear relationships between input data and provide predictions superior to classical techniques. Finally, hybrid approaches, for example, involving the use of PCA and SVM, may help to accelerate the prediction process.

However, despite these improvements, most of the existing models still address only the issues of either fetal health classification or pregnancy risks assessment and ignore other problem. Besides, currently, there are not enough integrative solutions for solving two problems at once. Furthermore, there are not enough studies devoted to providing customized recommendations related to personal diet and physical exercise depending on the level of risk associated with certain factors. Hence, it seems crucial to develop an integrative approach addressing both issues.

Table I: comparative analysis of related work

Model	Methodology used	Key features	Result accuracy	Limitations
Previous ML study	Random Forest, XG Boost	Feature importance analysis, risk classifications	Accuracy > 90%	Limited interpretability
Neural network-based study	ANN	Handles complex nonlinear data	High predictions performance	Require large dataset
Hybrid ML models	PCA + SVM + AdaBoost	Improved classification performance	Accuracy up to ~ 98%	Complex implementation, no real world deployment

B. Research Gap

From the analysis of previous works on Machine Learning based maternal healthcare, a number of key limitations can be noted. First, there are no current solution that both monitors the fetus's state and forecast risks during pregnancy at once within one integrated system. Second, many solutions are static in the way they use clinical data, making it impossible to track the patient's condition in real time. Third, there are no solution providing personal recommendations regarding the patient's eating habits, sports activities, and overall lifestyle depending on her level of risk. Fourth, the majority of existing solutions are hospital-oriented, making it difficult for patients living far from a hospital to use them.

C. Aims of the proposed solution

The primary aim of the research will be to solve all the existing drawbacks of existing pregnancy tracking technology by developing comprehensive and innovative solution which will incorporate the best features of various methods. Currently, most of the technology does not provide real time monitoring, risk assessment and personalized recommendations for expecting mothers. The proposed solution will utilize machine learning algorithm to assess the health condition of the fetus as well as the pregnancy risk. Moreover, the solution will provide personalized recommendations regarding nutrition and physical activities which can help the mother maintain health during pregnancy.

III. Proposed Integrated Framework

A. System Overview

The given framework consists of components that make use of ML and a user-friendly application for analyzing the fetus's health and risks. The primary aim of the software is to assist in identifying potential issues early enough, thus providing an opportunity to take timely measures and positively influence the health conditions of the woman and her unborn child. Information on blood pressure, pulse rate, glucose, age, and previous illnesses,

among other factors, or processed by the system to identify any signs of preeclampsia.

The collected information allows classifying the risks associated with pregnancy into one of three categories: Low, Moderate, or Severe. In this way, healthcare professionals and the patient are able to assess the severity of their condition and appropriate measures to avoid complications. The prediction capabilities of the software are supported by recommendations, which are generated based on user's input and predicted risk level, as well as suggestions concerning nutrition, exercise, and overall life style.

A. Framework Architecture

Table II: Framework Architecture

Layer	Components	Description
Data Acquisition Layer	User Input Interface, Health	Collects maternal health data such as blood pressure, heart rate, blood sugar level, age and medical history through a web interface or IoT devices
Data Preprocessing Layer	Data cleaning, Normalization, Feature Selection	Handles missing values, removes noise, and prepares data for model training and prediction
Prediction Layer	Machine Learning (LR, SVM, RF, AdaBoost)	Applies trained ML models to classify fetal health risk into low, medium, and high categories
Recommendation Layer	Diet & Exercise Module, Health Advisory	Provides personalized suggestions such as diet plans, exercises, and preventive care based on predicted risk
Application Layer	Backend Server, API Services	Manages data flow between frontend and ML models processes requests, and returns predictions
Presentation Layer	Dashboard, Visualization Interface	Displays prediction results and recommendations in an easy-to-understand format

IV. Proposed Integrated Framework

In particular, the suggested system utilizes numerous components that will ensure a faster and more efficient prediction process. Firstly, the user interface will allow patients to easily add their health-related information and receive recommendation from the system. Secondly, the authentication will ensure that the access remains secure after login and registration features. Thirdly, the API component will link frontend and backend components via REST APIs. Next, the data processing component will clean and validate the received information to ensure correct predictions. Moreover, the prediction component will predict the pregnancy risk complications with the help of machine learning algorithms and classification. After that, the recommendation component will recommend individual recommendations for patients based on obtained predictions. Finally, the report generation component will enable users to download their reports, while the model training component will train the model on appropriate datasets.

Table III: Framework for Proposed Integrated

Module	Components	Technology Used	Functionality
User Interface Module	Dashboard, Assessment Pages, Results Page, History	React.js, typescript, CSS	Collects user input and display prediction results in an interactive format

Authentication Module	Login, register, useAuth.tsx, auth.py	JWT, PyJWT, bcrypt	Manages user authentication and secure access
API Communication Module	api.ts, FastAPI routes	REST API, HTTPX	Handles data exchange between frontend and backend
Data Processing Module	Input validation, preprocessing	Pandas, Numpy, Pydantic	Cleans and prepares data for model prediction
Prediction Module	predict.py, trained modules	Scikit-learn, joblib	Predicts fetal health and pregnancy risk level

V. Implementation

A. Technology Stack

Table IV: Technology that used

Tier	Technology	Purpose
Frontend	React.js (TypeScript)	Builds interactive and dynamic user interface
Frontend	HTML, CSS	Provides structure and styling
Backend	FastAPI	Handles API requests and business logic
Backend	Uvicorn	Runs the FastAPI server
API Integration	REST API	Connects frontend and backend Handles API communication
Database	MongoDB Atlas	Stores user data and prediction history in cloud
Machine Learning	Scikit-learn, Joblib	Builds prediction models Saves and loads trained models
Data processing	Pandas, Numpy	Performs data preprocessing
Security	bcrypt	Secures passwords using hashing
Cloud Deployment	Render, Vercel	Hosts and deploys frontend application Hosts backend APIs

B. Database schema Design

The database is powered by MongoDB Atlas. There are separate collections for users, assessments, and reports in the database. In the users collection, basic information such as the name, email address, and password hash value is stored to enable authentication. The assessment collection is used for storing maternal health information, which includes the blood pressure, heart rate, glucose level, age, medical history, and the risk probability predictions made from the information. The report collection is used to store reports that were generated.

C. Security Implementation

There are several security protocols in place to keep the data of the users secure and allow for the safe running of the system. For authentication purposes, JWTs (JSON Web Tokens) are used to give secure access during each session. The passwords used are not in their plain form but have been hashed using the bcrypt function to make

it hard for them to be decoded. Validation of the input is done by the backend to ensure that no wrong data enters the database. The APIs used are kept secure to avoid any unauthorized access.

VI. Results and Evaluation

The system is developed to determine fetal health status and identifies pregnancy risks and it is done by machine learning. It was fed with vital data from women on blood pressure, heart rate, glucose level, age, and medical background. Later, it was put through a test based on sample inputs to verify its performance. It showed that the system can predict pregnancy risk with sufficient accuracy by dividing it into three levels of low, moderate, and high. This proves that the proposed system can detect pregnancy risks in time and inform accordingly.

Apart from prediction, it provides useful recommendations about food, physical activities, and other aspects. It was tested to evaluate its efficiency, user-friendliness. The interaction between frontend, backend, and machine learning components was seamless in order to make real-time prediction possible.

VII. Discussion

1.Findings
This system uses maternal health information along with machine learning models to predict the risk of pregnancy and fetal health condition. Parameters such as blood pressure, glucose level, and health background serve as significant elements determining risk levels. The proposed system can distinguish low, medium, and high risks. It generates recommendations based on predictions, providing more meaningful information for patients.

2.Strength of the integrated approach
One of the most important advantages is that all components are implemented in one application. It is characterized by an attractive interface, fast processing and accurate machine learning models. Its prediction capabilities along with personalized recommendations distinguish it from traditional standalone systems. Using cloud storage increases its scalability and availability.

3. Limitations
There are certain limitations in the proposed solution. The accuracy of prediction algorithms depends on training data sets. Insufficient data might lead to poor performance under various circumstances. Users need to enter input parameters, which could introduce errors in the process. The lack of real time health monitoring using wearing devices is another limitation.

4. Future research
Using wearable devices would provide real-time information about health parameters. Deep learning methods might enhance system capabilities further. Support for multiple languages and mobile apps will expand the applicability domain of the system.

VIII. Conclusion

This innovative solution helps with machine learning and web technologies that health monitoring during pregnancy. It analyzes various factors such as blood pressure, heart rate, glucose, age, and medical history and categorizes pregnancy risks as low, medium, or high. This classification process is performed with good accuracy, and due to its user interface and robust backend, data entry becomes effortless, and immediate results can be received. Aside from risk prediction, the tool provides customized recommendations on nutrition, physical activity, and general lifestyle management for women in their pregnancies.
Data protection and cloud storage are secure as login features accessibility and security of information. This system integration allows for optimal functioning of all components and rapid analysis. There are certain limitations in this system, although it sets an excellent foundation for future modifications. Further data collection and implementation of monitoring can transform it into an effective healthcare device. The system supports prenatal risk assessment and decision-making processes.

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