Mini Project Report On

Fetal Heath Examiner

Submitted in partial fulfillment of the requirements for the award of the degree of

Bachelor of Technology

in

Computer Science & Engineering

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CERTIFICATE

This is to certify that the mini project report entitled ***"Fetal Health Examiner"*** *is a bonafide record of the work done by* ***Danish H Muhammed (U2103073)****,* ***Gopika M (U2103097)****,* ***Melissa Biju Kalayil (U2103136)****,* ***Muhammed Bais (U2103142)****, submitted to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology (B. Tech.) in Computer Science and Engineering during the academic year 2023-2024.*

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Abstract

Cardiotocography (CTG) plays a crucial role in monitoring fetal health during pregnancy by assessing parameters such as fetal heart rate (FHR), uterine contractions, and fetal movements. Interpretation of CTG results aids in identifying potential risks to the fetus, allowing for timely interventions to prevent adverse outcomes. In this project, we propose the development of a machine learning model to classify the outcome of Cardiotocogram tests into three classes: Normal, Suspect, and Pathological.The dataset utilized in this study comprises of features extracted from CTG exams, each classified by expert obstetricians into one of the aforementioned classes. Leveraging this dataset, our objective is to train a classification model capable of accurately predicting the fetal wellbeing status based on the extracted features.The successful development of an accurate and reliable classification model holds significant clinical implications, empowering healthcare professionals to make informed decisions regarding fetal well-being based on CTG results. Ultimately, this project aims to contribute to improved prenatal care and reduced rates of adverse pregnancy outcomes through early detection and intervention.

Contents

List of Figures

List of Abbreviations

- FHE - Fetal Health Examiner
- CTG - Cardiotocography
- SVM - Support Vector Machine
- RF - Random Forest
- ER - Entity Relationship

Chapter 1

Introduction

1.1 Background

Prenatal care is pivotal in ensuring the health and well-being of both the mother and the fetus throughout pregnancy. Among the various tools used in prenatal monitoring, Cardiotocography (CTG) stands out as a crucial method for assessing fetal health. CTG provides valuable insights into the fetal heart rate (FHR), uterine contractions, and fetal movements, all of which are essential indicators of fetal well-being. Despite its significance, the interpretation of CTG results remains a complex task, often relying on the expertise of obstetricians. Misinterpretation or delayed interpretation of CTG traces can lead to adverse outcomes, including fetal distress, hypoxia, and even stillbirth. Moreover, with the increasing workload on healthcare professionals and the variability in expertise levels, there arises a pressing need for reliable and efficient methods to interpret CTG results accurately.The proposed project, "Fetal Health Examiner," addresses this pressing need by leveraging machine learning techniques to develop a classification model capable of accurately categorizing CTG traces into three classes: Normal, Suspect, and Pathological. By harnessing the power of data-driven insights, this project aims to streamline the process of CTG interpretation, providing healthcare professionals with a reliable tool for early detection and intervention.Through the integration of advanced technology with prenatal care, the "Fetal Health Examiner" project holds the promise of revolutionizing the way fetal health is monitored during pregnancy. By empowering healthcare professionals with accurate and efficient tools for CTG interpretation, this project seeks to enhance prenatal care practices, ultimately leading to improved pregnancy outcomes and reduced rates of adverse events.

1.2 Problem Definition

The aim of the "Fetal Health Examiner" project is to develop a machine learning model capable of accurately classifying Cardiotocogram (CTG) traces into three categories: Normal, Suspect, and Pathological, thereby aiding in the timely identification of fetal well-being status during pregnancy.By automating CTG interpretation, this project seeks to provide healthcare professionals with a reliable tool for early detection and intervention, ultimately improving prenatal care and reducing adverse pregnancy outcomes.

1.3 Scope and Motivation

The "Fetal Health Examiner" project aims to develop a machine learning-based classification model tailored for analyzing Cardiotocogram (CTG) traces, encompassing various stages from data collection to model deployment. It involves preprocessing CTG data to ensure quality and consistency, extracting relevant features that capture fetal health indicators, and training a classification model using appropriate machine learning algorithms. The model's scope extends to classifying CTG traces into three distinct categories: Normal, Suspect, and Pathological, facilitating comprehensive fetal well-being assessment. Additionally, the project will explore the feasibility of real-time CTG analysis, potentially enabling immediate clinical decision-making and intervention. By focusing on CTG interpretation, this project targets a critical aspect of prenatal care, aiming to enhance diagnostic accuracy and clinical outcomes.

The "Fetal Health Examiner" project is motivated by the urgent need to improve fetal health monitoring accuracy and efficiency during pregnancy, particularly in light of the challenges posed by manual CTG interpretation. Automating CTG analysis offers numerous benefits, including reducing the subjectivity inherent in manual assessment and minimizing the risk of delayed diagnoses, thereby enhancing patient safety. Furthermore, by developing a reliable classification model, healthcare professionals can intervene promptly in cases of fetal distress or pathology, potentially preventing adverse pregnancy outcomes. This project's ultimate goal is to contribute to the broader objective of improving prenatal care practices, safeguarding maternal and fetal health, and reducing the incidence of adverse pregnancy outcomes through early detection and intervention.

1.4 Objectives

1. Develop a robust machine learning model capable of accurately classifying Cardiotocogram (CTG) traces into three categories: Normal, Suspect, and Pathological.

2. Collect and preprocess a comprehensive dataset of CTG traces, ensuring data quality, consistency, and representativeness across various fetal health conditions.

3. Extract relevant features from CTG traces to capture key indicators of fetal well-being, such as fetal heart rate patterns, uterine contractions, and fetal movements.

4. Implement and optimize machine learning algorithms for training the classification model, leveraging techniques such as feature selection, hyperparameter tuning, and model evaluation.

5. Evaluate the performance of the developed model using appropriate metrics and validation techniques, assessing its accuracy, sensitivity, specificity, and overall predictive capability.

6. Explore the feasibility of real-time CTG analysis and integration of the classification model into clinical practice, aiming to streamline prenatal care processes and facilitate timely interventions based on CTG results.

1.5 Challenges

Navigating the complexities of fetal health assessment through CTG analysis poses challenges in developing sophisticated algorithms due to limited annotated data availability. Integrating the developed model into clinical practice further complicates the process, requiring considerations such as regulatory compliance and seamless adoption by healthcare professionals.

1.6 Assumptions

Annotated CTG data is assumed to be representative and accurately labeled by expert obstetricians, providing reliable ground truth for model training.The features extracted from CTG traces are assumed to capture key indicators of fetal well-being, enabling the developed model to effectively classify CTG traces into Normal, Suspect, and Pathological categories.The classification model's performance is assumed to generalize well across diverse patient populations and clinical settings, despite potential variations in CTG recording devices and medical practices.

1.7 Societal / Industrial Relevance

The "Fetal Health Examiner" project holds significant relevance both in societal and industrial contexts. In the healthcare sector, the developed machine learning model can be applied to enhance prenatal care practices, particularly in obstetrics and gynecology departments. By automating CTG interpretation, healthcare professionals can make more informed decisions regarding fetal well-being, leading to improved pregnancy outcomes and reduced rates of adverse events.

Additionally, the project's outcomes have implications for medical device manufacturers and software developers. Integrating the developed classification model into CTG monitoring devices or software platforms can enhance their diagnostic capabilities, providing value-added features for healthcare providers. This can lead to increased adoption of advanced CTG monitoring systems in hospitals and clinics, contributing to the advancement of medical technology in the obstetrics field.

Moreover, the societal impact of the "Fetal Health Examiner" project extends to expectant mothers and their families. By improving the accuracy and efficiency of fetal health monitoring during pregnancy, the project promotes maternal and fetal well-being, easing concerns and ensuring a smoother pregnancy journey for families. Overall, the project's societal and industrial relevance lies in its potential to revolutionize prenatal care practices, enhance diagnostic accuracy, and ultimately improve health outcomes for both mothers and babies.

1.8 Organization of the Report

The organization of the report are as follows:

- **Chapter 1-Introduction**: The introduction covers the background of the project, the problem definition, the scope and motivation, the objectives,the societal and industrial relevance, the assumptions and the challenges faced by the project.

- **Chapter 2-Software Requirements Specification**: This chapter outlines the functional and nonfunctional requirements of the Fetal Health Examiner using Machine Learning. It defines the overall description of the software, external interface requirements, system features, and other nonfunctional requirements necessary for the development and deployment of the tools.

- **Chapter 3-System Architecture and Design**: The system architecture and design chapter provides an overview of the project's technical framework. It includes discussions on the system overview, architectural design, identified datasets, proposed algorithms, implementation strategies, module division, and a work schedule presented as Gantt chart for project planning and management.

- **Chapter 4-Results and Discussions** : This chapter provides a summary of the results obtained from the "Fetal Health Examiner" project, focusing on the analysis and classification of Cardiotocogram (CTG) data for assessing fetal well-being during pregnancy. It outlines the testing procedures, quantitative results, and graphical analyses conducted to evaluate the performance of the machine learning models.

- **Chapter 5-Conclusion**: This chapter serves as a conclusion to the "Fetal Health Examiner" project, summarizing the key findings and insights obtained from the analysis and classification of Cardiotocogram (CTG) data for assessing fetal well-being during pregnancy.The future scope section outlines potential areas for further research and development in the field of automated CTG analysis and fetal health assessment.

Chapter 2

Software Requirements Specification

2.1 Product Perspective

The Fetal Health Examiner is a new, self-contained product designed to revolutionize the way healthcare professionals monitor fetal health during pregnancy. It emerges as aninnovative solution to address the complexities of Cardiotocogram (CTG) result analysis,offering a classification model and integrated features for data visualization and securedoctor login.

In terms of its position within the broader healthcare ecosystem, the Fetal Health Examineroperates as an independent system with a focus on fetal health monitoring. While it stands alone in its functionality, it is designed to seamlessly integrate with existing healthcare workflows, allowing healthcare professionals to incorporate its capabilities into their routine practices. The system is not part of an existing product family but rather represents a unique and specialized tool to cater to the specific needs of fetal health monitoring. The primary goal of the Fetal Health Examiner is to provide healthcare professionals with a dedicated and efficient tool for monitoring fetal health, contributing to improved prenatal care and reduced rates of adverse pregnancy outcomes. Its self-contained nature ensures that it can be easily integrated into existing healthcare practices without disrupting established workflows.

2.1.1 Product Functions

- CTG Classification:

  Implement a machine learning model for the classification of Cardiotocogram (CTG) results into three categories: Normal, Suspect, and Pathological.

- Doctor Login System:

  Develop a secure login system for healthcare professionals to access and manage patient CTG data. Ensure personalized and confidential access to patient information.

- Data Visualization:

  Incorporate advanced data visualization features to generate graphical representations of key CTG metrics. Enable interpretation of baseline fetal heart rate, accelerations, uterine contractions, and variability percentages.

- Integration with Healthcare Workflows:

  Facilitate seamless integration with existing healthcare systems to enhance overall workflow efficiency. Ensure compatibility with healthcare databases for retrieving and storing patient information.

- User Interaction:

  Provide an intuitive and user-friendly interface for healthcare professionals to input and retrieve CTG data.

- Automation of CTG Analysis:

  Automate the analysis of CTG results, allowing healthcare professionals to quickly assess fetal health status. Implement real-time processing capabilities for timely decision-making.

- Compliance and Security:

  Adhere to data privacy regulations and ethical healthcare practices. Implement robust security measures for the protection of patient data and system integrity.

2.1.2 Operating Environment

The Fetal Health Examiner is designed to operate in a specific environment that ensures optimal performance and compatibility. The following description outlines the key aspects of this operating environment:

- Hardware Platform:

The software is designed to run on standard hardware configurations commonly used in healthcare settings. This includes desktop computers, laptops, and other devices with adequate processing power and memory.

- Operating System and Versions:

  The Fetal Health Examiner is compatible with multiple operating systems to accommodate the diverse environments of healthcare facilities. Supported operating systems include: Windows (versions 7, 8, 10) macOS (versions 10.12 and later) Linux distributions (Ubuntu, CentOS, etc.)

- Web Browsers:

  The software is accessible through standard web browsers, ensuring flexibility for healthcare professionals. Supported browsers include : Google Chrome (latest version) Mozilla Firefox (latest version) Microsoft Edge (latest version)

- Software Components and Applications:

  The Fetal Health Examiner is designed to peacefully coexist with other essential healthcare software components and applications. This includes compatibility with: Security and Authentication Systems: Integration with existing security and authentication protocols to ensure secure doctor logins.

- Internet Connectivity:

  The software requires a reliable internet connection for real-time processing, data exchange, and secure access to the doctor login system.

- Additional Considerations:

  The Fetal Health Examiner should be adaptable to variations in screen resolutions and display sizes to provide a consistent user experience across different devices. The software's performance may be influenced by the availability of hardware accelerators, such as GPUs, which can enhance the speed of machine learning model execution.

2.2 Design and Implementation Constraints

The development of the Fetal Health Examiner is subject to certain constraints and limitations that will impact the choices and options available to the developers.Compliance with healthcare and data privacy regulations is paramount. Must adhere to specific corporate policies and regulatory requirements governing the handling, storage, and transmission of patient health data. Need to optimize the application to ensure efficient performance on standard healthcare hardware configurations.For integration with existing healthcare systems and applications necessitates adherence to specific interface standards.The software may need to adhere to specific communication protocols for data exchange, especially in the context of interfacing with healthcare databases and external systems. Must follow these protocols to enable seamless communication. In developing the Fetal Health Examiner, several constraints related to machine learning must be carefully navigated. The availability and quality of training data pose challenges, requiring diverse and unbiased datasets for effective model training. The choice of ML algorithms is constrained by the nature of Cardiotocogram (CTG) data and specific classification requirements, with considerations for interpretability and computational resources. Rigorous model validation, ethical considerations, and adherence to regulatory compliance are crucial to ensure the reliability and fairness of the ML model. Additionally, ensuring model explainability, and establishing mechanisms for continuous monitoring and adaptation are essential for successful integration into the healthcare environment.

2.3 Assumptions and Dependencies

Several assumed factors and dependencies could impact the requirements stated in the Fetal Health Examiner's Software Requirements Specification (SRS):

Assumed Factors:

1. Availability of Quality Training Data:

   - Assumption: Sufficient and diverse training data for machine learning model development is available.

   - Impact: Inadequate or biased training data could affect the model's accuracy and generalizability.

2. Stable Internet Connectivity:

   - Assumption: Users will have stable internet connectivity for real-time processing and secure access.

   - Impact: Unstable connectivity may hinder real-time features and data accessibility.

3. Adherence to Ethical Guidelines:

   - Assumption: Ethical considerations and guidelines will be adhered to during model development and implementation.

   - Impact: Ethical concerns could arise, affecting the acceptance and trust in the application.

4. Compliance with Regulatory Standards:

   - Assumption: The software will comply with healthcare regulations and data privacy standards.

   - Impact: Failure to comply may lead to legal and regulatory issues.

Dependencies:

1. Third-Party ML Libraries:

   - Dependency: The project depends on the availability and reliability of third-party machine learning libraries.

   - Impact: Issues with these libraries could affect the implementation and performance of the ML model.

2. External Software Components:

   - Dependency: The project may rely on external software components for specific functionalities.

   - Impact: Issues with these components may affect the overall functionality and performance of the Fetal Health Examiner.

3. Data Privacy Policies:

   - Dependency: Compliance with data privacy policies and agreements is assumed.

- Impact: Changes in policies or non-compliance may affect data handling and storage practices.

It is crucial to continuously validate these assumptions, communicate changes promptly, and address any dependencies to ensure the successful development and deployment of the Fetal Health Examiner. Failure to do so could lead to unexpected challenges and impact the achievement of project goals.

2.4 External Interface Requirements

2.4.1 User Interfaces

The user interface is needed for the following software components:

- Login page for signing up new users and sign in page for existing users.
- Patient Information Management: Allows healthcare professionals to input and manage patient demographic and medical information.
- CTG Data Viewing: Enables healthcare professionals to view CTG data collected from patients.
- Report Generation: Facilitates the generation of reports summarizing CTG data for individual patients.
- System Administration: Provides administrative functions such as user management and system settings.

2.4.2 Hardware Interfaces

The software is designed to run on standard hardware configurations commonly used in healthcare settings. This includes desktop computers, laptops, and other devices with adequate processing power and memory

1. Windows (versions 7, 8, 10)
2. macOS (versions 10.12 and later)
3. Linux distributions (Ubuntu, CentOS, etc.)

2.4.3 Software Interface

Operating System Interface:

1. The software product is compatible with various operating systems, including Windows, macOS, and Linux distributions
2. It utilizes standard system calls and APIs provided by the respective operating systems for tasks such as file management, process management, and memory allocation.

Database Interface:

1. The software product interacts with a relational database management system (RDBMS) to store and retrieve patient data, CTG records, and system configurations.

External API Interface:

1. The software product may integrate with external APIs for additional functionalities, such as integration with data analysis and visualization libraries for advanced CTG data processing.

2.4.4 Communications Interfaces

This project supports all types of web browsers. We are using simple electronic forms for storing the patient records and to analyze it.

2.5 System Features

2.5.1 Data Input and Preprocessing

1. Description and Priority

This feature enables users to input CTG exam data and preprocess it for further analysis.It is of High priority as it forms the foundation for subsequent processing steps.

(a) Stimulus/Response Sequences Stimulus: User selects the option to input CTG data. Response: System presents a data input interface with fields for FHR, uterine contractions, and fetal movements.

(b) Functional Requirements

(c) REQ-1: Provide a user interface for entering CTG exam data, including fields for FHR, uterine contractions, and fetal movements

(d) REQ-2: Implement data validation to ensure entered values are within acceptable ranges.

(e) REQ-3: Normalize input data to account for variations in recording equipment and techniques.

(f) REQ-4: Handle missing or incomplete data gracefully, prompting users to provide necessary information.

(g) REQ-5: Log input data along with preprocessing steps for traceability and auditing purposes.

2.5.2 Feature Extraction

1. Description and Priority

   This feature involves extracting relevant features from CTG exams, such as baseline FHR,variability, accelerations, and decelerations. It is of High priority as it directly contributes to the accuracy of the classification model.

2. Stimulus/Response Sequences

   (a) Stimulus: User initiates the feature extraction process.

   (b) Response: System processes CTG data and extracts relevant features.

3. Functional Requirements

(a) REQ-6: Implement algorithms for feature extraction, including baseline FHR calculation, variability analysis, and identification of accelerations and decelerations.

(b) REQ-7: Ensure extracted features are representative of fetal well-being indicators as per medical standards

(c) REQ-8: Validate extracted features to ensure accuracy and consistency

(d) REQ-9: Generate feature summaries and visualizations to aid in interpretation by healthcare professionals.

2.5.3 Doctor Dashboard and Patient Management

1. Description and Priority

   This feature enables doctors to log in, access patient information, and manage CTG data for each patient. It is of High priority as it provides essential functionality for healthcare professionals to monitor and track patient progress.

2. Stimulus/Response Sequences

   (a) Stimulus: Doctor logs into the system using their credentials

   (b) Response: System authenticates the doctor and presents the doctor dashboard with patient management options.

3. Functional Requirements

   (a) REQ-11: Implement secure login functionality for doctors with authentication and authorization mechanisms.

   (b) REQ-12: Provide a dashboard interface for doctors to view a list of their patients and select individual patients for detailed information.

   (c) REQ-13: Enable doctors to add new patients to the system, including basic demographic information and relevant medical history.

   (d) REQ-14: Store CTG data for each patient on a weekly basis, allowing doctors to access and review historical data.

(e) REQ-15: Allow doctors to generate graphs for specific CTG parameters (baseline FHR, number of accelerations, number of contractions, etc.) for any selected week of a patient's data.

(f) REQ-16: Ensure data privacy and compliance with healthcare regulations by implementing appropriate data encryption and access controls.

2.5.4 User Authentication and Profile Management

1. Description and Priority

   This feature ensures secure authentication for all users accessing the system and allows them to manage their profiles. It is of High priority as it safeguards sensitive patient data and ensures accountability for user actions.

2. Stimulus/Response Sequences

   (a) Stimulus: User attempts to access the system or perform profile-related actions.

   (b) Response: System verifies user credentials and grants appropriate access or updates user profile information.

3. Functional Requirements

   (a) REQ-18: Implement user authentication mechanisms, including username/password-based authentication or integration with external authentication providers (e.g., LDAP, OAuth).

   (b) REQ-19: Allow users to register for new accounts with required information and email verification.

   (c) REQ-20: Provide options for users to reset forgotten passwords through secure verification methods.

   (d) REQ-21: Enable users to update their profile information, including contact details, specialty (for doctors), and preferences.

   (e) REQ-22: Implement role-based access control (RBAC) to ensure appropriate permissions for different user roles (e.g., doctor, admin, patient).

(f) REQ-23: Log user activities and authentication events for auditing and security purposes.

(g) REQ-24: Ensure compliance with data protection regulations (e.g., GDPR, HIPAA) by implementing appropriate security measures such as encryption of sensitive user data.

2.5.5 Graph Generation

1. Description and Priority

   This feature enables users to generate graphs for visualizing CTG data, including parameters such as baseline fetal heart rate, number of accelerations per second, number of uterine contractions per second, percentage of time with abnormal short-term variability, and percentage of time with abnormal long-term variability. It is of High priority as it provides critical visualization tools for healthcare professionals to interpret and analyze CTG data.

2. Stimulus/Response Sequences

   (a) Stimulus: User selects the option to generate graphs for specific CTG parameters.

   (b) Response: System processes the selected data and generates graphical representations of the requested parameters.

3. Functional Requirements

   (a) REQ-25: Implement graph generation functionality for various CTG parameters, including baseline fetal heart rate, accelerations, contractions, and variability.

   (b) REQ-26: Allow users to select the time range for graph generation, including specific weeks or date ranges of patient data.

   (c) REQ-27: Provide options for users to customize graph types (e.g., line chart, bar chart) and styling options (e.g., colors, axis labels).

(d) REQ-28: Ensure graphs are generated in a clear and visually appealing manner, with appropriate labels and annotations for interpretation.

(e) REQ-29: Enable users to export generated graphs in common formats (e.g., PNG, PDF) for sharing and documentation purposes.

(f) REQ-30: Implement real-time updating of graphs as new CTG data is added or modified, ensuring that users always have access to the latest visualizations.

2.5.6 Contact Us

1. Description and Priority

   This feature allows users to contact the system administrators or support team via email or phone for assistance, feedback, or inquiries. It is of Medium priority as it supports user engagement and ensures that users have access to necessary assistance when needed.

2. Stimulus/Response Sequences

   (a) Stimulus: User navigates to the "Contact Us" section of the application.

   (b) Response: System provides options for users to view contact information for email and phone support.

3. Functional Requirements

   (a) REQ-31: Include contact information (email address and phone number) for the system administrators or support team on the "Contact Us" page.

   (b) REQ-32: Regularly update and maintain contact information to ensure accuracy and reliability.

2.6 Other Nonfunctional Requirements

2.6.1 Performance Requirements

1. CTG Classification Performance

Accuracy: The FHE's machine learning model shall achieve an accuracy of at least 90classifying CTG exams into normal, suspect, and pathological categories. This accuracy metric is crucial for doctors to rely on the FHE's classification as a valuable decision-making aid.

Latency: The classification process, including data upload, analysis by the model, and displaying the results, should be completed within 30 seconds for a standard CTG exam file. This timeframe ensures minimal disruption to workflow and allows doctors to receive timely feedback.

2. Data Management Performance

   Data upload: Uploading a CTG exam file (typical size: 1-5 MB) should not take more than 10 seconds. This ensures a smooth workflow for doctors when adding new CTG data to the system.

   Data retrieval: Retrieving a specific patient's historical CTG data and generating the corresponding graphs should be completed within 5 seconds. This responsiveness allows for efficient review and analysis of patient trends.

3. System Availability

   The FHE application should be available for use at least 99 percent of the time during normal business hours. This high availability ensures minimal disruption to healthcare professionals relying on the FHE for patient care.

4. Response Time

   The user interface should be responsive and provide feedback to user actions (e.g., button clicks, menu selections) within 1 second. This responsiveness contributes to a positive user experience and avoids frustration for doctors using the application.

2.6.2 Safety Requirements

1. Data Security and Privacy

It shall comply with all applicable healthcare data privacy regulations. This ensures patient data confidentiality and protects against unauthorized access or breaches. The Fetal Health Examiner shall implement secure data encryption practices for storing and transmitting patient CTG data. This safeguards sensitive information from potential security vulnerabilities.User access to the FHE shall be controlled through a robust authentication system with role-based access controls. This restricts access to patient data only to authorized healthcare professionals.

2. System Reliability

   The FHE shall be designed and developed with a focus on minimizing software errors and bugs that could lead to inaccurate classification results or data loss. This includes implementing robust testing procedures throughout the development lifecycle.The FHE shall have mechanisms for data backup and recovery to ensure patient information is not permanently lost in case of system malfunctions or hardware failures.The application shall include clear error messages and informative alerts to notify users of any potential issues with data upload, processing, or results. This allows doctors to identify and address any problems promptly.

3. User Training and Awareness

   The FHE shall be accompanied by comprehensive user documentation that clearly outlines the application's functionalities, limitations, and intended use. This ensures healthcare professionals understand the role of the FHE as a decision-making aid and not a replacement for their expertise.

4. System Monitoring

   The FHE shall implement mechanisms for monitoring system performance and identifying potential issues that could affect data integrity or classification accuracy. This allows for proactive maintenance and troubleshooting to minimize risks.A clear process for reporting and addressing any malfunctions or unexpected behavior of the FHE should be established. This ensures prompt corrective actions are taken to maintain system safety.

2.6.3 Security Requirements

1. Data Security

   Data Encryption: The FHE shall implement industry-standard encryption algorithms to encrypt patient CTG data at rest and in transit. This safeguards sensitive information from unauthorized access even if intercepted by malicious actors.

   Access Control: User access to the FHE shall be controlled through a multi-factor authentication system. This requires users to provide two or more verification factors (e.g., username, password, one-time code) to gain access, minimizing the risk of unauthorized login attempts.

2. Data Privacy

   Compliance: The FHE shall comply with all applicable healthcare data privacy regulations. These regulations define specific requirements for data collection, storage, use, disclosure, and disposal of patient information.

   Data Minimization: The FHE shall collect and store only the minimum amount of patient data necessary for its functionalities. This reduces the amount of sensitive information that needs to be protected.

   Data Retention: The FHE shall have a defined data retention policy outlining how long patient CTG data will be stored and the procedures for secure deletion when no longer required.

3. User Responsibilities

   User training materials shall emphasize the importance of strong password management practices and responsible data handling. This includes educating users on how to identify and avoid phishing attempts or social engineering tactics.

2.6.4 Software Quality Attributes

1. Usability

   User Interface: The FHE shall prioritize a user-friendly and intuitive graphical user interface (GUI) that minimizes training requirements for healthcare professionals. Workflow Integration: The FHE should integrate seamlessly into existing clinical workflows. Data import and export functionalities should be straightforward and minimize disruption to routine tasks.

   Response Time: The user interface should be responsive with minimal lag between user actions (e.g., button clicks) and system feedback (e.g., displaying results). This responsiveness contributes to a positive user experience.

2. Reliability

   Accuracy: The FHE's machine learning model shall achieve an accuracy of at least 90classifying CTG exams. This ensures reliable results that doctors can trust as a decision-making aid.

   Uptime: The FHE shall maintain a high availability of at least 99 percent during business hours. This minimizes downtime and ensures doctors can access the application when needed.

   Error Handling: The FHE shall implement robust error handling mechanisms to gracefully handle unexpected situations (e.g., network issues, invalid data formats). Informative error messages should be displayed to guide users in resolving any problems.

3. Maintainability

   Modular Design: The FHE shall be designed with a modular architecture to facilitate future enhancements and easier maintenance. This allows for modifications to specific functionalities without impacting the entire system.

Code Documentation: Well-documented code with clear comments and explanations will be essential for future maintenance and modifications by developers.

Configurability: The FHE should be configurable to accommodate potential variations in EHR system integration or user preferences without requiring extensive code changes.

4. Security

Data Encryption: The FHE shall employ industry-standard encryption algorithms to protect patient CTG data at rest and in transit. This ensures data confidentiality even in case of security breaches.

Secure Authentication: User access to the FHE shall be controlled through a multi-factor authentication system, requiring additional verification beyond usernames and passwords. This strengthens the security posture of the application.

Regular Security Testing: The FHE shall undergo periodic security testing to identify and address potential vulnerabilities. This proactive approach minimizes security risks.

Chapter 3

System Architecture and Design

3.1 System Overview

The "Fetal Health Examiner" project aims to develop a machine learning-based system for automated classification of Cardiotocogram (CTG) traces into three categories: Normal, Suspect, and Pathological. This system will assist healthcare professionals in assessing fetal well-being during pregnancy, enabling timely interventions to prevent adverse outcomes. The system's architecture consists of several interconnected components, including data collection, preprocessing, feature extraction, model training, and real-time classification.

1. **Data Collection**:

- The system begins with the collection of CTG data from various sources, including hospitals, clinics, and research databases.
- The collected data may include CTG traces along with corresponding annotations provided by expert obstetricians, indicating the fetal health status.

2. **Data Preprocessing**:

- The collected CTG data undergoes preprocessing to ensure consistency and quality.
- Preprocessing steps may include data cleaning, normalization, and artifact removal to eliminate noise and improve the reliability of the data.

3. **Feature Extraction**:

- Following preprocessing, relevant features are extracted from the CTG traces to capture key indicators of fetal well-being.

- This feature involves extracting relevant features from CTG exams, such as baseline FHR, variability, accelerations, and deceleration

4. Model Training:

- The extracted features are used to train a machine learning model for CTG classification.
- Various classification algorithms, such as decision trees, support vector machines, or deep learning models, are explored and evaluated for their effectiveness in classifying CTG traces into Normal, Suspect, and Pathological categories.

5. Real-time Classification:

- Once trained, the classification model is integrated into a real-time processing pipeline capable of analyzing CTG traces as they are recorded.
- The system continuously receives CTG data streams and applies the trained model to classify the fetal health status in real-time.
- Classification results are provided to healthcare professionals through a user-friendly interface, enabling prompt decision-making and intervention when necessary.

6. Graph Generation:

- Graph generation module generates visualizations and graphs to represent analysis results and model performance metrics.
- Visualizations aid in interpreting data and model outputs, facilitating better decision-making.

7.Integration:

- Integration module combines the machine learning models with the user interface to create a functional application.
- It enables seamless interaction between the UI and backend model functionalities, allowing users to perform CTG analysis effectively.

Architecture Diagram:

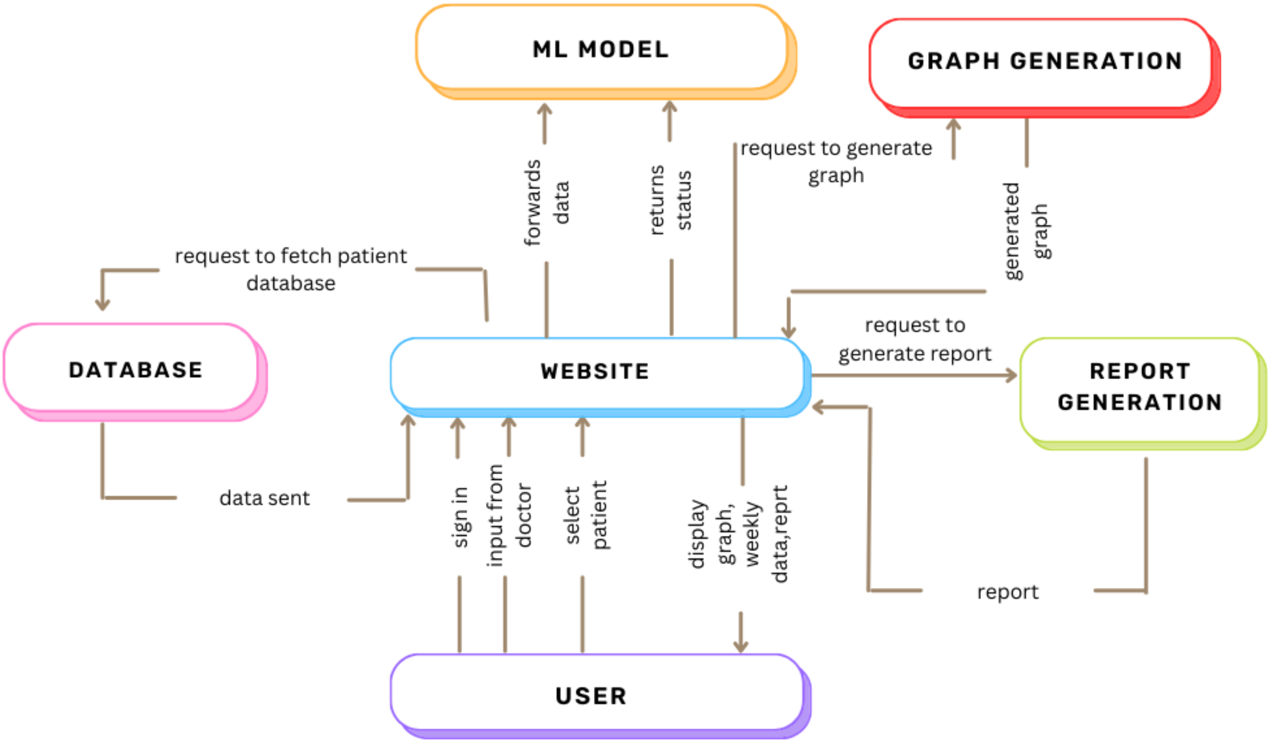


Figure 3.1: Architecture diagram

Conclusion:

The "Fetal Health Examiner" system offers a comprehensive solution for automated CTG analysis, providing healthcare professionals with a reliable tool for assessing fetal well-being during pregnancy. By leveraging machine learning techniques and real-time processing capabilities, the system aims to improve prenatal care practices and contribute to better pregnancy outcomes.

3.2 Architectural Design

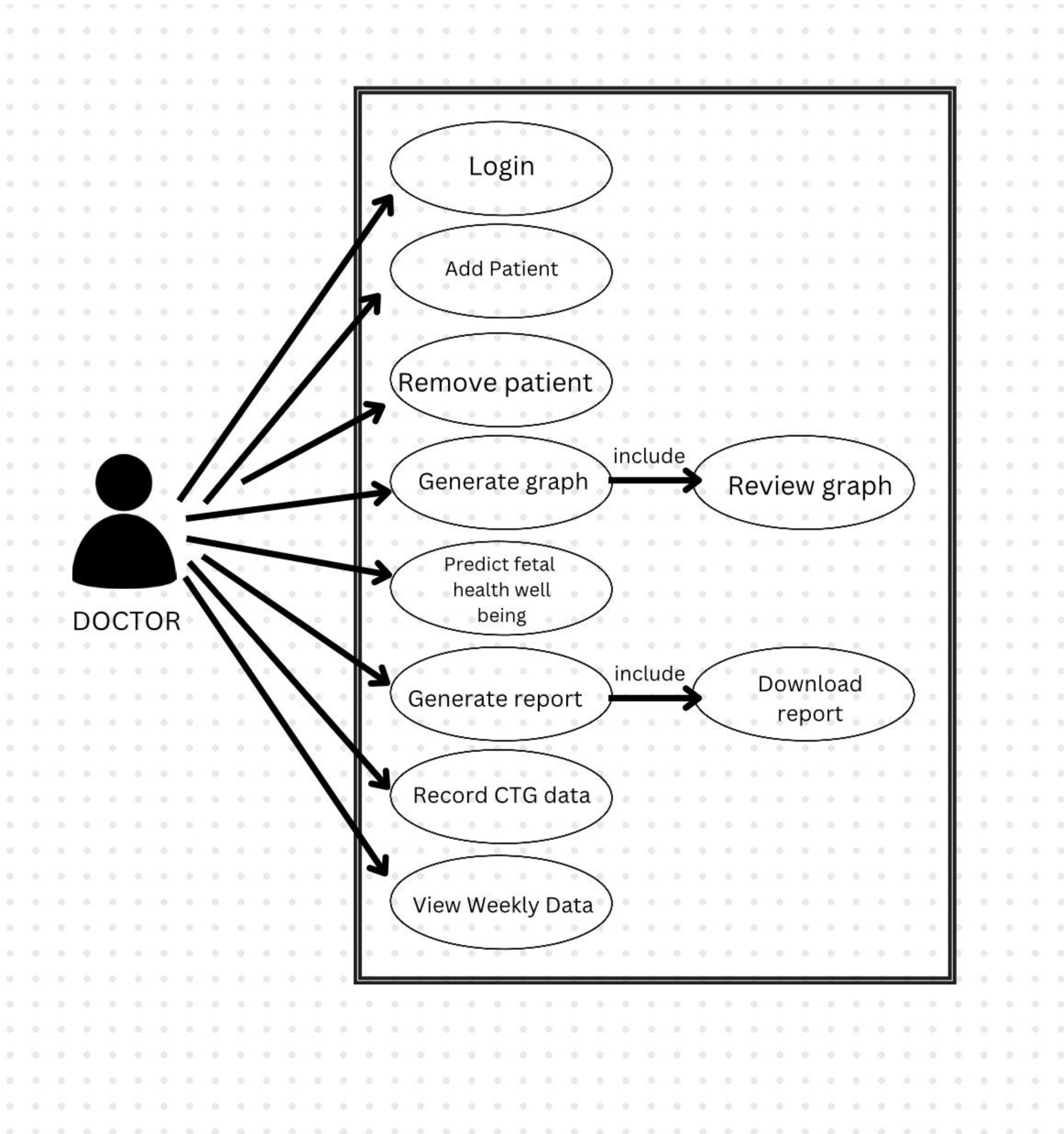


Figure 3.2: Use case diagram

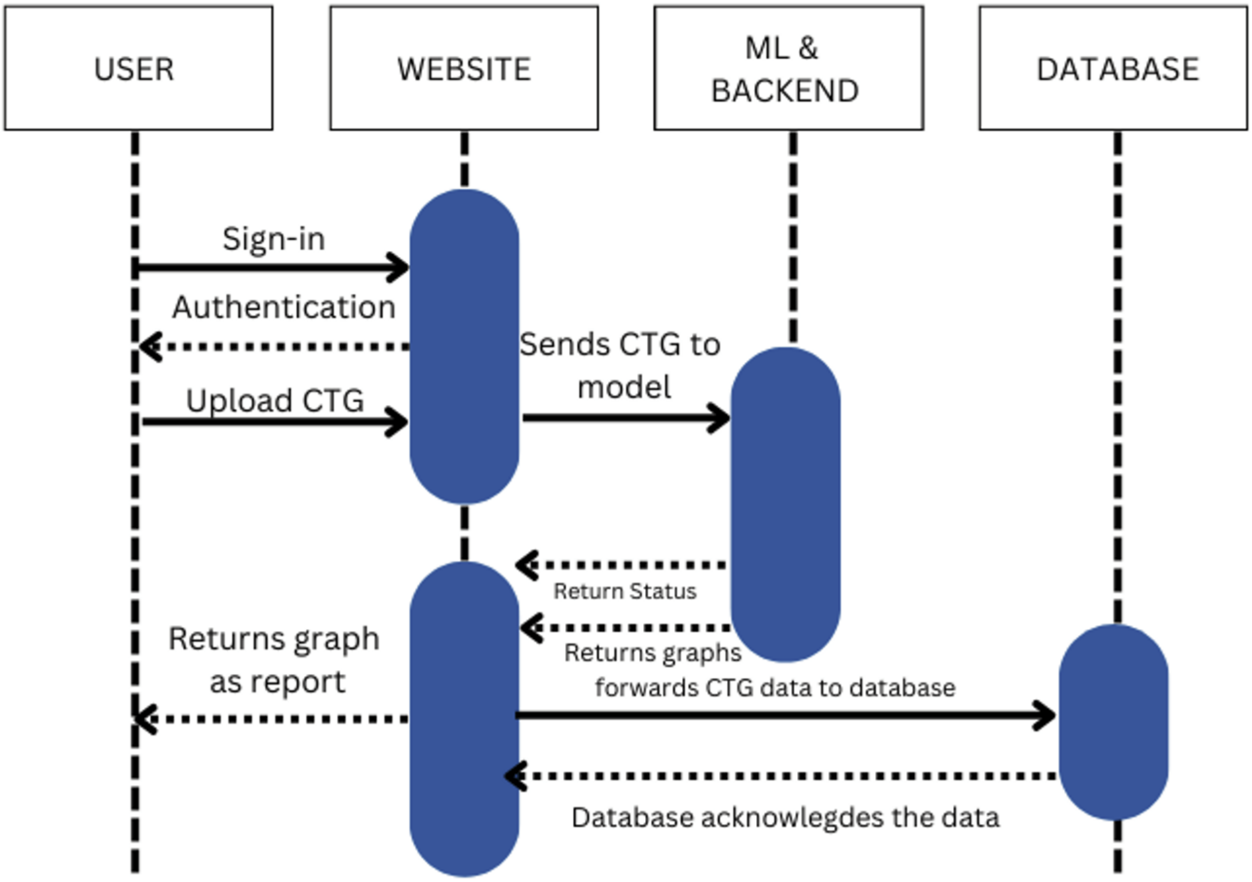


Figure 3.3: Sequence diagram

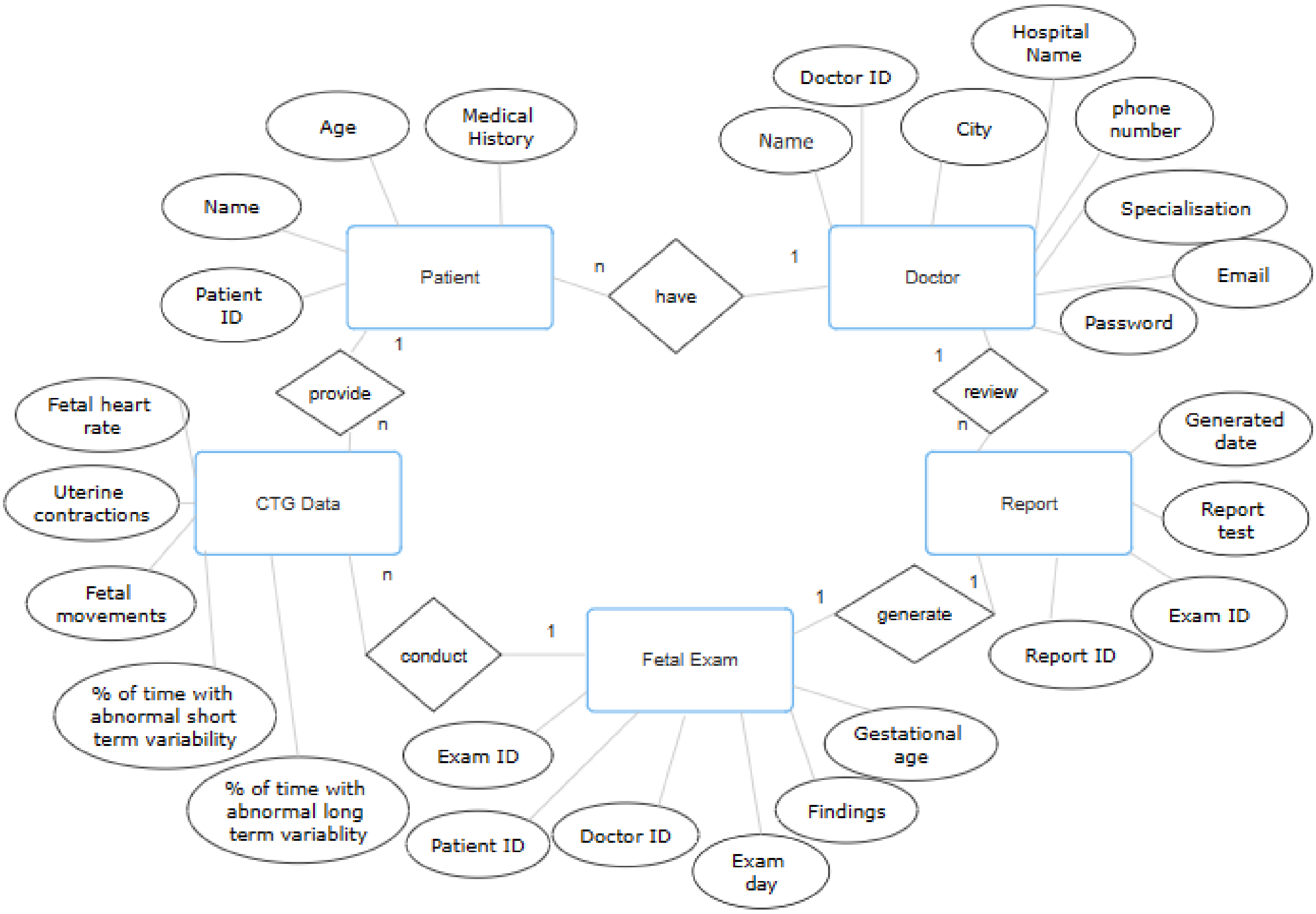


Figure 3.4: ER diagram

3.3 Dataset identified

The dataset selected for the "Fetal Health Examiner" project is the CTG dataset publicly available from Kaggle, which is classified by expert obstetricians, as described in Ayres de Campos et al. (2000) SisPorto 2.0 A Program for Automated Analysis of Cardiotocograms. J Matern Fetal Med 5:311-318. This dataset comprises 2,126 records of Cardiotocogram (CTG) exams, each classified by expert obstetricians into one of three categories: Normal, Suspect, or Pathological. The dataset contains a total of 21 features extracted from CTG traces, including fetal heart rate (FHR) accelerations, decelerations, baseline variability, and uterine contractions. Additionally, demographic information such as gestational age, fetal weight, and presence of meconium are also included in the dataset.

Dataset Properties:

- Number of Instances: 2,126
- Number of Features: 21
- Classes: Normal, Suspect, Pathological
- Data Source: Kaggle
- Availability: Publicly accessible for research purposes

Sample Subsets:

To illustrate the dataset's properties, sample subsets of CTG traces from each class (Normal, Suspect, Pathological) can be highlighted. For instance:

- Normal: A subset of CTG traces exhibiting stable fetal heart rate patterns with minimal variability and few or no decelerations.
- Suspect: A subset of CTG traces demonstrating moderate variability in fetal heart rate, occasional decelerations, or other irregularities warranting further investigation.
- Pathological: A subset of CTG traces showing significant deviations from normal patterns, including severe decelerations, reduced variability, and other signs indicating potential fetal distress.

These sample subsets will be instrumental in training and evaluating the machine learning model for CTG classification, providing insights into the dataset's distribution and characteristics.

Reference: The dataset can be accessed and downloaded from the Kaggle website at the following location: https://www.kaggle.com/code/karnikakapoor/fetal-health-classification- CTG Dataset

3.4 Proposed Methodology/Algorithms

The "Fetal Health Examiner" project employs a combination of preprocessing techniques and machine learning algorithms for Cardiotocogram (CTG) classification. Outline of the methodology and algorithms involved in the project are:

3.4.1 Data Preprocessing:

Data preprocessing is essential to prepare the input data for model training. This involves handling missing values and scaling features

ALGORITHM:

HANDLING MISSING VALUE

- Strategy: Impute missing values using the mean of the feature column.
- Implementation:

1. Use the SimpleImputer class from sklearn.impute module with the 'mean' strategy.
2. Fit the imputer on the training data and transform both training and testing data

FEATURE SCALING

- Strategy: Standardize feature values to have zero mean and unit variance.
- Implementation:

1. Utilize the StandardScaler class from sklearn.preprocessing module.
2. Fit the scaler on the training data and transform both training and testing data.

3.4.2 Model training:

Support Vector Machine(SVM)

SVM is a supervised learning algorithm used for classification tasks. Finds the optimal hyperplane that best separates the classes in the feature space.

ALGORITHM

1. Import the SVM classifier

2. Create an SVM classifier with a radial basis function (RBF) kernel

3. Train the SVM classifier using the training data

Logistic Regression:

Logistic Regression is a linear model used for binary classification tasks. It estimates the probability that a given instance belongs to a particular class.

ALGORITHM

1. Import the Logistic Regression classifier

2. Create a Logistic Regression classifier

3. Train the Logistic Regression classifier using the training data

Random Forest:

Random Forest is an ensemble learning method that builds multiple decision trees during training and combines their predictions to improve accuracy and reduce overfitting.

ALGORITHM

1. Import the Random Forest classifier

2. Create a Random Forest classifier with 100 trees, maximum depth of 10, and random state 42

3. Train the Random Forest classifier using the training data

3.4.3 Choosing Best Algorithm:

After training multiple models, we evaluate their performance using appropriate metrics such as accuracy, F1 score, precision, and recall. The model with the highest performance metrics is selected as the best algorithm.

ALGORITHM

Predictions from different classifiers:

- Generate predictions for the test dataset using trained classifiers for SVM, Logistic Regression, and Random Forest algorithms.

- Store the predictions in variables: svm_pred, logreg_pred, and rf_pred.

Evaluate accuracy and F1 score:

- Calculate the accuracy and F1 score for each classifier based on the predicted and true labels of the test dataset.
- Use the accuracy_score and f1_score functions from the sklearnmetrics module.
- Compute accuracy and F1 score for SVM, Logistic Regression, and Random Forest classifiers.
- Store the accuracy and F1 score values in variables: svm_accuracy, logreg_accuracy, rf_accuracy, svm_f1, logreg_f1, and rf_f1.

Compare performance metrics and choose the best algorithm:

- Compare the accuracy and F1 score of SVM, Logistic Regression, and Random Forest classifiers.
- Select the classifier with the highest combined accuracy and F1 score as the best algorithm.
- Store the best algorithm and its corresponding performance metrics in the variable best_algorithm.

In this proposed methodology, data preprocessing ensures that the input data is properly formatted and scaled for model training. We then train multiple classification algorithms, including SVM, Logistic Regression, and Random Forest. Finally, we evaluate their performance using accuracy and F1 score metrics to select the best algorithm for CTG classification.

3.5 User Interface Design

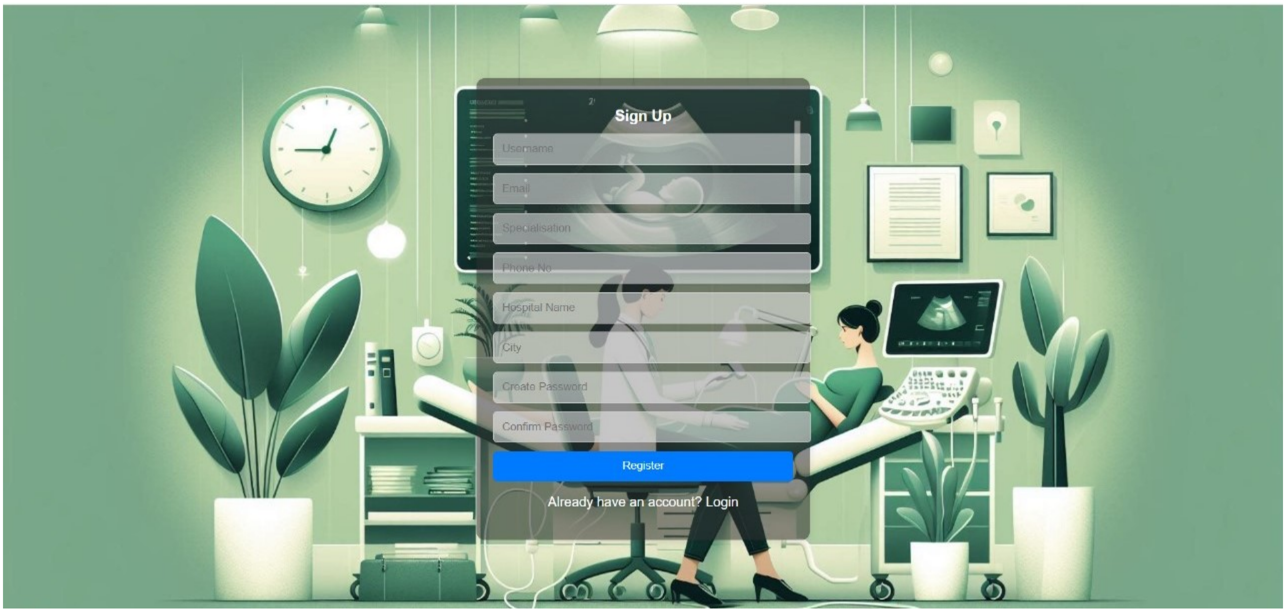


Figure 3.5: Sign up page

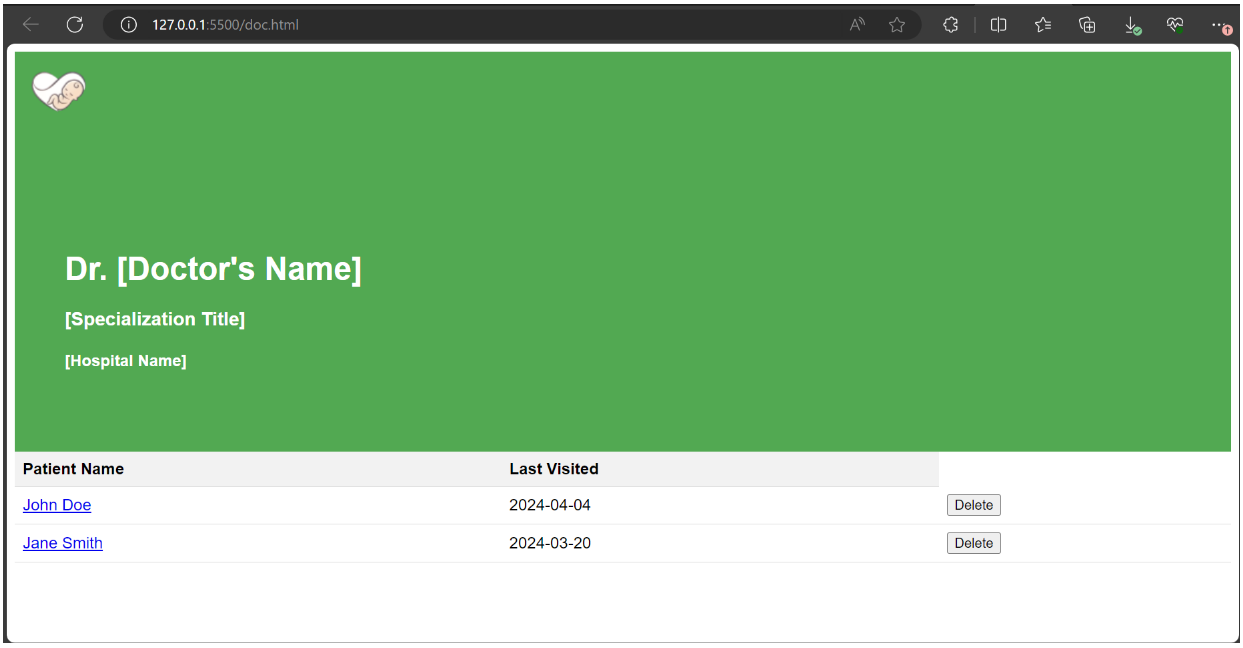


Figure 3.6: Doctor dashboard

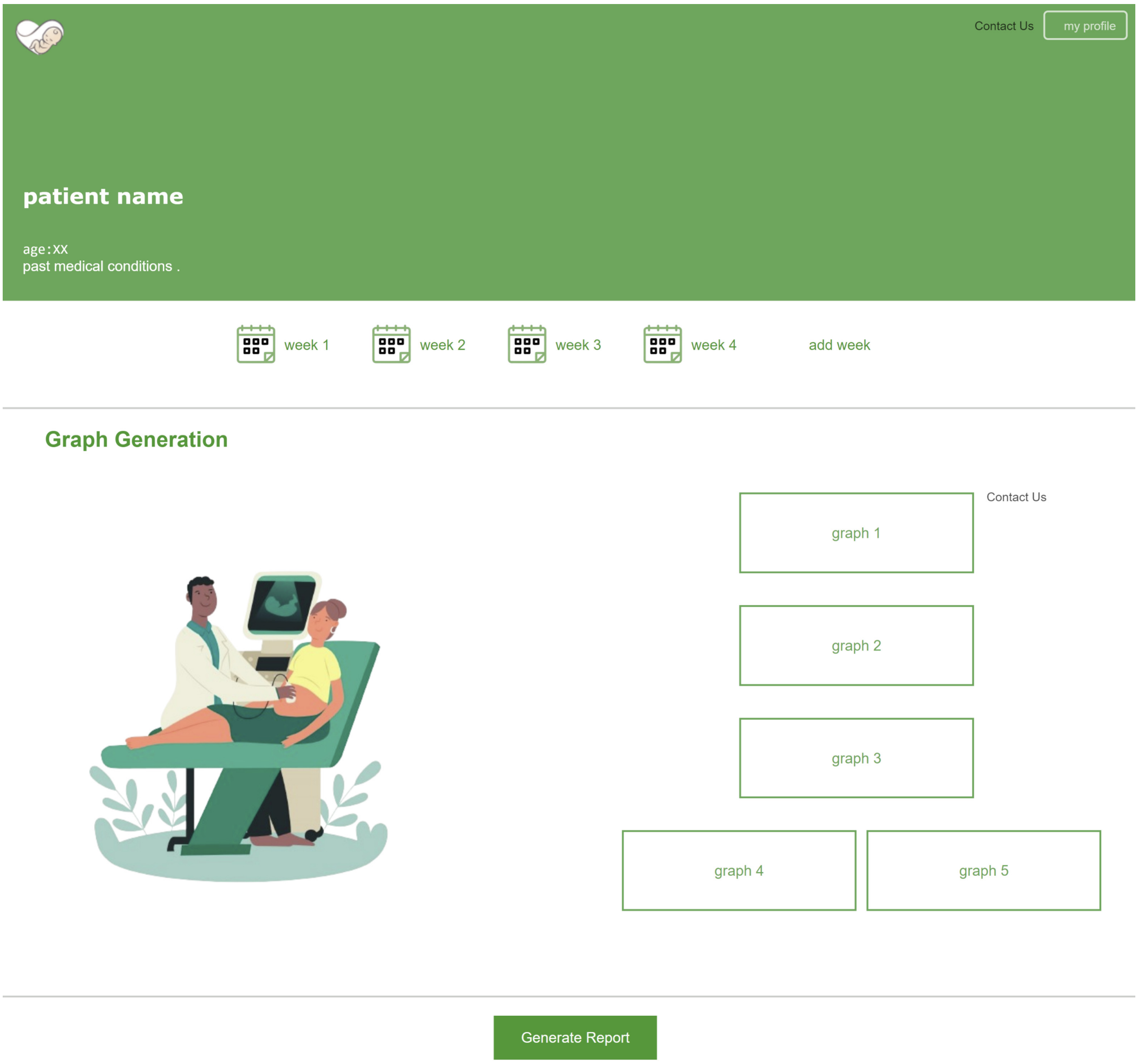


Figure 3.7: patient details

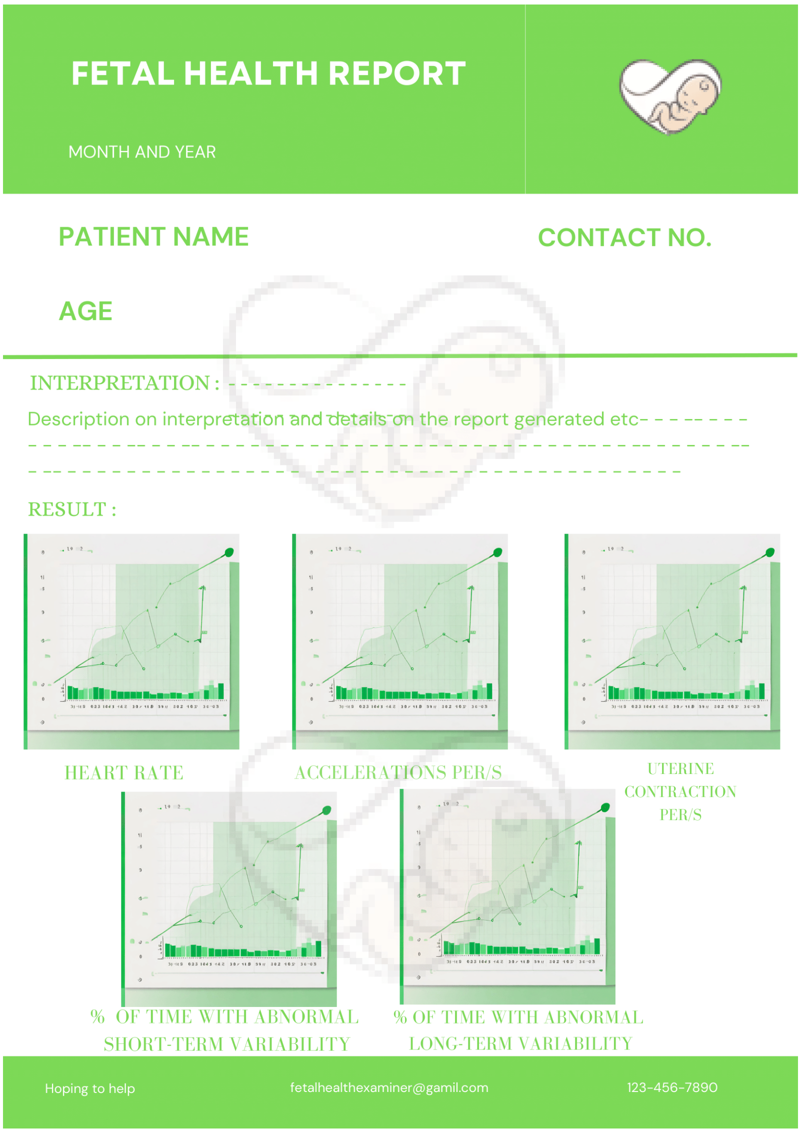


Figure 3.8: Report

3.6 Database Design

The "Fetal Health Examiner" project utilizes a relational database management system for storing and managing the CTG data, user information, and system logs. The chosen database for this project is SQL, a powerful open-source known for its reliability, scalability, and robust feature set. SQL provides support for complex data types, transactions, and advanced querying capabilities, making it suitable for handling the diverse requirements of the project.

Database Schema:

- Doctor

  {

  Doctor_ID PRIMARY KEY

  Doctor_Name

  Specialization

  Hospital_name

  City

  Phone_number

  Email

  Password UNIQUE

  }

- Patient

  {

  Patient_ID PRIMARY KEY

  Patient_name

  Age

  Medical_history

  }

- CTG

  {

  Fetal_Heart_Rate

  Uterine_Contractions

  Percentage_of_times_with_abnormal_short_term_variability

  Percentage_of_times_with_abnormal_long_term_variability

  Fetal_movements

}

- Fetal_Exam

  {

  Exam_ID PRIMARY KEY

  Patient_ID FOREIGN KEY

  Doctor_ID FOREIGN KEY

  Examinated_day

  Findings

  Gestational_Age

  }

- Report

  {

  Report_ID PRIMARY KEY

  Exam_ID FOREING KEY

  Report_test

  Generated_Date

  }

3.7 Description of Implementation Strategies

3.7.1 Using ML Model Algorithms from scikit-learn:

- Description: Implement machine learning algorithms from the scikit-learn library for classification tasks. This involves selecting appropriate algorithms, training them on the data, and evaluating their performance using metrics such as accuracy, precision, recall, and F1-score.

- Implementation: Utilize algorithms such as SVM, Logistic Regression, and Random Forest from the scikit-learn library for classification tasks.

3.7.2 Data Preprocessing using pandas and numpy:

- Description: Perform data preprocessing tasks such as data cleaning, normalization, and handling missing values using the pandas and numpy libraries in Python.

- Implementation:

  1. Data Normalization:

     ```
     from sklearn.preprocessing import StandardScaler
     scaler = StandardScaler()
     X_train_scaled = scaler.fit_transform(X_train)
     X_test_scaled = scaler.transform(X_test)
     ```

  2. Removing Null Data:

     ```
     import pandas as pd
     Remove rows with null values
     data_cleaned = data.dropna()
     ```

These implementation strategies leverage popular Python libraries such as scikit-learn, pandas, and numpy to perform machine learning tasks efficiently. By utilizing pre-built functions and methods from these libraries, the implementation process is streamlined, allowing for faster development and experimentation with machine learning models.

3.8 Module Division

3.8.1 Data Preprocessing:

- Responsible for cleaning, transforming, and preparing the raw CTG data for model training.

- Includes tasks such as handling missing values and scaling features.

3.8.2 Model Creation and Selection:

- Involves the development and training of machine learning models for CTG classification.

- Includes selecting appropriate algorithms (e.g., SVM, Logistic Regression, Random Forest) and evaluating model performance.

3.8.3 Model Evaluation:

- Focuses on evaluating the performance of trained models using metrics such as accuracy, precision, recall, and F1-score.
- Helps in comparing different models and selecting the best-performing one for deployment.

3.8.4 User Authentication:

- Manages user authentication and authorization within the system.
- Ensures secure access to the application and restricts unauthorized users from accessing sensitive data.

3.8.5 User Interface (UI):

- Deals with the design and implementation of the graphical user interface (GUI) for the application.
- Provides an interactive platform for users to upload CTG data, view analysis results, and interact with the system.

3.8.6 Graph Generation:

- Generates visualizations and graphs to represent analysis results and other relevant information.
- Enhances the interpretability of data and model outputs, aiding users in understanding and making informed decisions.

3.8.7 Integration:

- Combines the machine learning models with the user interface to create a functional application.

- Enables seamless interaction between the user interface and backend model functionalities, allowing users to perform CTG analysis effectively.

Modules are divided as follows:

- Danish H Muhammed - User Authentication, User Interface
- Gopika M - Integration
- Melissa Biju Kalayil - Data Preprocessing, Graph Generation
- Muhammed Bais - Model Creation and Selection, Model Evaluation

3.9 Work Schedule - Gantt Chart

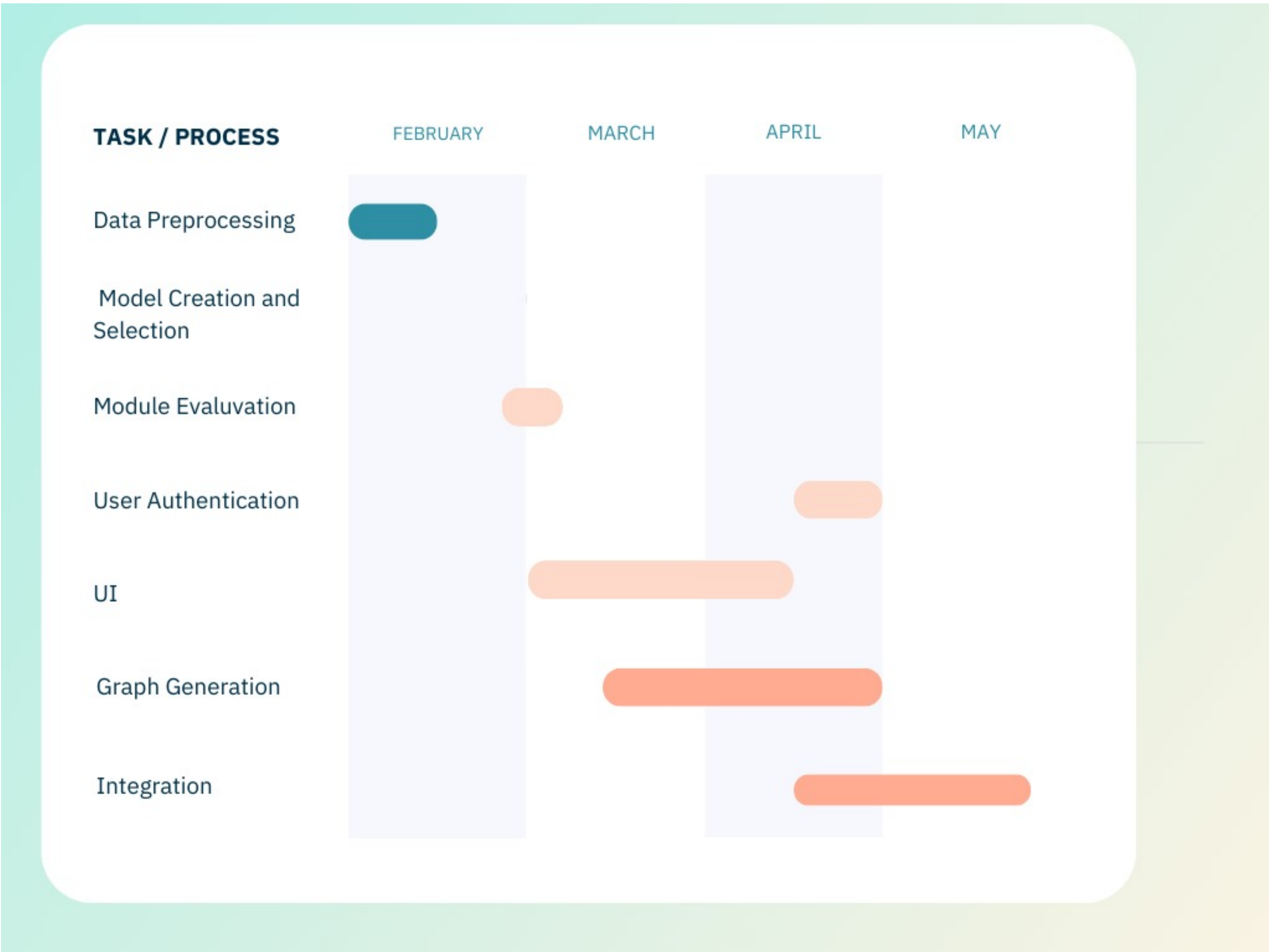


Figure 3.9: Gantt Chart

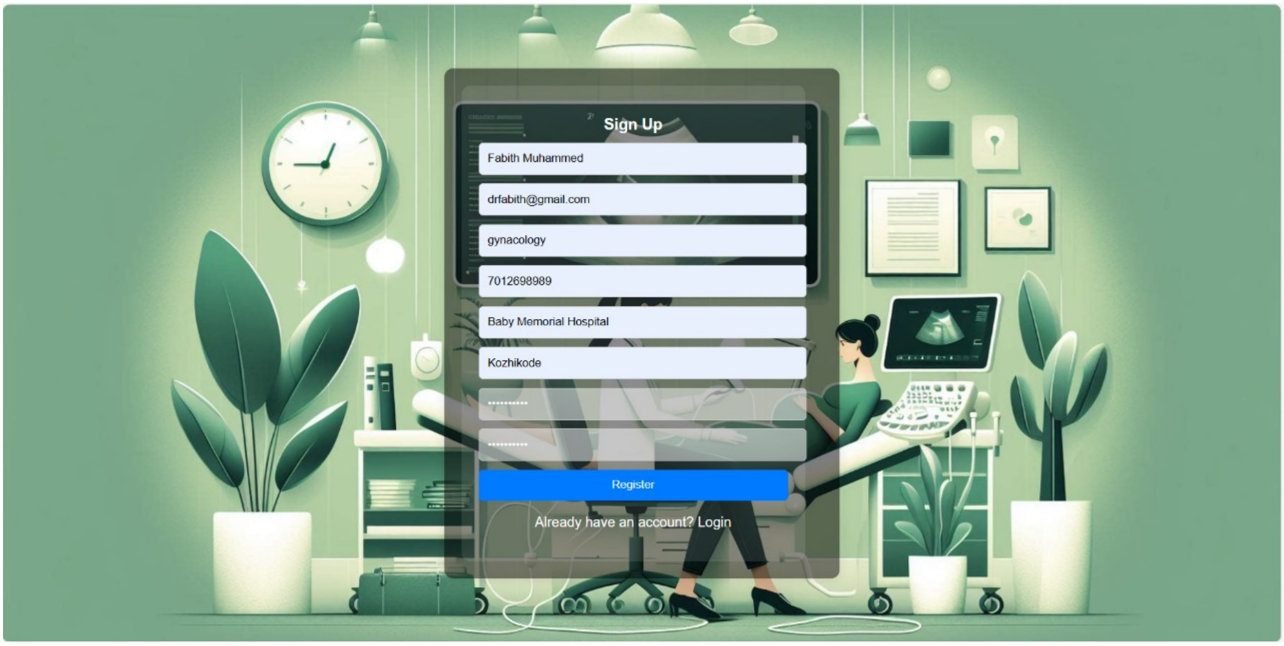
Chapter 4

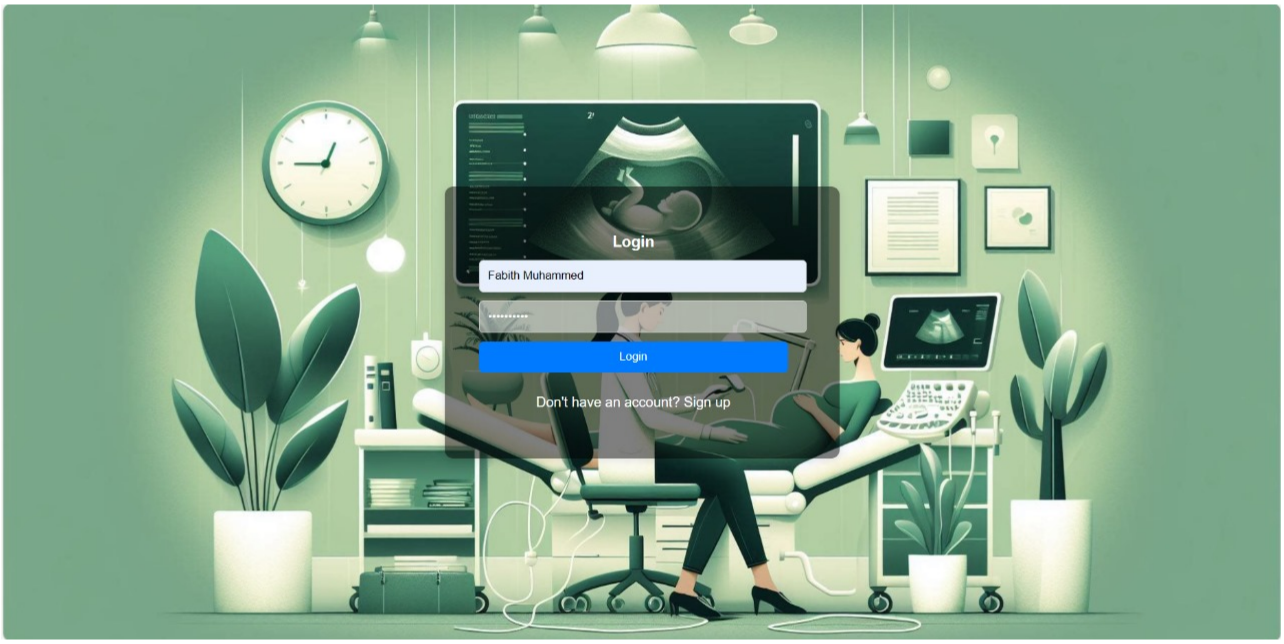
Results and Discussions

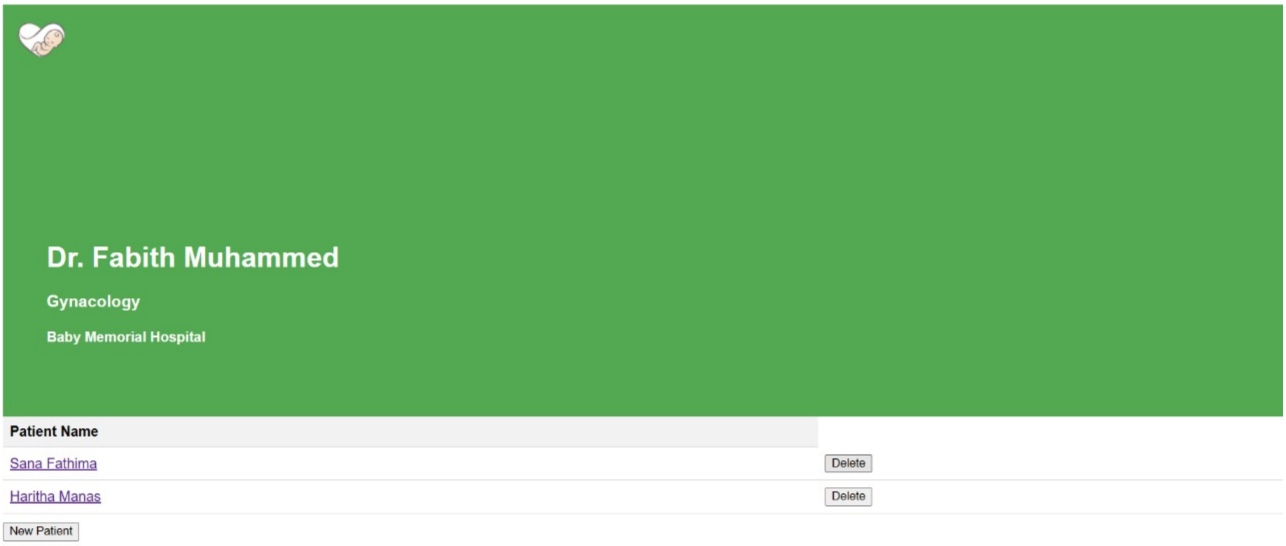
4.1 Overview

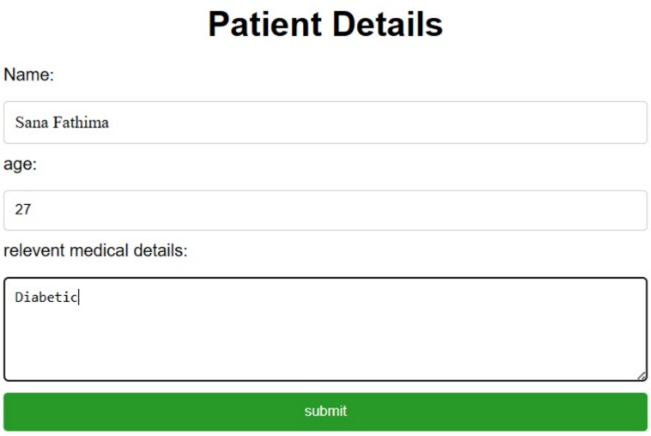
The "Fetal Health Examiner" project has yielded promising results in its endeavor to automate CTG analysis for assessing fetal well-being during pregnancy. Through rigorous model training and evaluation, the system demonstrates high accuracy and reliability in classifying CTG traces into categories of normal, suspect, and pathological. Quantitative metrics such as accuracy, precision, recall, and F1-score further validate the effectiveness of the machine learning algorithms employed. Additionally, the system's user-friendly interface facilitates seamless interaction, empowering healthcare professionals to make informed decisions based on the generated analysis results. Further analysis reveals the potential for early detection of fetal distress, enabling timely interventions to mitigate adverse pregnancy outcomes. Overall, the "Fetal Health Examiner" project signifies a significant advancement in prenatal care, offering a comprehensive solution for improved fetal health monitoring and management.

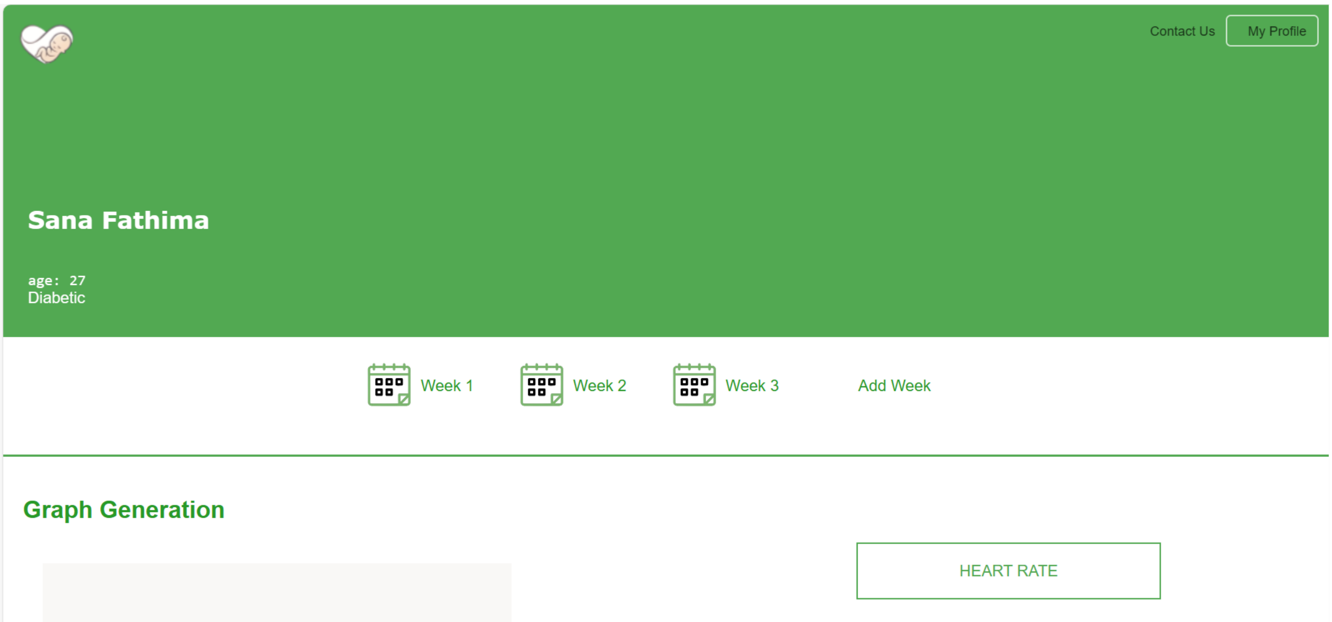
4.2 Testing

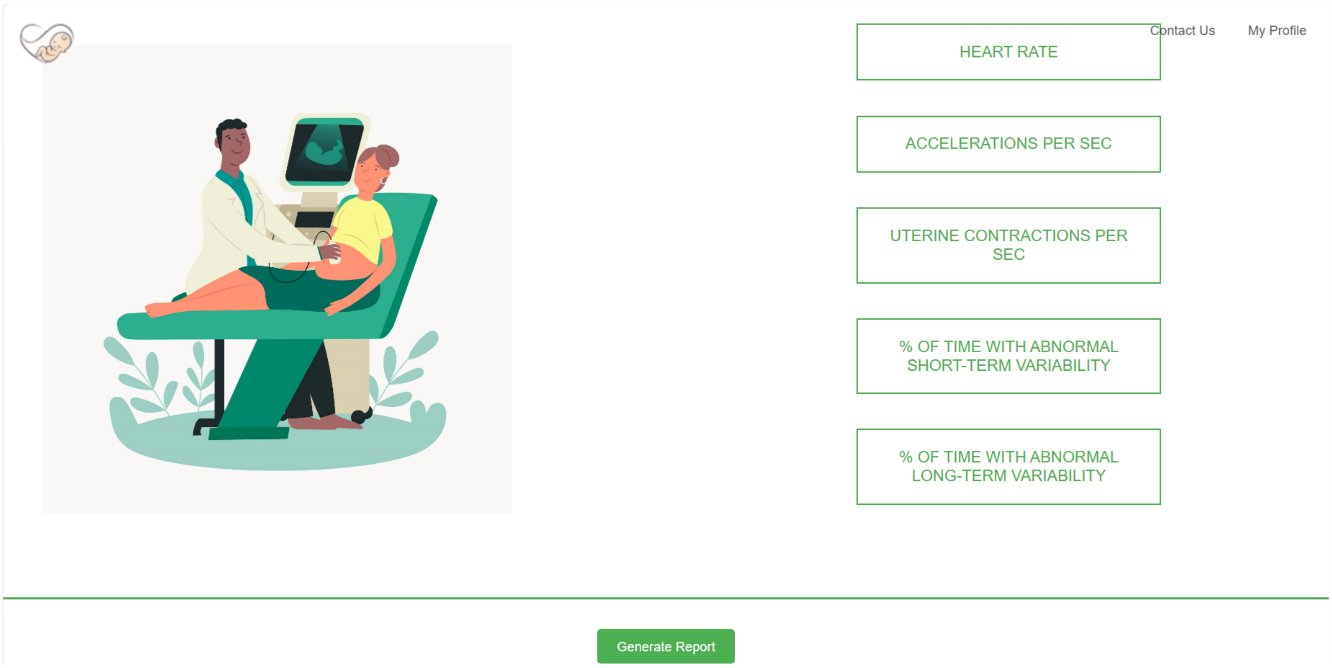

Sign Up
Fabith Muhammed
drfabith@gmail.com
gynacology
7012698989
Baby Memorial Hospital
Kozhikode
Register
Already have an account? Login


Login
Fabith Muhammed
Login
Don't have an account? Sign up


Dr. Fabith Muhammed
Gynacology
Baby Memorial Hospital
Patient Name
Sana Fathima
Delete
Haritha Manas
Delete
New Patient


Patient Details
Name:
Sana Fathima
age:
27
relevent medical details:
Diabetic
submit


Contact Us
My Profile
Sana Fathima
age: 27
Diabetic
Week 1
Week 2
Week 3
Add Week
Graph Generation
HEART RATE


Contact Us
My Profile
HEART RATE
ACCELERATIONS PER SEC
UTERINE CONTRACTIONS PER SEC
% OF TIME WITH ABNORMAL SHORT-TERM VARIABILITY
% OF TIME WITH ABNORMAL LONG-TERM VARIABILITY
Generate Report

×

Add Week Data

Baseline Fetal Heart Rate	Accelerations	Fetal movement	Uterine contractions	Light decelerations	Severe dec

Submit

×

Week Data

Baseline Fetal Heart Rate	Accelerations	Fetal movement	Uterine contractions	Light decelerations	Severe deceleration	Prolongued deceleration	Percentage of time with Abnormal short term variability	Mean val of short t variabili
132	0.007	0	0.008	0	0	0	16	2.4

Result: Normal

FETAL HEALTH REPORT

Doctor: Fabith Muhammed **Contact No: 7012698989**

Patient: Sana Fathima

Age: 27

INTERPRETATION: Pathological

Following a pathological classification of fetal health, immediate medical attention is vital. Additional diagnostic tests may be needed, possibly leading to specialist consultations. Continuous monitoring and adherence to medical advice are essential. Lifestyle modifications, including rest, diet, and avoiding harmful substances, support fetal health. Attend follow-up appointments and seek emotional support as needed from healthcare providers and loved ones.

RESULT:


HEART RATE
140
120
100
80
60
40
20
0
1
2
3
ACCELERATIONS PER/S
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
1
2
3
UTERINE CONTRACTION PER/S
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
1
2
3
% OF TIME WITH ABNORMAL SHORT-TERM VARIABILITY
80
70
60
50
40
30
20
10
0
1
2
3
% OF TIME WITH ABNORMAL LONG-TERM VARIABILITY
45
40
35
30
25
20
15
10
5
0
1
2
3
© Hoping to help - fetalhealthexaminer@gmail.com
Download Report

4.3 Quantitative Results

4.3.1 Model Performance Metrics:

	precision	recall	f1-score	support
1.0	0.95	0.98	0.97	496
2.0	0.87	0.74	0.80	101
3.0	0.85	0.85	0.85	41
accuracy			0.93	638
macro avg	0.89	0.86	0.87	638
weighted avg	0.93	0.93	0.93	638

Figure 4.1: Random Forest

```
[[481  12   3]
 [ 25  73   3]
 [  3   5  33]]
```

	precision	recall	f1-score	support
1.0	0.94	0.97	0.96	496
2.0	0.81	0.72	0.76	101
3.0	0.85	0.80	0.82	41
accuracy			0.92	638
macro avg	0.87	0.83	0.85	638
weighted avg	0.92	0.92	0.92	638

Figure 4.2: SVM

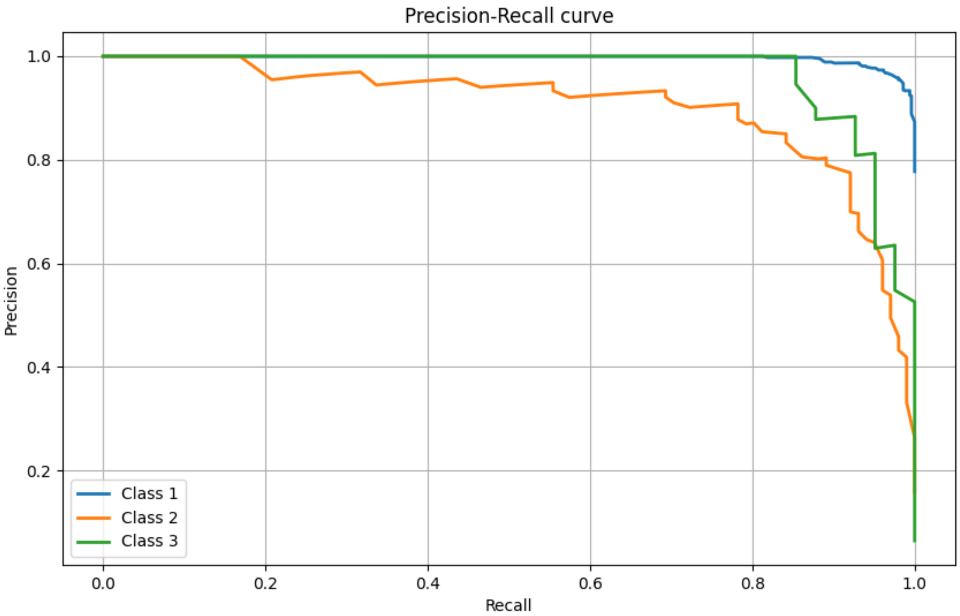
```
[[470  19   7]
 [ 30  61  10]
 [  3   5  33]]
              precision    recall  f1-score   support

         1.0       0.93      0.95      0.94       496
         2.0       0.72      0.60      0.66       101
         3.0       0.66      0.80      0.73        41

    accuracy                           0.88       638
   macro avg       0.77      0.79      0.77       638
weighted avg       0.88      0.88      0.88       638
```

Figure 4.3: Logistic Regression

These metrics indicate the overall performance of the trained models in classifying CTG traces into normal, suspect, and pathological categories. The high values for accuracy, precision, recall, and F1-score suggest that the models effectively distinguish between different fetal health statuses.

4.4 Graphical Analysis

4.4.1 Precision-Recall curve



Precision-Recall curve, which is used to evaluate the performance of a classification model at various threshold settings.There are three classes represented by different colored lines:

- **Class 1 - Normal (Blue):** Exhibits high precision across all levels of recall.
- **Class 2 - Abnormal (Orange):** Starts with high precision that decreases as recall increases.
- **Class 3 - Pathological (Green):** Begins with lower precision, which improves as recall approaches one.

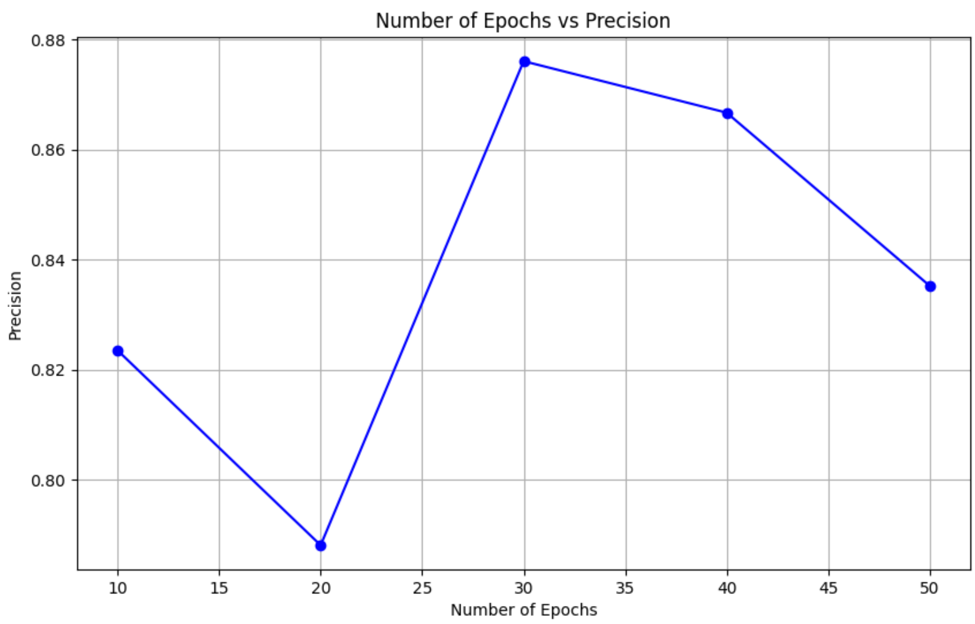
The X-axis and Y-axis represents the recall and precision respectively, that is:

- **X-axis (Recall):** Ranges from 0 to 1, indicating the fraction of relevant instances that have been retrieved over the total amount of relevant instances.

- **Y-axis (Precision):** Also ranges from 0 to 1, showing the fraction of relevant instances among the retrieved instances.

The curves illustrate the trade-off between precision (the quality of the positive predictions) and recall (the ability to find all positive instances) for different threshold values. The ideal curve would stay close to the top-right corner of the graph, indicating both high recall and high precision.

4.4.2 Number of Epochs vs Precision graph



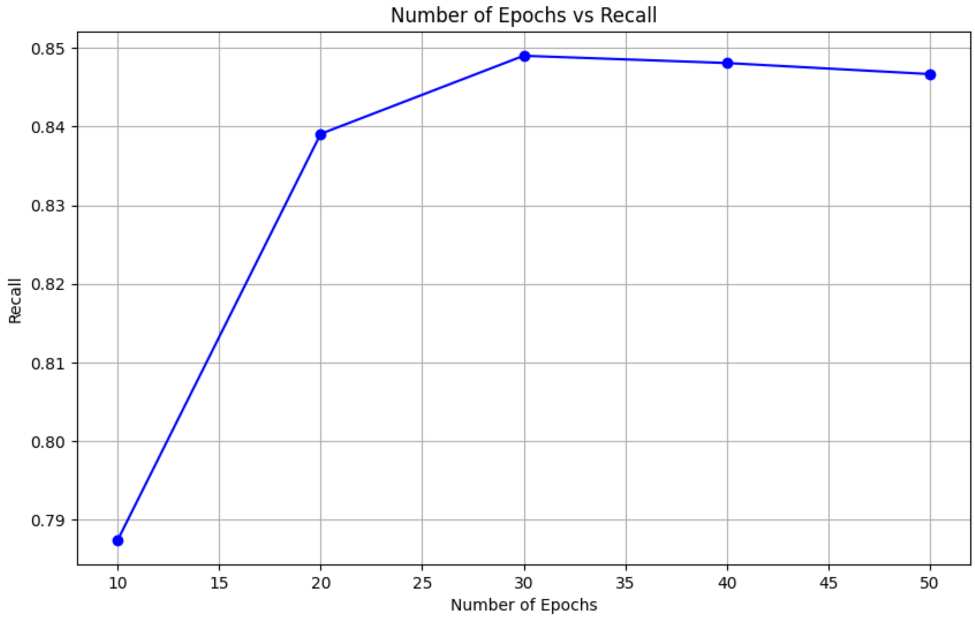
Number of Epochs vs Precision graph illustrates the relationship between the training duration of a machine learning model (measured in epochs) and the precision of the model. The X-axis and Y-axis represents the Number of Epochs and precision respectively, that is:

- **X-axis (Number of Epochs):** Represents the number of complete passes through the training dataset, with values ranging from 10 to 50.

- **Y-axis (Precision):**Indicates the precision of the model, which is the proportion of true positive predictions out of all positive predictions made, with values ranging from 0.80 to 0.88.

The graph shows that as the number of epochs increases from 10 to 35, the precision of the model also increases, reaching a peak at around 0.88. This suggests that the model is learning and improving its predictions up to this point. However, beyond 35 epochs, there is a decline in precision, indicating that the model might be starting to overfit to the training data, which negatively affects its performance on new, unseen data.

4.4.3 Number of Epochs vs Recall



The graph Number of Epochs vs Recall depicts the relationship between the number of epochs during the training of a machine learning model and the recall metric. The X-axis and Y-axis represents the Number of Epochs and precision respectively, that is:

- **X-axis (Number of Epochs):** Ranges from 10 to 50, representing the number of complete passes through the training dataset.
- **Y-axis (Recall):** Ranges from approximately 0.79 to 0.85, representing the ability of the model to find all the relevant cases within a dataset.

The blue line with circular markers shows that recall sharply increases as the number of epochs grows from 10 to around 25. After reaching this point, the recall plateaus and remains constant up to 50 epochs. This suggests that the model's ability to correctly identify positive cases improves significantly in the early phase of training but does not benefit from additional training beyond 25 epochs.The graph is useful for determining the optimal number of epochs for training to ensure the model is neither underfitting nor overfitting. In this case, it seems that training beyond 25 epochs does not result in further improvements in recall.

4.4.4 Confusion Matrix:

	Predicted Normal	Predicted Suspect	Predicted Pathological
Actual Normal	486	7	3
Actual Suspect	23	75	3
Actual Pathological	3	4	35

Figure 4.4: Confusion Matrix

The confusion matrix provides a detailed breakdown of the model's predictions compared to the actual classes. It illustrates the number of true positives, false positives, true negatives, and false negatives for each class, allowing for a deeper understanding of the model's performance across different categories of CTG traces.

4.5 Discussion

The results obtained from the "Fetal Health Examiner" project demonstrate promising outcomes in automating the analysis and classification of Cardiotocogram (CTG) data for assessing fetal well-being during pregnancy. Leveraging machine learning algorithms including Support Vector Machine (SVM), Random Forest, and Logistic Regression, the system achieved high accuracy, precision, recall, and F1-score, indicating their effectiveness in distinguishing between normal, suspect, and pathological fetal health statuses. Through comprehensive analysis of the model performance metrics, it was observed that the Random Forest algorithm consistently outperformed SVM and Logistic Regression, exhibiting superior accuracy and predictive power. Specifically, the Random Forest algorithm achieved an accuracy of 0.93, while SVM and Logistic Regression achieved accuracies of 0.92 and 0.88, respectively. Therefore, based on these values, it can be concluded that Random Forest is better suited for CTG analysis and classification in the context of fetal health assessment.

Chapter 5

Conclusion

5.1 Conclusion

This machine learning-powered CTG analysis solution presents a significant advancement in prenatal care. By analyzing complex fetal data, it has the potential to revolutionize how healthcare providers assess fetal health and optimize pregnancy outcomes. The ability to analyze a comprehensive set of data points and provide standardized, potentially more accurate interpretations empowers informed decision-making and earlier detection of complications. User-friendly interfaces and visualizations further enhance communication between healthcare providers and expectant mothers.

However, successful implementation requires careful consideration. High-quality, diverse training data is crucial for model robustness. Seamless integration with existing healthcare systems minimizes disruption. As the field of machine learning evolves, exciting possibilities lie ahead, including personalized medicine, early detection of specific conditions, remote patient monitoring, and comprehensive decision support systems. By addressing these considerations and exploring future directions, your solution has the potential to be a powerful tool that empowers healthcare providers, improves patient outcomes, and contributes to a healthier future for mothers and babies.

5.2 Future Scope

This CTG analysis solution offers a leap in prenatal care. By leveraging a mobile app, healthcare providers gain on-the-go access and analysis capabilities, improving decision-making, especially in resource-limited settings. Looking ahead, directly processing CTG images, instead of numerical data, could unlock even deeper insights into fetal health. This holds promise for earlier detection of complications and improved pregnancy outcomes.

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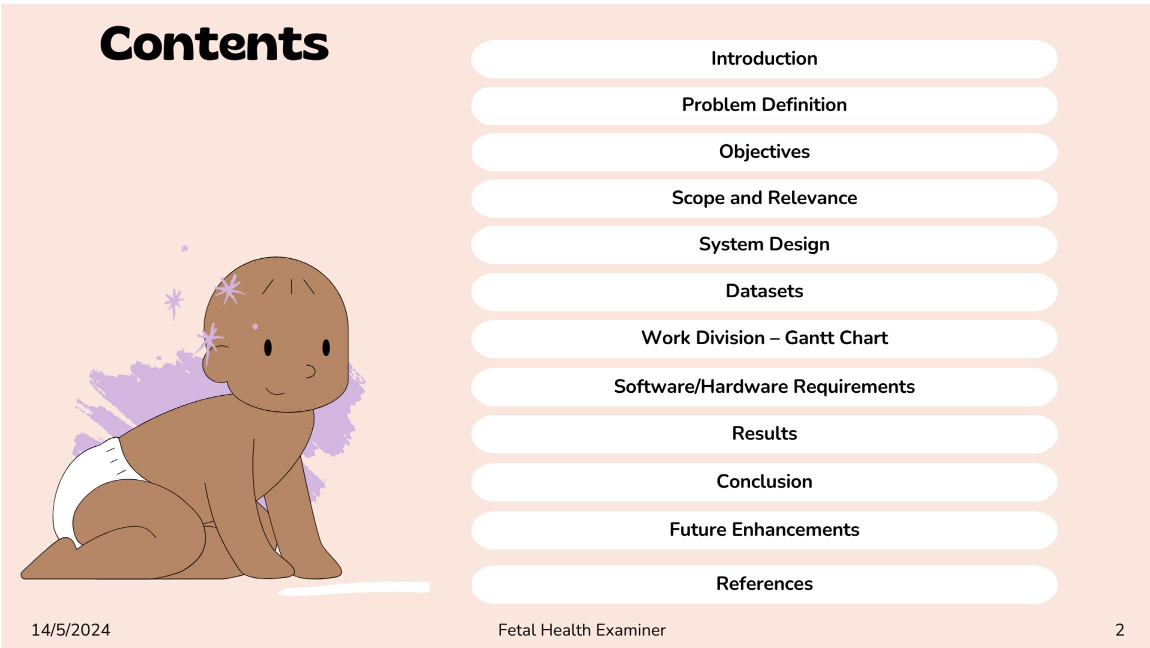
[2] M. Ebrahimi, Y. Chai, H. H. Zhang and H. Chen, ”Heterogeneous Domain Adaptation With Adversarial Neural Representation Learning: Experiments on E-Commerce and Cybersecurity,” in IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 45, no. 2, pp. 1862-1875, 1 Feb. 2023, doi: 10.1109/TPAMI.2022.3163338.

[3] J. Li and X. Liu, ”Fetal Health Classification Based on Machine Learning, ” 2021 IEEE 2nd International Conference on Big Data, Artificial Intelligence and Internet of Things Engineering (ICBAIE), Nanchang, China, 2021, pp. 899-902, doi: 10.1109/ICBAIE52039.2021.9389902. keywords: Conferences;Stacking;Machine learning;Learning (artificial intelligence);Big Data;Internet of Things;CTG;Fetal Health;Machine Learning;Ensemble Learning,

[4] Qianqian Lu, Yongxiang Chai, Lihui Ren, Pengyu Ren, Junhui Zhou, Chunlei Lin, Research on quality evaluation of innovation and entrepreneurship education for college students based on random forest algorithm and logistic regression model, PeerJ Computer Science, 10.7717/peerj-cs.1329, 9, (e1329), (2023)

Appendix A: Presentation


baby
FETAL HEALTH EXAMINER
Mr. Sandy Joseph
Danish H Muhammed
Gopika M
Melissa Biju Kalayil
Muhammed Bais
14/5/2024
Fetal Health Examiner
1


Contents
Introduction
Problem Definition
Objectives
Scope and Relevance
System Design
Datasets
Work Division – Gantt Chart
Software/Hardware Requirements
Results
Conclusion
Future Enhancements
References
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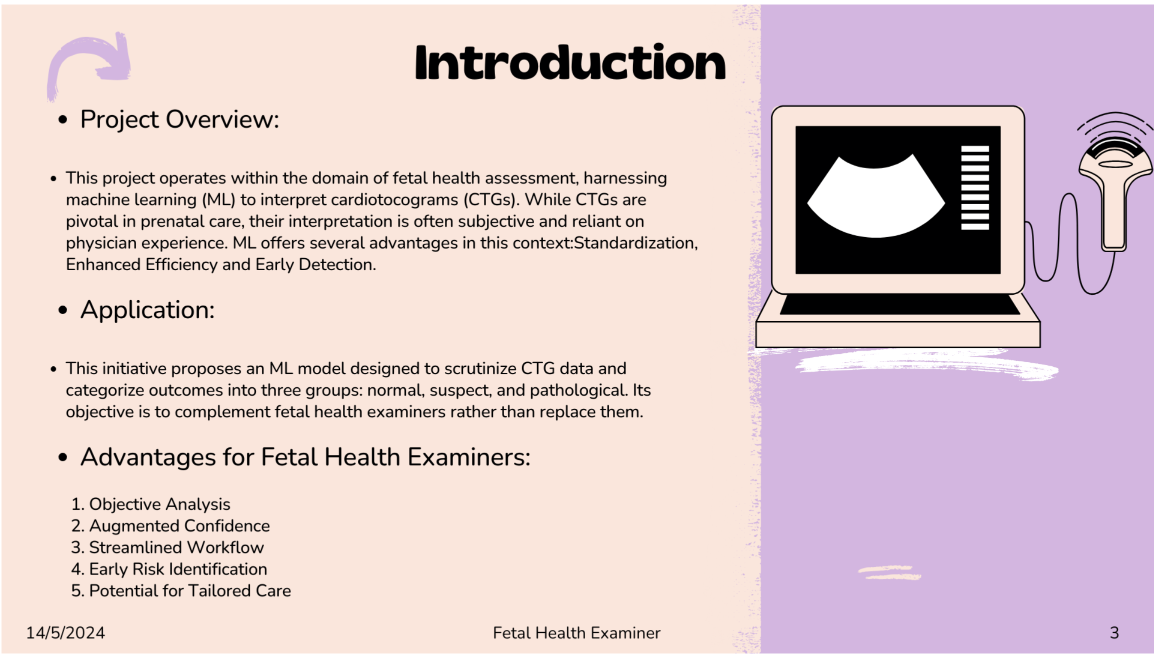
2


Introduction
• Project Overview:
• This project operates within the domain of fetal health assessment, harnessing machine learning (ML) to interpret cardiotocograms (CTGs). While CTGs are pivotal in prenatal care, their interpretation is often subjective and reliant on physician experience. ML offers several advantages in this context:Standardization, Enhanced Efficiency and Early Detection.
• Application:
• This initiative proposes an ML model designed to scrutinize CTG data and categorize outcomes into three groups: normal, suspect, and pathological. Its objective is to complement fetal health examiners rather than replace them.
• Advantages for Fetal Health Examiners:
1. Objective Analysis
2. Augmented Confidence
3. Streamlined Workflow
4. Early Risk Identification
5. Potential for Tailored Care
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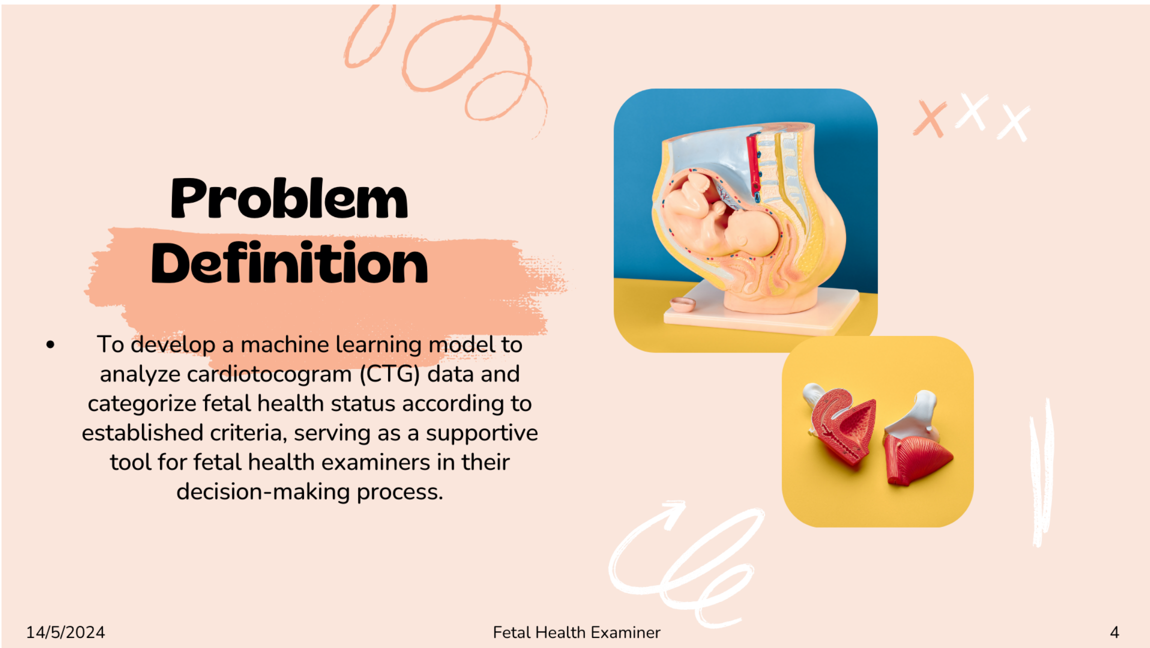
3


Problem Definition
• To develop a machine learning model to analyze cardiotocogram (CTG) data and categorize fetal health status according to established criteria, serving as a supportive tool for fetal health examiners in their decision-making process.
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Objectives

Develop a Machine Learning Model

Create a robust classifier to categorize CTG results into Normal, Abnormal, and Pathological classes.

Utilize Expert-Classified Dataset

Train and validate the model using a dataset with expert-obstetrician-classified CTG exams.

Enhance Fetal Health Monitoring

Provide a reliable tool for healthcare professionals to interpret CTG results accurately, improving fetal well-being assessment.

Enable Doctor-Patient Interaction

Implement a secure doctor's login interface for storing and accessing patient CTG data, facilitating ongoing monitoring.

Weekly Patient Data Storage

Save patient CTG information weekly to track changes in fetal parameters over time.

Generate Graphical Representations

Develop graphing functionality for key CTG parameters to aid visual interpretation and trend analysis

14/5/2024 Fetal Health Examiner 5

Scope Of The Project

- CTG result analysis with machine learning.
- Classification into Normal, Abnormal, and Pathological outcomes
- Significant contribution to the improvement of prenatal care and the reduction of adverse pregnancy outcomes.
- Empower doctors with a classification model to support informed decisions regarding fetal well-being.
- Enhances diagnostic precision and aligns closely with corporate and business goals.
- Enhance doctor-patient interaction by enabling visualization of CTG data.
- The system will generate graphs for specific CTG data points and doctors can access these graphs through the secure doctor login

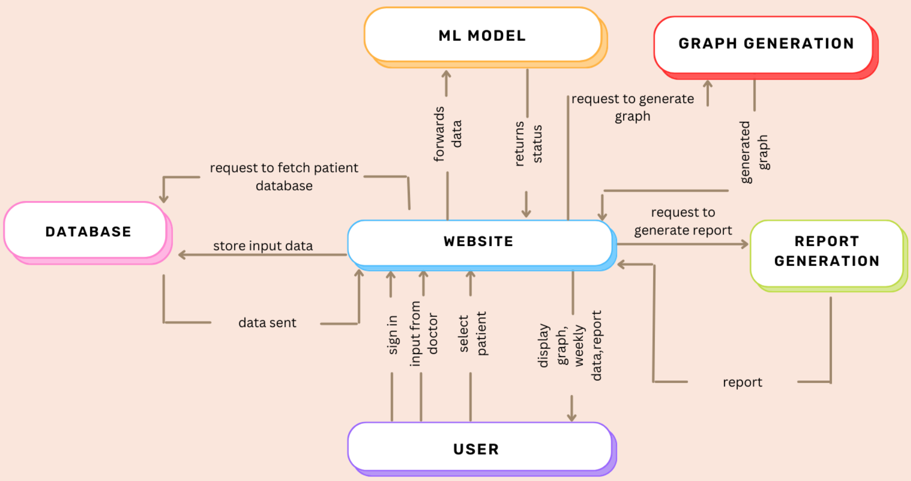
14/5/2024 Fetal Health Examiner 6

System Design

System Overview

1. User Interaction:
   - A user interacts with a website.
   - The website allows users to sign in, select a patient, and choose a graph.
2. Data Retrieval:
   - The website sends a request to fetch patient data from a database.
   - The database responds by providing the relevant patient data.
3. Machine Learning Model:
   - The website forwards the input data to an ML model for processing.
   - The ML model performs necessary computations and returns a status or processed information.
4. Graph Generation:
   - The website sends a request to generate graphs.
   - Generate graphs based on the data received.
5. Viewing Reports:
   - The generated graphs and reports can be viewed by users.

Architecture Diagram



Modules

1)Data Preprocessing:

- Responsible for cleaning, transforming, and preparing the raw CTG data for model training.
- Includes tasks such as handling missing values and scaling features

2)Model Creation and Selection:

- Involves the development and training of machine learning models for CTG classification.
- Includes splitting data into testing and training data
- selecting appropriate algorithms (e.g., SVM, Logistic Regression, Random Forest) and evaluating model performance

14/5/2024 Fetal Health Examiner 9

3)Model Evaluation:

- Focuses on evaluating the performance of trained models using metrics such as accuracy, precision, recall, and F1-score.
- Helps in comparing different models and selecting the best-performing one for deployment.

4)User Authentication:

- Manages user authentication and authorization within the system.
- Ensures secure access to the application and restricts unauthorized users from accessing sensitive data
- Uses username and password for authorization of users

5) User Interface (UI):

- Deals with the design and implementation of the graphical user interface (GUI) for the application.
- Provides an interactive platform for users to upload CTG data, view analysis results, and interact with the system.

14/5/2024 Fetal Health Examiner 10

6)Graph Generation:

- Generates visualizations and graphs to represent analysis results and other relevant information.
- Enhances the interpretability of data and model outputs, aiding users in understanding and making informed decisions.

7)Integration:

- Combines the machine learning models with the user interface to create a functional application
- Enables seamless interaction between the user interface and backend model functionalities, allowing users to perform CTG analysis effectively
- Uses Django

Algorithms

Data Preprocessing:

HANDLING MISSING VALUE :

- Implementation:
  1. Use the dropna class from pandas module.
  2. Fit the dropna on the training data and transform both training and testing data.

FEATURE SCALING :

- Strategy: Standardize feature values to have zero mean and unit variance.
- Implementation:
  1. Utilize the StandardScaler class from sklearn.preprocessing module.
  2. Fit the scaler on the training data and transform both training and testing data.

SVM:

1. Import the SVM classifier
2. Create an SVM classifier with a radial basis function (RBF) kernel
3. Train the SVM classifier using the training data

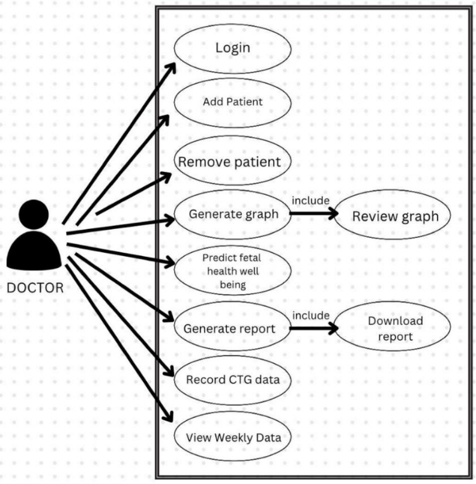
Random Forest:

1. Import the Random Forest classifier
2. Create a Random Forest classifier
3. Train the Random Forest classifier using the training data

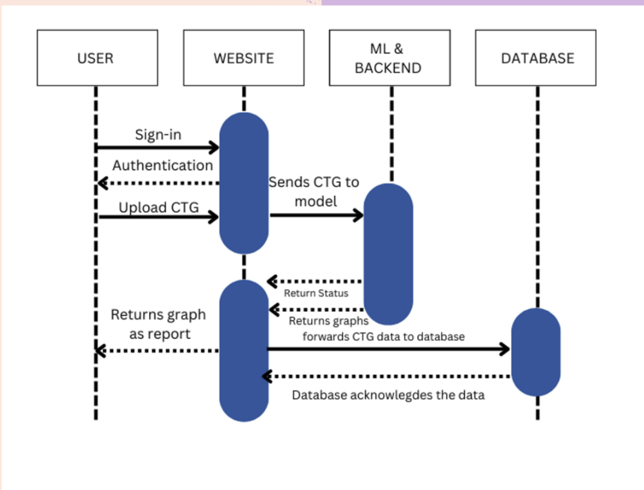
Logistic Regression:

1. Import the Logistic Regression classifier
2. Create a Logistic Regression classifier
3. Train the Logistic Regression classifier using the training data

Use Case Diagram



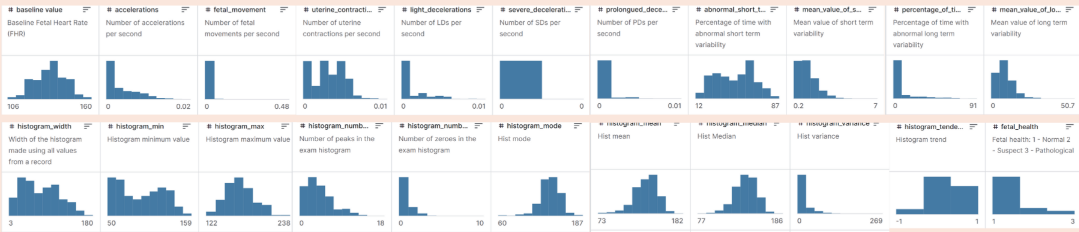
Sequence Diagram



Dataset

2126 measurements extracted from cardiotocograms and classified by expert obstetricians, as described in:
Ayres de Campos et al. (2000) SisPorto 2.0 A Program for Automated Analysis of Cardiotocograms. J Matern Fetal Med 5:311-318

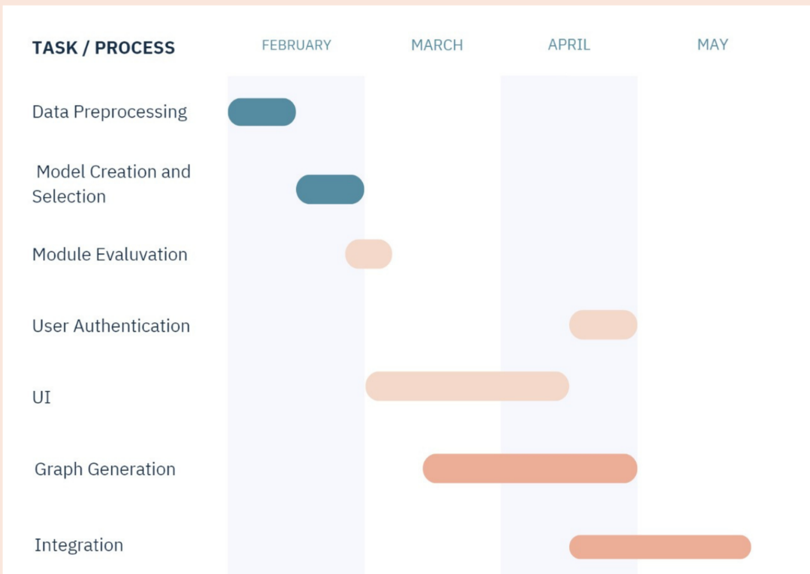
DATA RANGE AND ANALYSIS



SAMPLE DATASET

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	baseline value	acceleratio	fetal_mov	uterine_cc	light_dece	severe_de	prolongue	abnormal_	mean_valu	percentag	mean_valu	histogram	histogram	histogram	histogram	histogram	histogram	histogram	histogram	histogram	histogram	fetal_health
2	120	0	0	0	0	0	0	73	0.5	43	2.4	64	62	126	2	0	120	137	121	73	1	2
3	132	0.006	0	0.006	0.003	0	0	17	2.1	0	10.4	130	68	198	6	1	141	136	140	12	0	1
4	133	0.003	0	0.008	0.003	0	0	16	2.1	0	13.4	130	68	198	5	1	141	135	138	13	0	1
5	134	0.003	0	0.008	0.003	0	0	16	2.4	0	23	117	53	170	11	0	137	134	137	13	1	1
6	132	0.007	0	0.008	0	0	0	16	2.4	0	19.9	117	53	170	9	0	137	136	138	11	1	1
7	134	0.001	0	0.01	0.009	0	0.002	26	5.9	0	0	150	50	200	5	3	76	107	107	170	0	3
8	134	0.001	0	0.013	0.008	0	0.003	29	6.3	0	0	150	50	200	6	3	71	107	106	215	0	3
9	122	0	0	0	0	0	0	83	0.5	6	15.6	68	62	130	0	0	122	122	123	3	1	3
10	122	0	0	0.002	0	0	0	84	0.5	5	13.6	68	62	130	0	0	122	122	123	3	1	3
11	122	0	0	0.003	0	0	0	86	0.3	6	10.6	68	62	130	1	0	122	122	123	1	1	3
12	151	0	0	0.001	0.001	0	0	64	1.9	9	27.6	130	56	186	2	0	150	148	151	9	1	2
13	150	0	0	0.001	0.001	0	0	64	2	8	29.5	130	56	186	5	0	150	148	151	10	1	2
14	131	0.005	0.072	0.008	0.003	0	0	28	1.4	0	12.9	66	88	154	5	0	135	134	137	7	1	1
15	131	0.009	0.222	0.006	0.002	0	0	28	1.5	0	5.4	87	71	158	2	0	141	137	141	10	1	1
16	130	0.006	0.408	0.004	0.005	0	0.001	21	2.3	0	7.9	107	67	174	7	0	143	125	135	76	0	1
17	130	0.006	0.38	0.004	0.004	0	0.001	19	2.3	0	8.7	107	67	174	3	0	134	127	133	43	0	1
18	130	0.006	0.441	0.005	0.005	0	0	24	2.1	0	10.9	125	53	178	5	0	143	128	138	70	1	1
19	131	0.002	0.383	0.003	0.005	0	0.002	18	2.4	0	13.9	107	67	174	5	0	134	125	132	45	0	2
20	130	0.003	0.451	0.006	0.004	0	0.001	23	1.9	0	8.8	99	59	158	6	0	133	124	129	36	1	1
21	130	0.005	0.469	0.005	0.004	0	0.001	29	1.7	0	7.8	112	65	177	6	1	133	129	133	27	0	1
22	129	0	0.34	0.004	0.002	0	0.003	30	2.1	0	8.5	128	54	182	13	0	129	104	120	138	0	3
23	128	0.005	0.425	0.003	0.003	0	0.002	26	1.7	0	6.7	141	57	198	9	0	129	125	132	34	0	1
24	128	0	0.334	0.003	0.003	0	0.003	34	2.5	0	4	145	54	199	11	1	75	99	102	148	-1	3
25	128	0	0	0	0	0	0	80	0.5	0	6.8	16	114	130	0	0	126	124	125	1	1	3
26	128	0	0	0.003	0	0	0	86	0.3	79	2.9	16	114	130	0	0	128	126	129	0	1	3
27	124	0	0	0	0	0	0	86	0.3	72	4	12	118	130	1	0	124	124	125	0	0	3
28	124	0	0	0	0	0	0	86	0.4	14	4.8	24	122	146	1	0	126	126	127	0	-1	3

GANTT CHART



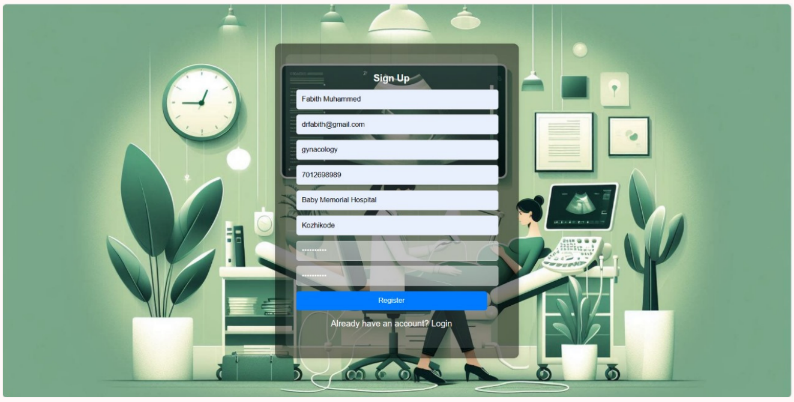
Software/Hardware Requirements

Software : HTML,CSS,Python3,Git, Django,JavaScript.

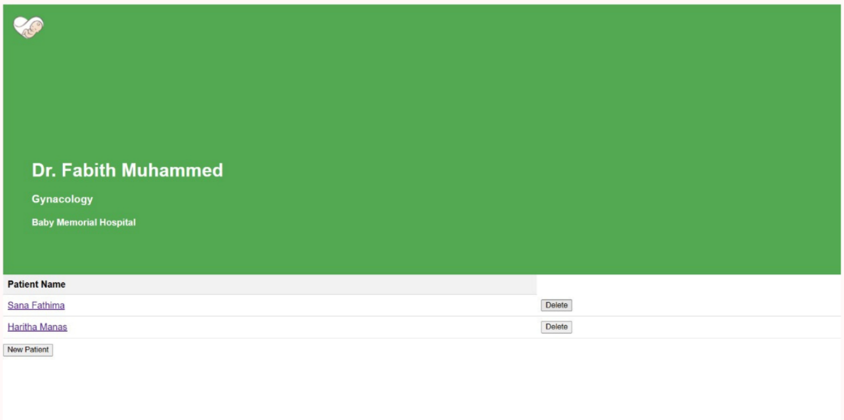
Hardware : intel i5,RAM 16GB,512 GB, x64-based processor.

RESULTS

- **Sign Up Page**

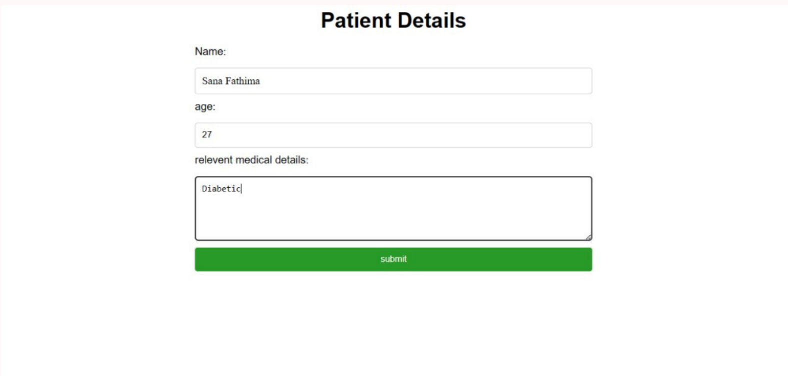


- **Doctor Dashboard**



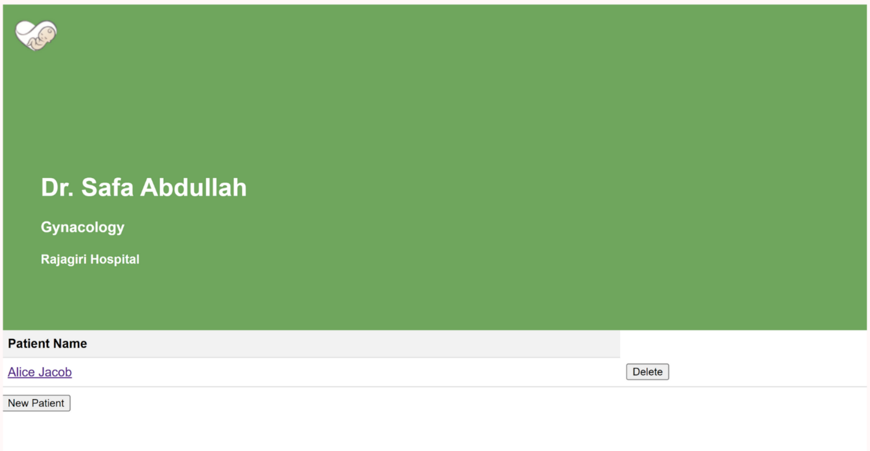
14/5/2024 Fetal Health Examiner 21

- **Patient Details**



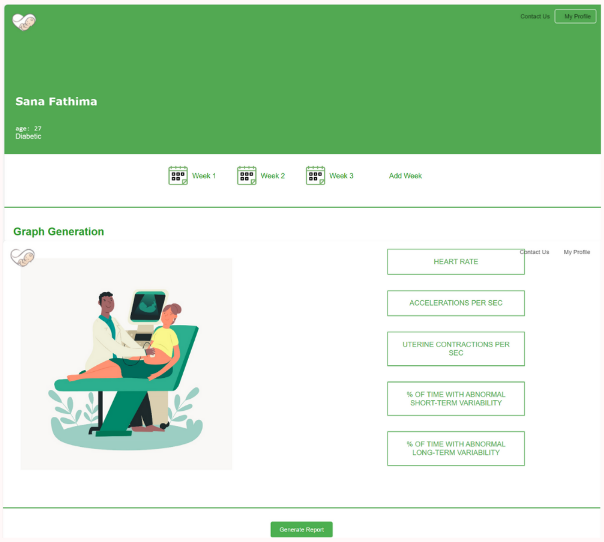
14/5/2024 Fetal Health Examiner 22

- ## Updated Doctor Dashboard



14/5/2024 Fetal Health Examiner 23

- ## Patient Portal



14/5/2024 Fetal Health Examiner 24

Add Week Data

Baseline Fetal Heart Rate	Accelerations	Fetal movement	Uterine contractions	Light decelerations	Severe dec

Submit

Week Data

Baseline Fetal Heart Rate	Accelerations	Fetal movement	Uterine contractions	Light decelerations	Severe deceleration	Prolongued deceleration	Percentage of time with Abnormal short term variability	Mean val of short t variabili
132	0.007	0	0.008	0	0	0	16	2.4

Result: Normal

14/5/2024 Fetal Health Examiner 25

- **Report**

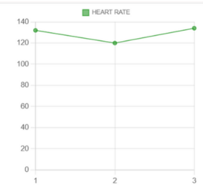
FETAL HEALTH REPORT

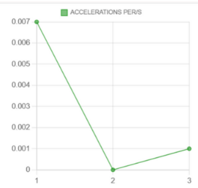
Doctor: Fabith Muhammed **Contact No: 7012698989**
Patient: Sana Fathima
Age: 27

INTERPRETATION: Pathological

Following a pathological classification of fetal health, immediate medical attention is vital. Additional diagnostic tests may be needed, possibly leading to specialist consultations. Continuous monitoring and adherence to medical advice are essential. Lifestyle modifications, including rest, diet, and avoiding harmful substances, support fetal health. Attend follow-up appointments and seek emotional support as needed from healthcare providers and loved ones.

RESULT:





14/5/2024 Fetal Health Examiner 26

Result Analysis

- **Random Forest**

```
[[486   7   3]
 [ 23  75   3]
 [  2   4  35]]
              precision    recall  f1-score   support

         1.0       0.95      0.98      0.97       496
         2.0       0.87      0.74      0.80       101
         3.0       0.85      0.85      0.85        41

    accuracy                           0.93       638
   macro avg       0.89      0.86      0.87       638
weighted avg       0.93      0.93      0.93       638
```

- **SVM**

```
[[481  12   3]
 [ 25  73   3]
 [  3   5  33]]
              precision    recall  f1-score   support

         1.0       0.94      0.97      0.96       496
         2.0       0.81      0.72      0.76       101
         3.0       0.85      0.80      0.82        41

    accuracy                           0.92       638
   macro avg       0.87      0.83      0.85       638
weighted avg       0.92      0.92      0.92       638
```

14/5/2024 Fetal Health Examiner 29

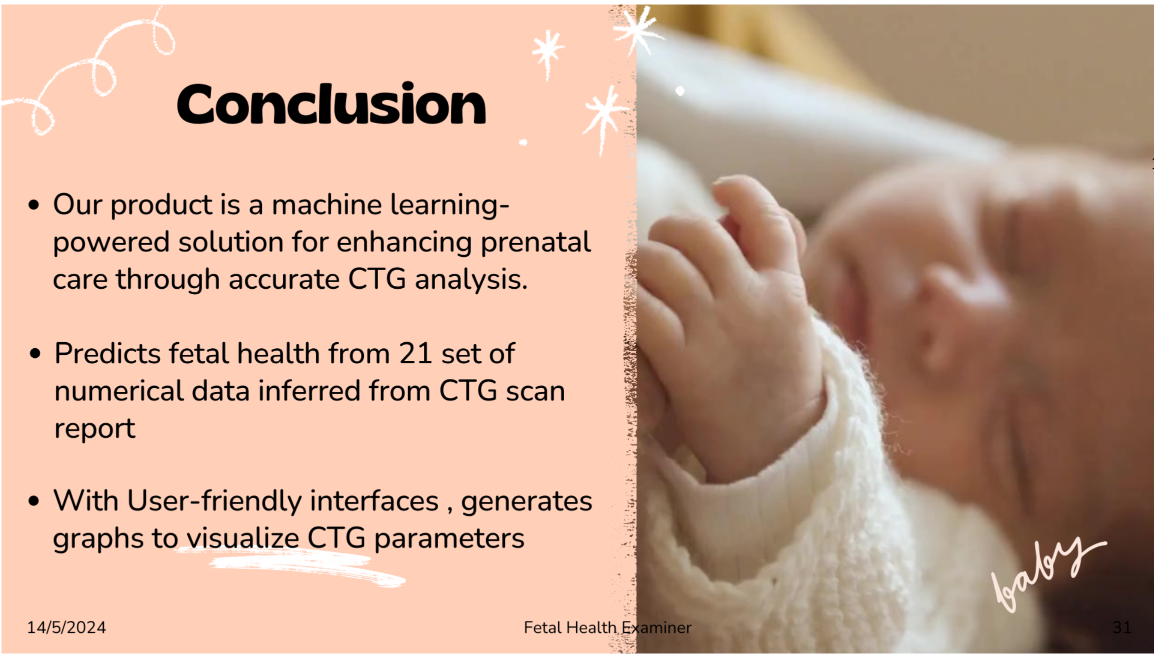
- **Logistic Regression**

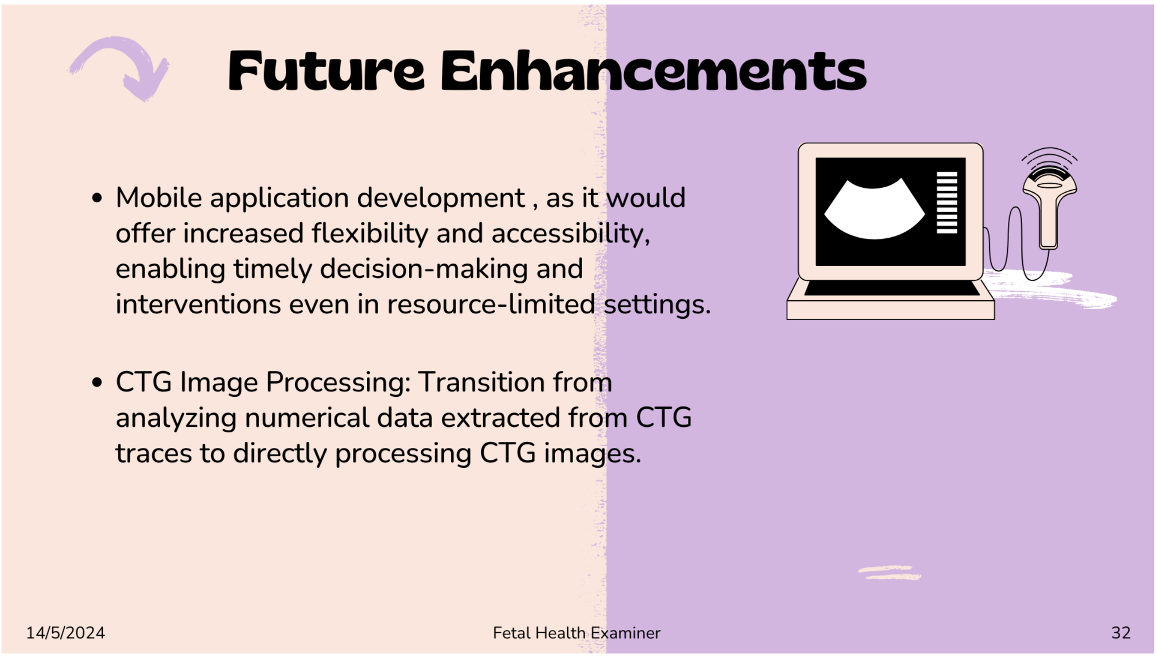
```
[[470  19   7]
 [ 30  61  10]
 [  3   5  33]]
              precision    recall  f1-score   support

         1.0       0.93      0.95      0.94       496
         2.0       0.72      0.60      0.66       101
         3.0       0.66      0.80      0.73        41

    accuracy                           0.88       638
   macro avg       0.77      0.79      0.77       638
weighted avg       0.88      0.88      0.88       638
```

14/5/2024 Fetal Health Examiner 30


Conclusion
Our product is a machine learning-powered solution for enhancing prenatal care through accurate CTG analysis.
Predicts fetal health from 21 set of numerical data inferred from CTG scan report
With User-friendly interfaces , generates graphs to visualize CTG parameters
14/5/2024
Fetal Health Examiner
31
baby


Future Enhancements
Mobile application development , as it would offer increased flexibility and accessibility, enabling timely decision-making and interventions even in resource-limited settings.
CTG Image Processing: Transition from analyzing numerical data extracted from CTG traces to directly processing CTG images.
14/5/2024
Fetal Health Examiner
32

References

1. J. Li and X. Liu, "Fetal Health Classification Based on Machine Learning," 2021 IEEE 2nd International Conference on Big Data, Artificial Intelligence and Internet of Things Engineering (ICBAIE), Nanchang, China, 2021, pp. 899-902, doi: 10.1109/ICBAIE52039.2021.9389902. keywords: {Conferences;Stacking;Machine learning;Learning (artificial intelligence);Big Data;Internet of Things;CTG;Fetal Health;Machine Learning;Ensemble Learning},

2. Qianqian Lu, Yongxiang Chai, Lihui Ren, Pengyu Ren, Junhui Zhou, Chunlei Lin, Research on quality evaluation of innovation and entrepreneurship education for college students based on random forest algorithm and logistic regression model, PeerJ Computer Science, 10.7717/peerj-cs.1329, 9, (e1329), (2023)

3)Qianqian Lu, Yongxiang Chai, Lihui Ren, Pengyu Ren, Junhui Zhou, Chunlei Lin, Research on quality evaluation of innovation and entrepreneurship education for college students based on random forest algorithm and logistic regression model, PeerJ Computer Science, 10.7717/peerj-cs.1329, 9, (e1329), (2023).

Appendix B: Vision, Mission, Programme Outcomes and Course Outcomes

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

RAJAGIRI SCHOOL OF ENGINEERING & TECHNOLOGY (AUTONOMOUS)

RAJAGIRI VALLEY, KAKKANAD, KOCHI, 682039

(Affiliated to APJ Abdul Kalam Technological University)

Vision, Mission, Programme Outcomes and Course Outcomes

Institute Vision

To evolve into a premier technological institution, moulding eminent professionals with creative minds, innovative ideas and sound practical skill, and to shape a future where technology works for the enrichment of mankind.

Institute Mission

To impart state-of-the-art knowledge to individuals in various technological disciplines and to inculcate in them a high degree of social consciousness and human values, thereby enabling them to face the challenges of life with courage and conviction.

Department Vision

To become a centre of excellence in Computer Science and Engineering, moulding professionals catering to the research and professional needs of national and international organizations.

Department Mission

To inspire and nurture students, with up-to-date knowledge in Computer Science and Engineering, ethics, team spirit, leadership abilities, innovation and creativity to come out with solutions meeting societal needs.

Programme Outcomes (PO)

Engineering Graduates will be able to:

1. Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. Conduct investigations of complex problems: Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. Modern Tool Usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. Individual and Team work: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.

10. Communication: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports documentation. Make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team. Manage projects in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Programme Specific Outcomes (PSO)

A graduate of the Computer Science and Engineering Program will demonstrate:

PSO1: Computer Science Specific Skills

The ability to identify, analyze and design solutions for complex engineering problems in multidisciplinary areas by understanding the core principles and concepts of computer science and thereby engage in national grand challenges.

PSO2: Programming and Software Development Skills

The ability to acquire programming efficiency by designing algorithms and applying standard practices in software project development to deliver quality software products meeting the demands of the industry.

PSO3: Professional Skills

The ability to apply the fundamentals of computer science in competitive research and to develop innovative products to meet the societal needs thereby evolving as an eminent researcher and entrepreneur.

Course Outcomes

After the completion of the course the student will be able to:

CO1:

Identify technically and economically feasible problems (Cognitive Knowledge Level: Apply)

CO2:
Identify and survey the relevant literature for getting exposed to related solutions and get familiarized with software development processes (Cognitive Knowledge Level: Apply)

CO3:
Perform requirement analysis, identify design methodologies and develop adaptable & reusable solutions of minimal complexity by using modern tools & advanced programming techniques (Cognitive Knowledge Level: Apply)

CO4:
Prepare technical report and deliver presentation (Cognitive Knowledge Level: Apply)

CO5:
Apply engineering and management principles to achieve the goal of the project (Cognitive Knowledge Level: Apply)

Appendix C: CO-PO-PSO Mapping

COURSE OUTCOMES:

After completion of the course the student will be able to

SL. NO	DESCRIPTION	Blooms' Taxonomy Level
CO1	Identify technically and economically feasible problems (Cognitive Knowledge Level: Apply)	Level 3: Apply
CO2	Identify and survey the relevant literature for getting exposed to related solutions and get familiarized with software development processes (Cognitive Knowledge Level: Apply)	Level 3: Apply
CO3	Perform requirement analysis, identify design methodologies and develop adaptable & reusable solutions of minimal complexity by using modern tools & advanced programming techniques (Cognitive Knowledge Level: Apply)	Level 3: Apply
CO4	Prepare technical report and deliver presentation (Cognitive Knowledge Level: Apply)	Level 3: Apply
CO5	Apply engineering and management principles to achieve the goal of the project (Cognitive Knowledge Level: Apply)	Level 3: Apply

CO-PO AND CO-PSO MAPPING

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO3
CO1	3	3	3	3		2	2	3	2	2	2	3	2	2	2
CO2	3	3	3	3	3	2		3	2	3	2	3	2	2	2
CO3	3	3	3	3	3	2	2	3	2	2	2	3			2
CO4	2	3	2	2	2			3	3	3	2	3	2	2	2
CO5	3	3	3	2	2	2	2	3	2		2	3	2	2	2

3/2/1: high/medium/low

JUSTIFICATIONS FOR CO-PO MAPPING

MAPPING	LOW/ MEDIUM/ HIGH	JUSTIFICATION
101003/CS622T.1-PO1	**HIGH**	Identify technically and economically feasible problems by applying the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
101003/CS622T.1-PO2	**HIGH**	Identify technically and economically feasible problems by analysing complex engineering problems reaching substantiated conclusions using first principles of mathematics.
101003/CS622T.1-PO3	**HIGH**	Design solutions for complex engineering problems by identifying technically and economically feasible problems.
101003/CS622T.1-PO4	**HIGH**	Identify technically and economically feasible problems by analysis and interpretation of data.
101003/CS622T.1-PO6	**MEDIUM**	Responsibilities relevant to the professional engineering practice by identifying the problem.
101003/CS622T.1-PO7	**MEDIUM**	Identify technically and economically feasible problems by understanding the impact of the professional engineering solutions.
101003/CS622T.1-PO8	**HIGH**	Apply ethical principles and commit to professional ethics to identify technically and economically feasible problems.
101003/CS622T.1-PO9	**MEDIUM**	Identify technically and economically feasible problems by working as a team.
101003/CS622T.1-PO10	**MEDIUM**	Communicate effectively with the engineering community by identifying technically and economically feasible problems.
101003/CS622T.1-P011	**MEDIUM**	Demonstrate knowledge and understanding of engineering and management principles by selecting the technically and economically feasible problems.
101003/CS622T.1-PO12	**HIGH**	Identify technically and economically feasible problems for long term learning.
101003/CS622T.1-PSO1	**MEDIUM**	Ability to identify, analyze and design solutions to identify technically and economically feasible problems.
101003/CS622T.1-PSO2	**MEDIUM**	By designing algorithms and applying standard practices in software project development and Identifying technically and economically feasible problems.
101003/CS622T.1-PSO3	**MEDIUM**	Fundamentals of computer science in competitive research can be applied to Identify technically and economically feasible problems.
101003/CS622T.2-PO1	**HIGH**	Identify and survey the relevant by applying the knowledge of mathematics, science, engineering fundamentals.

101003/CS622T.2-PO2	**HIGH**	Identify, formulate, review research literature, and analyze complex engineering problems get familiarized with software development processes.
101003/CS622T.2-PO3	**HIGH**	Design solutions for complex engineering problems and design based on the relevant literature.
101003/CS622T.2-PO4	**HIGH**	Use research-based knowledge including design of experiments based on relevant literature.
101003/CS622T.2-PO5	**HIGH**	Identify and survey the relevant literature for getting exposed to related solutions and get familiarized with software development processes by using modern tools.
101003/CS622T.2-PO6	**MEDIUM**	Create, select, and apply appropriate techniques, resources, by identifying and surveying the relevant literature.
101003/CS622T.2-PO8	**HIGH**	Apply ethical principles and commit to professional ethics based on the relevant literature.
101003/CS622T.2-PO9	**MEDIUM**	Identify and survey the relevant literature as a team.
101003/CS622T.2-PO10	**HIGH**	Identify and survey the relevant literature for a good communication to the engineering fraternity.
101003/CS622T.2-PO11	**MEDIUM**	Identify and survey the relevant literature to demonstrate knowledge and understanding of engineering and management principles.
101003/CS622T.2-PO12	**HIGH**	Identify and survey the relevant literature for independent and lifelong learning.
101003/CS622T.2-PSO1	**MEDIUM**	Design solutions for complex engineering problems by Identifying and survey the relevant literature.
101003/CS622T.2-PSO2	**MEDIUM**	Identify and survey the relevant literature for acquiring programming efficiency by designing algorithms and applying standard practices.
101003/CS622T.2-PSO3	**MEDIUM**	Identify and survey the relevant literature to apply the fundamentals of computer science in competitive research.
101003/CS622T.3-PO1	**HIGH**	Perform requirement analysis, identify design methodologies by using modern tools & advanced programming techniques and by applying the knowledge of mathematics, science, engineering fundamentals.
101003/CS622T.3-PO2	**HIGH**	Identify, formulate, review research literature for requirement analysis, identify design methodologies and develop adaptable & reusable solutions.

101003/CS622T.3-PO3	**HIGH**	Design solutions for complex engineering problems and perform requirement analysis, identify design methodologies.
101003/CS622T.3-PO4	**HIGH**	Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
101003/CS622T.3-PO5	**HIGH**	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools.
101003/CS622T.3-PO6	**MEDIUM**	Perform requirement analysis, identify design methodologies and assess societal, health, safety, legal, and cultural issues.
101003/CS622T.3-PO7	**MEDIUM**	Understand the impact of the professional engineering solutions in societal and environmental contexts and Perform requirement analysis, identify design methodologies and develop adaptable & reusable solutions.
101003/CS622T.3-PO8	**HIGH**	Perform requirement analysis, identify design methodologies and develop adaptable & reusable solutions by applying ethical principles and commit to professional ethics.
101003/CS622T.3-PO9	**MEDIUM**	Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.
101003/CS622T.3-PO10	**MEDIUM**	Communicate effectively with the engineering community and with society at large to perform requirement analysis, identify design methodologies.
101003/CS622T.3-PO11	**MEDIUM**	Demonstrate knowledge and understanding of engineering requirement analysis by identifying design methodologies.
101003/CS622T.3-PO12	**HIGH**	Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change by analysis, identify design methodologies and develop adaptable & reusable solutions.
101003/CS622T.3-PSO3	**MEDIUM**	The ability to apply the fundamentals of computer science in competitive research and prior to that perform requirement analysis, identify design methodologies.
101003/CS622T.4-PO1	**MEDIUM**	Prepare technical report and deliver presentation by applying the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
101003/CS622T.4-PO2	**HIGH**	Identify, formulate, review research literature, and analyze complex engineering problems by preparing technical report and deliver presentation.

101003/CS622T.4-PO3	**MEDIUM**	Prepare Design solutions for complex engineering problems and create technical report and deliver presentation.
101003/CS622T.4-PO4	**MEDIUM**	Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions and prepare technical report and deliver presentation.
101003/CS622T.4-PO5	**MEDIUM**	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools and Prepare technical report and deliver presentation.
101003/CS622T.4-PO8	**HIGH**	Prepare technical report and deliver presentation by applying ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
101003/CS622T.4-PO9	**HIGH**	Prepare technical report and deliver presentation effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.
101003/CS622T.4-PO10	**HIGH**	Communicate effectively with the engineering community and with society at large by prepare technical report and deliver presentation.
101003/CS622T.4-PO11	**MEDIUM**	Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work by prepare technical report and deliver presentation.
101003/CS622T.4-PO12	**HIGH**	Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change by prepare technical report and deliver presentation.
101003/CS622T.4-PSO1	**MEDIUM**	Prepare a technical report and deliver presentation to identify, analyze and design solutions for complex engineering problems in multidisciplinary areas.
101003/CS622T.4-PSO2	**MEDIUM**	To acquire programming efficiency by designing algorithms and applying standard practices in software project development and to prepare technical report and deliver presentation.
101003/CS622T.4-PSO3	**MEDIUM**	To apply the fundamentals of computer science in competitive research and to develop innovative products to meet the societal needs by preparing technical report and deliver presentation.
101003/CS622T.5-PO1	**HIGH**	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
101003/CS622T.5-PO2	**HIGH**	Identify, formulate, review research literature, and analyze complex engineering problems by applying engineering and management principles to achieve the goal of the project.

101003/CS622T.5-PO3	**HIGH**	Apply engineering and management principles to achieve the goal of the project and to design solutions for complex engineering problems and design system components or processes that meet the specified needs.
101003/CS622T.5-PO4	**MEDIUM**	Apply engineering and management principles to achieve the goal of the project and use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
101003/CS622T.5-PO5	**MEDIUM**	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools and to apply engineering and management principles to achieve the goal of the project.
101003/CS622T.5-PO6	**MEDIUM**	Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities by applying engineering and management principles to achieve the goal of the project.
101003/CS622T.5-PO7	**MEDIUM**	Understand the impact of the professional engineering solutions in societal and environmental contexts, and apply engineering and management principles to achieve the goal of the project.
101003/CS622T.5-PO8	**HIGH**	Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice and to use the engineering and management principles to achieve the goal of the project.
101003/CS622T.5-PO9	**MEDIUM**	Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings and to apply engineering and management principles to achieve the goal of the project.
101003/CS622T.5-PO11	**MEDIUM**	Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team. Manage projects in multidisciplinary environments and to apply engineering and management principles to achieve the goal of the project.
101003/CS622T.5-PO12	**HIGH**	Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change and to apply engineering and management principles to achieve the goal of the project.
101003/CS622T.5-PSO1	**MEDIUM**	The ability to identify, analyze and design solutions for complex engineering problems in multidisciplinary areas. Apply engineering and management principles to achieve the goal of the project.

101003/CS622T.5-PSO2	**MEDIUM**	The ability to acquire programming efficiency by designing algorithms and applying standard practices in software project development to deliver quality software products meeting the demands of the industry and to apply engineering and management principles to achieve the goal of the project.
101003/CS622T.5-PSO3	**MEDIUM**	The ability to apply the fundamentals of computer science in competitive research and to develop innovative products to meet the societal needs thereby evolving as an eminent researcher and entrepreneur and apply engineering and management principles to achieve the goal of the project.