Certainly! Here's the updated version of your theoretical approach, incorporating both **patient data** and **CTG scan images** for the AI and ML model:

**AI and ML Implementation for “Development and Evaluation of an Online Cardiotocography Course Tailored to LMIC Settings: A Feasibility Study Conducted in a Tertiary Care Hospital in Sri Lanka”**

**Objective**

The integration of **Artificial Intelligence (AI)** and **Machine Learning (ML)** techniques into the analysis of **Cardiotocography (CTG)** data aims to predict **fetal distress** and generate detailed, actionable reports. This project combines **patient data** and **CTG scan images** to predict outcomes and assist clinicians in decision-making. By using a combination of **XGBoost**, **Support Vector Machines (SVM)**, and **K-Nearest Neighbors (KNN)** for classification, alongside **Large Language Models (LLMs)** for report generation, this system will offer scalable, efficient solutions for improving neonatal outcomes in **Low and Middle-Income Countries (LMICs)**.

**Proposed Output**

The output from this AI model will combine **patient data** and **CTG scan images** to generate a comprehensive prediction and interpretation report. Here's a sample output:

**Simple Output at the End of the Model Run Based on the CTG SCAN IMAGE AND DATA:**

1. **Baseline Fetal Heart Rate (FHR):**
   * **190 bpm:** The initial values suggest tachycardia, which could be indicative of **fetal distress**, possibly due to maternal fever, fetal anemia, or hyperthyroidism. The abnormal FHR could also be related to **hypoxia** or **infection**.
2. **Variability:**
   * Sharp drops to **120 bpm** and **100 bpm** are noted. This pattern could indicate **decelerations**, possibly due to **umbilical cord compression** or **fetal hypoxia**. A non-reassuring pattern may warrant immediate clinical attention.
3. **CTG Scan Image Interpretation:**
   * The **CTG scan image** will also be processed using **image recognition models** (e.g., **Convolutional Neural Networks (CNNs)**) to identify visual patterns indicative of **fetal distress** or abnormal conditions. For instance, the image may highlight **decelerations** or other irregularities that align with the FHR values.
4. **Patient Data Correlation:**
   * **Maternal Information:** The patient’s **age**, **gestational age**, **comorbidities** (e.g., diabetes), and other **clinical factors** are used in conjunction with the **CTG scan** and FHR data to improve prediction accuracy. For example, if the patient is experiencing **gestational diabetes**, the model can weigh this as a risk factor.
5. **Clinical Action:**
   * The system will recommend clinical actions based on the results of both the **FHR** and **CTG scan image**. Actions may include:
     + Immediate reassessment via **ultrasound**
     + Oxygen administration to the mother
     + **Preparation for delivery** if the distress is confirmed, or other interventions depending on the severity of the findings.

**Methodology:**

This approach utilizes **two parallel strategies** to predict fetal distress and generate detailed reports, incorporating both **patient data** and **CTG scan images**.

1. **Machine Learning (ML) for Classification:**
   * ML models will be trained to **classify fetal distress** based on both **patient data** and **CTG scan image data**. The combination of these two types of data will provide a more accurate and holistic prediction of fetal health.
     + **XGBoost:** Used for efficiently handling complex interactions between features like FHR, uterine contractions, and maternal data.
     + **Support Vector Machines (SVM):** SVM will create optimal decision boundaries to classify the fetal distress condition, taking both data types into account.
     + **K-Nearest Neighbors (KNN):** KNN will classify CTG patterns based on the majority class of neighboring instances, considering both **numerical values** (FHR, variability) and **image-based features** from CTG scans.
2. **Convolutional Neural Networks (CNNs) for CTG Scan Image Analysis:**
   * **CTG scan images** will be analyzed using **CNNs**, which are well-suited for image classification tasks. These models will automatically detect and interpret important visual features from the CTG scans (e.g., **decelerations**, **accelerations**, **baseline fluctuations**).
   * The image model will process the CTG scan to extract visual patterns, which will then be integrated with the **numerical data** (FHR, uterine contractions, etc.) to improve classification and prediction accuracy.
3. **Large Language Model (LLM) for Report Generation:**
   * After classifying the fetal distress condition using both the patient data and CTG scan images, a **Large Language Model (LLM)** will be employed to generate a detailed **report** based on the predicted outcome.
     + The LLM will incorporate clinical knowledge, research, and guidelines to provide a **structured report**. This report will describe the fetal heart rate pattern, interpret the CTG scan, suggest possible causes, and recommend clinical actions.
   * The LLM will be trained using existing **clinical reports**, **research articles**, and **guidelines** to ensure that it generates relevant and accurate reports. It will also consider maternal data (age, gestational age, etc.) to tailor the recommendations accordingly.

**Model Development Process:**

1. **Data Collection:**
   * The system will collect two types of data:
     + **Patient Data**: Including maternal health information (e.g., age, comorbidities, medical history).
     + **CTG Scan Images**: The images will be preprocessed to extract features relevant for the classification task, such as fetal heart rate trends and uterine contraction patterns.
2. **Preprocessing:**
   * **Patient Data Preprocessing**: Clean the data, handle missing values, and normalize features (e.g., age, FHR).
   * **CTG Scan Image Preprocessing**: Normalize images, resize them for consistency, and augment data for better model generalization.
3. **Feature Selection:**
   * Identify and select important features from both the **numerical data** (e.g., FHR, uterine contractions) and **image data** (e.g., patterns in CTG scans) that contribute most to predicting fetal distress.
4. **Model Training:**
   * **ML Models (XGBoost, SVM, KNN)**: The numerical features from patient data and FHR will be used to train classification models.
   * **CNNs for Image Data**: CTG scan images will be processed using CNNs to extract visual patterns.
   * **LLM Training**: The LLM will be trained to generate clinically relevant reports based on the **predicted outcomes** and **patient information**.
5. **Model Evaluation:**
   * Evaluate the models using standard metrics like **accuracy**, **precision**, **recall**, **F1-score**, and **AUC-ROC** for classification tasks.
   * For the LLM, evaluate the quality of the generated reports based on **clinical relevance**, **accuracy**, and **completeness**.
6. **Integration:**
   * The classification models (ML models and CNNs) and LLM will be integrated into a single system, where the **CTG data input** (both patient and image data) will first be processed by the classification models, followed by report generation using the LLM.

**Outcome:**

By integrating **patient data** and **CTG scan images**, this system will provide:

* **Accurate classification** of fetal distress conditions.
* **Comprehensive, structured reports** that include clinical interpretation, possible causes, and recommended actions.
* A scalable solution that can be deployed in **LMICs**, where access to trained professionals and resources is often limited.

**Future Directions:**

* **Real-time Data Integration:** The system could process **real-time CTG data** and images from CTG machines to provide instant feedback to clinicians.
* **Clinical Trial Validation:** A large-scale clinical trial can be conducted to validate the system’s **real-world effectiveness** in diagnosing fetal distress and improving clinical outcomes.

**Report Structure**

**Cardiotocography (CTG) Preliminary Report**

Patient ID: [To be filled]

Date/Time of CTG: [To be filled]

Gestational Age: [To be filled]

Indication for CTG: [e.g., Routine monitoring, reduced fetal movements, high-risk pregnancy]

Observed Fetal Heart Rate (FHR) Data:

- Initial Baseline: 190 bpm (persistent x3 readings)

- Subsequent Values: 120 bpm → 100 bpm (x2 readings)

Key Findings:

1. Severe Tachycardia (190 bpm):

- Exceeds normal baseline (110-160 bpm).

- Possible causes:

- Maternal fever/infection (chorioamnionitis).

- Fetal anemia (e.g., Rh isoimmunization, parvovirus infection).

- Fetal/maternal hyperthyroidism.

- Chronic hypoxia with compensatory tachycardia.

2. Abrupt Deceleration to Bradycardia (100 bpm):

- Non-reassuring pattern; may indicate:

- Acute hypoxia (e.g., cord compression, placental abruption).

- Fetal acidosis or evolving distress.

- Concern: Lack of recovery to baseline suggests worsening status.

3. Variability & Additional Features:

- Data insufficient - requires visual tracing to assess variability (absent/minimal variability would escalate concern).

- No accelerations noted (if none present, increases suspicion of fetal compromise).

Clinical Correlation Needed:

- Maternal history: Fever, hypertension, diabetes, bleeding?

- Labor context: Contractions (timing/strength), rupture of membranes?

- Confirmatory tests:

- Urgent ultrasound (biophysical profile, Doppler flow studies).

- Fetal scalp stimulation/pH (if in labor).

- Maternal labs (CBC, CRP, TORCH screen if infection suspected).

Recommended Actions:

1. Immediate:

- Maternal repositioning (left lateral), O₂ supplementation.

- Discontinue oxytocin if in labor.

- Prepare for expedited delivery (C-section if persistent bradycardia).

2. Monitoring:

- Continuous CTG with obstetric review.

- Consider intrauterine resuscitation (tocolytics if hyperstimulation).

3. Documentation:

- Classify CTG as pathological (if decelerations are recurrent/late).

- Escalate to senior obstetrician/neonatology team.

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Provisional Interpretation:

- High suspicion of acute fetal compromise due to tachycardia → bradycardia sequence.

- Differential diagnoses:

- Umbilical cord accident (prolapse, tight nuchal cord).

- Placental insufficiency (abruption, previa).

- Sepsis/maternal hemodynamic instability.