CSE499b.18

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System Design for Intelligent Tutoring System (ITS)

1. System Overview

The *Intelligent Tutoring System* is an AI-driven personalised tutoring platform that adapts to real-time student performance. It provides:

- **Personalised Learning Paths** tailored to each student.
- **Real-time assessment** to dynamically adjust the difficulty.
- **Self-paced learning** with hints and explanations.
- **Enhanced Accessibility** for students of all backgrounds.

2. System Architecture

The system consists of the following components:

- **User Interface (UI)**
  - Web/Mobile application for student interactions.
  - Interactive dashboard for progress tracking.
- **AI-Powered Tutoring Engine**
  - **Large Language Models (LLMs):** Fine-tuned models like *PHI-2* and *GEMMA* process student queries.
  - **LangChain Framework:** Orchestrates multi-turn conversations.
- **Real-Time Adaptive Learning**
  - Uses **RAG (Retrieve and Generate)** to fetch relevant explanations.
  - Implements **LoRA fine-tuning** to specialise in math tutoring.
- **Assessment & Feedback System**
  - Tracks student responses and errors.
  - Provides hints and explanations dynamically.
- **Ethical & Secure Data Handling**
  - Ensures privacy, fairness, and accessibility.

3. Multi-Turn Instructional Design

Your system will engage students with step-by-step explanations, scaffolding learning based on their understanding. Here's an example:

Example Conversation for a Math Problem

Problem: Solve the equation: x2+4=(x+1)(x+3)x² + 4 = (x + 1)(x + 3)x2+4=(x+1)(x+3).

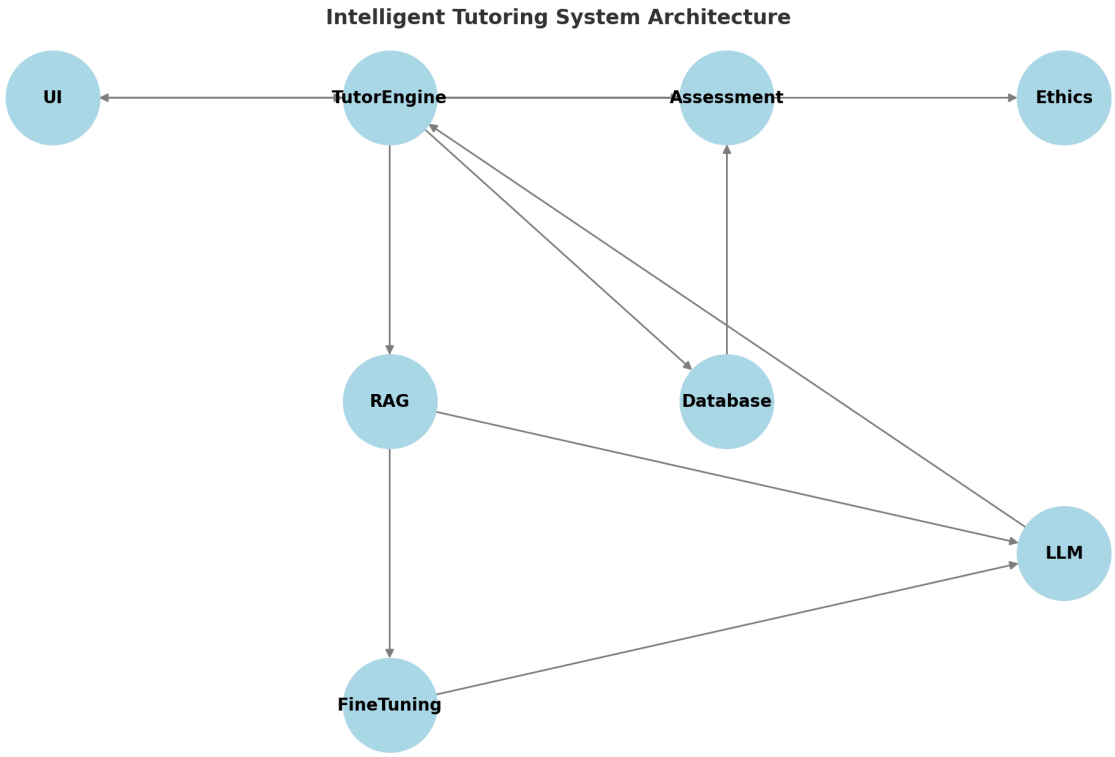
1️⃣ **Student:** "Solve x2+4=(x+1)(x+3)x² + 4 = (x + 1)(x + 3)x2+4=(x+1)(x+3)."
2️⃣ **System:** "Let's expand (x+1)(x+3)(x+1)(x+3)(x+1)(x+3). Do you know how to expand binomials? (Yes/No)"
3️⃣ **Student:** "No."
4️⃣ **System:** "No problem! Here's how we expand: x∗x=x2x*x = x²x∗x=x2, x∗3=3xx*3 = 3xx∗3=3x, 1∗x=x1*x = x1∗x=x, and 1∗3=31*3 = 31∗3=3. So, x2+4x+3x² + 4x + 3x2+4x+3. Do you get it now?"
5️⃣ **Student:** "Yes!"
6️⃣ **System:** "Great! Now subtract x2x²x2 from both sides to get 4=4x+34 = 4x + 34=4x+3. What's the next step?"
7️⃣ **Student:** "Subtract 3!"
8️⃣ **System:** "Correct! You get 1=4x1 = 4x1=4x. Now, solve for xxx."
9️⃣ **Student:** "Divide by 4, so x=1/4x = 1/4x=1/4!"
🔟 **System:** "Excellent! Would you like to try a similar problem?"

4. Implementation Details

- **Technology Stack**
    1. Frontend: React (Next.js) for UI
    2. Backend: FastAPI (Python) for AI processing
    3. Database: PostgreSQL for tracking user progress
    4. LLMs: GEMMA & PHI-2 via LangChain
    5. Model Fine-tuning: LoRA for efficiency
- **Workflow**
    1. **Student Input:** The user submits a problem.
    2. **AI Processing:** The model retrieves relevant hints.
    3. **Dynamic Scaffolding:** The system adapts based on user responses.
    4. **Assessment:** Tracks progress and recommends next steps.

5. Ethical Considerations

- **Fairness & Bias Mitigation:** Ensuring AI does not favor specific learning styles unfairly.
- **Privacy & Security:** Handling student data responsibly.
- **Inclusivity:** Supporting accessibility for students with disabilities.



Here is a visual representation of the *architecture of the Intelligent Tutoring System (ITS)*, *demonstrat*ing an advanced and structured approach. The figure illustrates the interactions between different components, making it easier to understand.

- **User Interface (UI):** The front end where students interact.
- **AI-Powered Tutoring Engine:** The system's core processes student queries.
- **Real-Time Assessment:** Evaluates student performance and adjusts content accordingly.
- **RAG (Retrieve & Generate):** Fetches relevant hints and explanations.
- **LoRA Fine-Tuning:** Optimizes LLMs for better responses.
- **Large Language Models (GEMMA, PHI-2):** The AI models powering tutoring.
- **Student Progress Database:** Stores student learning history.
- **Ethics & Privacy Management:** Ensures responsible AI use