

Design of a Calculus-Based AI System Integrating Retrieval-Augmented Generation and Multimodal Techniques

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Abstract

Against the backdrop of the rapid development of generative artificial intelligence, how to transform AI technology into an intelligent guidance tool with pedagogical significance has become an important issue in education. This research aims to construct a calculus AI teaching assistant system integrating multimodal input and retrieval-augmented generation (RAG) technology, and conduct experiments in a real teaching setting on the LINE platform. The system architecture adopts a local large-scale language model (Local LLM) combined with a vector database (ChromaDB), importing teachers' personal lecture notes and exercise solutions as a localized knowledge base to ensure that the generated content is consistent with classroom teaching. At the input end, speech recognition (Whisper), image formula recognition (OCR), and text processing mechanisms are integrated to overcome the difficulty of inputting mathematical formulas and reduce students' external cognitive load.

This research specifically designs a "scaffolding-style AI guidance mechanism," which uses prompt word engineering to prevent the system from directly providing answers. Instead, based on the scaffolding theory of Wood, Bruner, and Ross, it provides strategic prompts, step-by-step breakdowns, and diagnostic feedback to guide students step by step through the problem-solving process. Simultaneously, the SymPy symbolic computation module was introduced to improve the accuracy of mathematical inferences and reduce the risk of generative AI illusions. The research method adopted design-based research, which was iteratively optimized in actual classrooms, and the effectiveness was evaluated through learning achievement tests, the NASA-TLX Cognitive Load Scale, and the System Usability Scale (SUS).