Interactive Cognitive Agents for STEM Education

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Abstract

This thesis proposes an interactive cognitive agent designed to assist students in STEM education. The system combines dialogue-based tutoring with adaptive feedback mechanisms to improve engagement and learning outcomes. The project explores the integration of cognitive modeling, reinforcement learning, and multimodal interfaces in educational contexts.

Thesis Overview

Current intelligent tutoring systems often provide static feedback and limited personalization. This research aims to design an adaptive agent capable of dynamically adjusting its teaching strategies based on a student's cognitive and emotional state. The study addresses the gap between pedagogical theory and real-time AI-driven personalization.

Background

Educational AI systems have evolved from rule-based tutors to data-driven adaptive systems. Cognitive modeling, particularly ACT-R, provides a foundation for simulating student reasoning. This thesis extends these ideas by incorporating reinforcement learning for adaptive pedagogy.

Related Work

Previous works like AutoTutor and Duolingo leverage dialogue and adaptive content but lack deep personalization or transparency. My project enhances these approaches by integrating cognitive models for individualized feedback.

Contributions

1. A conversational cognitive agent architecture for STEM tutoring.
2. A user-adaptive policy model for dynamic teaching strategies.
3. An evaluation framework assessing both learning gain and engagement.

Thesis Question / Hypothesis

Hypothesis: A cognitive model-driven interactive agent will improve students' learning outcomes and engagement compared to rule-based tutoring systems.

Research Goal and Methodology

The research will involve building a tutoring prototype integrating natural language understanding and reinforcement-based adaptation. A user study with undergraduate students will be conducted to measure learning gains, satisfaction, and engagement metrics.

Evaluation and Validation Criteria

Quantitative validation will include pre- and post-test performance and interaction analysis. Qualitative measures will capture perceived engagement and tutor helpfulness.

Expected Outcomes and Significance

This work aims to advance personalized education by developing AI tutors that dynamically adapt to learner needs. The findings will contribute to cognitive modeling, affective computing, and educational AI.