DESIGNING AN ADAPTIVE RECOMMENDATION SYSTEM IN EDUCATION BASED ON KNOWLEDGE GRAPHS AND ARTIFICIAL INTELLIGENCE

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Abstract: Modern educational paradigms are rapidly shifting toward personalization, requiring systems that dynamically adapt to the unique learning paces, knowledge gaps, and backgrounds of individual students. Traditional recommendation systems in education often suffer from data sparsity and a lack of semantic understanding regarding the relationships between different learning concepts. This paper proposes a conceptual framework for an adaptive educational recommendation system that integrates Knowledge Graphs (KGs) with Artificial Intelligence (AI) algorithms. By mapping curriculum structures into a semantic graph and leveraging graph neural networks (GNNs) alongside reinforcement learning, the proposed system provides context-aware, sequential learning path recommendations. The architectural design demonstrates a significant potential to improve student engagement, optimize cognitive load, and bridge knowledge gaps effectively.

Keywords: adaptive learning, knowledge graph, artificial intelligence, recommendation system, personalized education.

Introduction

The one-size-fits-all model of traditional education is increasingly failing to meet the diverse needs of modern learners. With the rise of E-learning platforms and Massive Open Online Courses (MOOCs), huge volumes of educational data have become available. However, navigating these resources efficiently remains a challenge for students, often leading to cognitive overload or disengagement.

Adaptive learning systems aim to solve this by tailoring the educational content, difficulty, and sequencing to each student. Early adaptive systems relied heavily on manually created rule-based models, which are rigid and difficult to scale. Recent advances in Artificial Intelligence, particularly machine learning, have improved personalization. Yet, pure data-driven models (like collaborative filtering) often treat learning materials as isolated items, ignoring the critical prerequisite dependencies between academic concepts (e.g., a student must understand *linear equations* before learning *calculus*).

To address these limitations, this paper introduces a system design that pairs Knowledge Graphs (KGs) with dynamic AI recommendation algorithms. The Knowledge Graph acts as the structured "brain" of the educational domain, while AI components act as the adaptive engine that evaluates user states and recommends the optimal next step.

Theoretical Framework and Conceptual Mapping

Educational Knowledge Graph (EKG) Construction

The foundation of the proposed system is the Educational Knowledge Graph. Unlike generic knowledge graphs, an EKG captures concepts, resources, and their pedagogical relationships. The graph is formally defined as:

$G = (E, R, T)$

Where:

- E represents **Entities** (Learning concepts, quizzes, video lectures, modules).
- R represents **Relations** (e.g., is_prerequisite_of, is_part_of, is_example_of).

- T represents **Triples** in the form of (e_1, r, e_2).

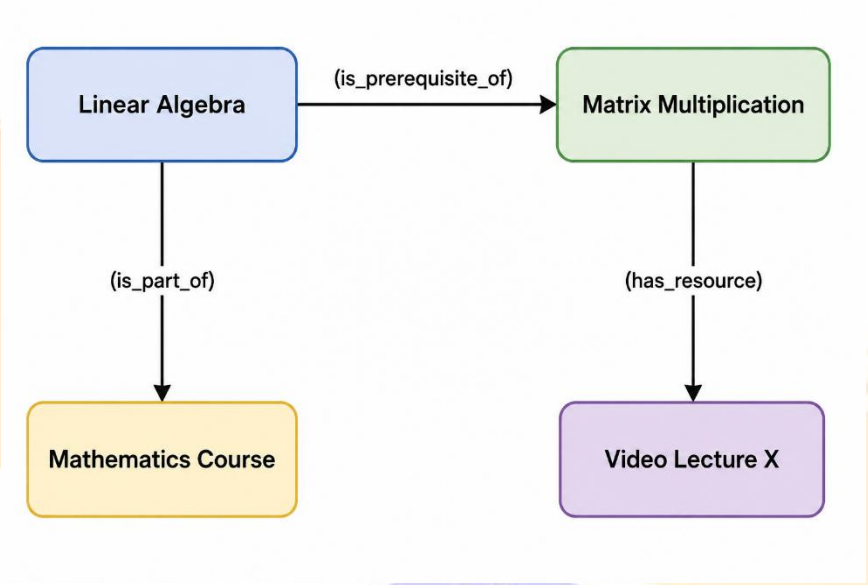

Figure 1. Knowledge Graph Representation of Educational Concepts, and Learning Resources.

Courses,

Student profile modeling (The learner state)

To make precise recommendations, the system must maintain a dynamic digital twin of the student's cognitive state. This profile updates continuously based on implicit data (time spent on a page, video pause rates) and explicit data (quiz scores, completed assignments). The student's mastery level over a specific concept c at time t is calculated using a modified Deep Knowledge Tracing (DKT) approach, assessing probabilities of mastery based on historical performance vectors.

Proposed System Architecture

The proposed architecture is divided into three interconnected layers: the Data Layer, the Semantic Knowledge Layer, and the Adaptive Recommendation Engine.

Results and Discussion

The integration of Knowledge Graphs and Artificial Intelligence provides several advantages for adaptive learning systems.

First, Knowledge Graphs enable semantic understanding of educational content. Unlike traditional databases, graph structures represent relationships among concepts, allowing the system to recommend resources based on conceptual dependencies rather than simple keyword matching.

Second, AI algorithms enhance personalization by continuously adapting recommendations according to learner progress. The system can identify weak areas and suggest appropriate remedial materials.

Third, the proposed model supports explainable recommendations. Since recommendations are derived from graph relationships, learners and instructors can understand why specific resources are suggested.

Furthermore, adaptive recommendation systems contribute to increased student engagement and improved learning outcomes. Personalized content delivery reduces cognitive overload and supports efficient knowledge acquisition.

Several challenges remain, including data quality, scalability of Knowledge Graphs, privacy concerns, and computational complexity. Future research should focus on optimizing graph

construction techniques and incorporating advanced deep learning models for recommendation generation.

Conclusion

This study presented a conceptual design of an adaptive recommendation system based on Knowledge Graph technology and Artificial Intelligence for educational environments. The proposed framework integrates semantic knowledge representation, learner modeling, and intelligent recommendation mechanisms to provide personalized learning experiences.

Knowledge Graphs offer a powerful approach for organizing educational knowledge, while AI techniques enable dynamic adaptation to learner needs. The implementation of such systems can improve educational effectiveness, increase learner engagement, and support individualized learning pathways.

Future studies may focus on developing prototype systems, evaluating recommendation accuracy, and integrating large language models to further enhance adaptive educational technologies.

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