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APPLICATION OF GRAPH DATABASES IN EDUCATION

Graph databases provide new opportunities in the development of modern education, such as supporting learning on Massive Open Online Course (MOOC), the ability to develop a personal educational trajectory by saving and managing learner data, tracking progress in learning, recommending educational materials relevant to the individual needs of the student, his interests and learning style, creating a comprehensive learner profile, development of independence, responsibility, critical thinking and motivation for self-development.

Keywords: *Graph databases, personalization of education, knowledge graph, educational system, student, targeted educational experience, and curriculum*

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ПРИМЕНЕНИЕ ГРАФОВЫХ БАЗ В ОБРАЗОВАНИИ

Графовые базы данных предоставляют новые возможности в развитии современного образования, такие как поддержка обучения на массовых открытых образовательных онлайн-платформах, возможность разработки персональной образовательной траектории путем сохранения и управления данными об обучающихся, отслеживание прогресса в обучении, рекомендации учебных материалов, релевантных индивидуальным потребностям обучающегося, его интересам и стилю обучения, создание комплексного профиля обучающегося, развитие самостоятельности, ответственности, критического мышления и мотивации к саморазвитию.

Ключевые слова: *графовые базы данных, персонализация образования, граф знаний, образовательная система, обучающийся, целенаправленный образовательный опыт, учебная программа*

Educators imagine a future where technology is used to enhance individualized education, encouraging ongoing learning throughout one's life. In this scenario, educational material can be tailored and delivered instantly in the most impactful manner for each learner. Graph databases play a crucial role in realizing this vision by efficiently managing, analyzing, and linking learner data to provide distinct, customized learning opportunities in real-time.

Graph database solutions assist in organizing learner information for educational institutions and education technology companies (EdTechs). By connecting learner data from various sources and identifying new relationships within the data, educators are able to provide more personalized learning experiences.

What is a graph database?

A graph database is a systematic collection of data that emphasizes the relationships between the different data entities. The NoSQL database uses mathematical graph theory to show data connections. Unlike relational databases, which store data in rigid table structures, graph databases store data as a network of entities and relationships. As a result, these databases often provide better performance and flexibility, as they are more suited for modeling real-world scenarios [1].

Developing an MOOC application for an educational institution with graph databases.

Graph databases are particularly well suited for supporting the learning journey on massive online open course (MOOC) platforms. Traditional learning platforms and learning management systems (LMS) used in MOOCs may not fully utilize the flexibility and opportunities for linking multiple resources that a dynamic platform can offer. By integrating graph databases into these platforms, learners can have a more enriched experience when interacting with course content. This allows for a more tailored and suitable learning experience, with information seamlessly transmitted between different components of the system [2].

Incorporating a traditional Learning Management System (LMS) into a Massive Open Online Course (MOOC) web application that utilizes a graph database can provide advantages in this situation. An LMS has valuable features, such as storing individual student data like login details, performance evaluations, course advancement, and other relevant information.

There are three main architectural connections in this type of application design [2]:

The connections between the MOOC's browser-based graphical user interface (GUI) web application and the graph database determines where the learner is situated in the curriculum graph and which nodes are immediately accessible, barring access restrictions if applicable. By providing a map of the curriculum and where the user is located in it, an MOOC application can use the graph database to help the user navigate back to previous nodes without getting lost in complex linkages—much like a road map.

The connection between the user interface and the LMS is primarily used to provide the user interface (UI) information about access restrictions for a particular learner if they are enrolled in a course that limits access to some information. Starting from the entry point of the curriculum graph, or from any other remembered bookmarked node in the graph, the user should be able to freely navigate to any other point and back using the structure of the graph.

The connection between the graph database and the LMS informs the latter about the overall structure (though not the details) of the curriculum. The LMS is used to store assessments for those aspects of the curriculum that do have associated assessments, and to provide to the graph database the assessments that are appropriate to each component of the curriculum. If a student undergoes an assessment more than once for the same component of the curriculum, the LMS holds the information needed to determine which components of the assessment should or should not be repeated.

Getting started with graph databases

When learning resources, content, and information about learners are stored as graphs, institutions can create comprehensive systems that support learning on a large scale. This approach can move away from memorization-based learning and instead provide personalized support to each learner throughout their educational journey by offering the resources they require at the right time.

Graph databases can enhance learning in other several ways [3]:

Visualizing complex relationships: Graph databases allow students to visualize complex relationships between data points, which can make it easier to understand and remember information. For example, a student could use a graph database to visualize the relationships between characters in a novel or the different parts of a scientific experiment.

Exploring data interactively: Graph databases allow students to explore data interactively, which can help them to develop a deeper understanding of the data. For example, a student could use a graph database to explore a social network and see how different people are connected to each other.

Identifying patterns and trends: Graph databases can help students to identify patterns and trends in data, which can lead to new insights. For example, a student could use a graph database to identify patterns in student performance data and develop targeted interventions to improve student outcomes.

Developing critical thinking skills: Graph databases can help students to develop critical thinking skills by encouraging them to ask questions about the data and to think about the relationships between different data points. For example, a student could use a graph database to explore the

relationships between different factors that contribute to climate change and develop their own hypotheses about how to mitigate climate change.

Let us give specific examples of how graph databases are being used to enhance learning.

In the classroom: Graph databases are being used in classrooms to help students learn about a variety of subjects, including science, social studies, and mathematics. For example, students can use graph databases to visualize the relationships between different elements in the periodic table or to explore the different factors that contribute to the Second World War.

In online learning: Graph databases are also being used in online learning environments to help students learn at their own pace and to explore topics in more depth. For example, students can use graph databases to explore interactive simulations of scientific experiments or to create their own knowledge graphs on a particular topic.

In research: Graph databases are being used by researchers to explore complex datasets and to develop new insights into a variety of topics. For example, researchers are using graph databases to study the spread of diseases, to identify patterns in financial data, and to develop new drug therapies.

Graph databases have the potential to revolutionize the way that we learn and to make learning more engaging, interactive, and effective. Graph databases can help students to develop critical thinking skills by encouraging them to explore data and to identify patterns and relationships.

Foster a love of learning: Graph databases can make learning more engaging and enjoyable for students. By providing a visual and interactive way to explore data, graph databases can help students to develop a love of learning that will last a lifetime.

The most interesting application of graph database is personalized education support.

Using a graph database in education can help educators create a knowledge graph, which organizes and links learning resources to form a comprehensive web of content. Unlike traditional online learning systems that offer fixed curriculum options, a knowledge graph system based on a graph database can provide a dynamic framework for school subjects and student learning records. By integrating artificial intelligence (AI) to analyze learning patterns in the graph database, AI can assess a learner's academic progress and tailor a personalized learning path for each student based on their individual needs. This can include recommendations for study paths, tracking progress, and reinforcing learning through retesting on specific topics as necessary.

For example, if a learner using an online learning system is trying to solve a particular question in “definite integrals” but they get stuck at a step that requires knowledge about differentiation of logarithmic functions, which they had either forgotten or skipped, the system can recommend content on that topic to the learner.

Some specific examples of how graph databases are being used to support personalized education:

In the classroom: Graph databases are being used in classrooms to help teachers track student progress and to identify students who are struggling. This information can then be used to provide students with additional support and to create personalized learning plans.

In online learning: Graph databases are being used in online learning environments to recommend resources to students based on their individual needs. For example, a graph database could recommend textbooks, articles, or videos that are relevant to a student's interests and learning style.

In research: Graph databases are being used by researchers to study the effectiveness of different personalized learning approaches. This research is helping to identify the best ways to use graph databases to support personalized education.

Providing feedback: Graph databases can be used to provide students with feedback on their work. This feedback can be tailored to each student's individual needs and learning style.

Creating learning communities: Graph databases can be used to create learning communities where students can connect with each other and share resources. This can help students to learn from each other and to develop a sense of community.

Empowering students: Graph databases can be used to empower students by giving them access to their own data and by allowing them to track their own progress. This can help students to become more self-directed learners and to take ownership of their own education.

Implementing graph databases in education can present several challenges [4]:

1. *Modeling Highly Interconnected Data:* Graph databases provide a high level of expressivity, making it challenging to model a domain on a graph.

2. *Graph Literacy:* In the educational context, graph literacy describes the competence to read, comprehend, and interpret formative assessment data in terms of data-based decision-making (DBDM) in order to derive and justify individual adaptations of instruction based on them¹. Misconceptions may arise in predicting future learning progress due to the characteristics of the database as well as the approach to graph literacy [5].

3. *Lack of Professional Development:* There can be a lack of professional development or technical assistance for school/program leaders and practitioners to translate multiple measures and multiple levels of student achievement data into a realistic action plan for improvement.

4. *Efficient Query Processing:* As graph databases grow in popularity, there is a need for more efficient ways of computing the answers of graph queries, specifically graph patterns, path queries, and combinations between them.

5. *Graph Analytics:* Systems should be able to run more complex analytical queries involving tasks such as more complex path finding, centrality, or clustering².

These challenges highlight the need for ongoing research and development in the field of graph databases in education.

To summarize all that has been said, we can say the following.

Graph databases offer unique capabilities for personalized education by connecting and analyzing diverse data sources to create a comprehensive learner profile [6].

1. *Learner Profiles and Adaptive Learning:* Graph databases can store and link information about learners' demographics, learning styles, interests, and performance.

This data can be used to create personalized learning paths, adapt content to individual needs, and provide targeted interventions.

2. *Competency Mapping and Skill Tracking:* Graphs can represent complex relationships between skills, knowledge, and competencies.

This allows educators to track learners' progress through a curriculum and identify areas where they need additional support.

3. *Collaborative Learning and Social Networks:* Graph databases can connect learners with peers, mentors, and experts. This fosters collaboration, peer support, and the sharing of knowledge and resources.

4. *Personalized Feedback and Assessment:* Graphs can store and analyze learner responses to assessments. This data can be used to provide personalized feedback, identify areas for improvement, and adjust teaching strategies accordingly.

5. *Learning Analytics and Data-Driven Decision Making:* Graph databases facilitate the analysis of large volumes of educational data. This enables educators to identify trends, patterns, and insights that can inform decision-making about curriculum, instruction, and support services.

Implementation Considerations:

Data Integration: Graph databases require the integration of data from multiple sources, such as student information systems, learning management systems, and assessments.

Data Privacy and Security: Graph databases must ensure the privacy and security of sensitive learner data.

Scalability: Graph databases should be scalable to handle large volumes of data and complex relationships.

User Interface and Accessibility: The user interface should be intuitive and accessible to educators and learners.

Benefits of Personalized Education with Graph Databases:

- Improved learner engagement and motivation.
- Increased academic achievement and skill development.
- Reduced dropout rates and increased completion.
- More effective and efficient use of educational resources.
- Data-driven decision-making to improve educational outcomes.

The main point of using graph databases in personalized education is to leverage their ability to capture and analyze complex relationships between various data points related to learners. By storing information in a graph structure, educators can create a comprehensive learner profile that includes demographics, learning preferences, performance data, social interactions, and more. This detailed profile enables educators to tailor learning experiences to individual needs, track progress more effectively, provide targeted support, foster collaboration, and make data-driven decisions to enhance educational outcomes. In essence, graph databases enable a more personalized and adaptive approach to education by offering a holistic view of each learner and their unique characteristics and learning journey.

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