The Application and Exploration of Knowledge Graphs in the Course of "Data Structures and Algorithms"

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Abstract. With the rapid development of information technology and the advent of the big data era, knowledge graphs, as an efficient way of organizing and managing information, have gradually attracted widespread attention. This paper builds a knowledge graph for the "Data Structures and Algorithms" course based on the Superstar platform, aiming to provide students with more systematic and intuitive learning resources, and to discuss the application effects of knowledge graphs in course teaching. Through practical research, this paper not only provides effective knowledge management and teaching methods for the "Data Structures and Algorithms" course, but also offers reference for the construction of knowledge graphs in other courses.

Keywords: Superstar platform; Data structure and algorithms; Knowledge Graphs.

1 Introduction

"Data Structures and Algorithms" is an important foundational course for computer science majors, playing a significant role in cultivating students' logical thinking and innovative abilities. However, due to the vast number of knowledge points and the abstract nature of the content, the course is difficult to understand. Traditional teaching methods struggle to meet the learning needs of students, hence the necessity to introduce new teaching methods to enhance the quality of teaching. Knowledge graphs, as a novel way of representing knowledge, can visually display the relationships between knowledge points, helping students to better understand and grasp the material. Therefore, this paper constructs a knowledge graph for the "Data Structures and Algorithms" course based on the Superstar platform and explores its practical application in teaching.

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2 Knowledge Graph Construction Techniques and Methods

2.1 Basic Concepts of Knowledge Graphs

A knowledge graph is a semantic network[1]represented in the form of a graph data structure consisting of entity nodes, entity attributes, and relationships between entities. It is a key foundational technology for cognitive intelligence. Knowledge graphs can abstract real-world entities as nodes and construct a vast network structure through the relationships between these nodes.

In a knowledge graph, nodes represent entities, which can be any real-world objects such as people, objects, events, etc. Edges represent the relationships between entities and can be any semantically meaningful connections, such as parent-child relationships, containment relationships, and so on. Through a knowledge graph, the entities of the real world can be represented in a graphical form, allowing for a more intuitive understanding and analysis of data.

The construction of a knowledge graph involves several fundamental concepts:

Entities (Nodes):These are the core components of a knowledge graph, representing the subjects or objects within a domain. In the context of "Data Structures and Algorithms[2]," entities might include specific algorithms, data structures, computational complexity, and various programming concepts.

Attributes: Each entity can have associated attributes that provide additional information or characteristics. For example, an algorithm entity might have attributes like time complexity, space complexity, or the type of problem it solves.

Relationships (Edges): These are the connections that exist between entities, defining how they relate to one another. Relationships can be directional, indicating a flow or influence, and can represent various types of connections, such as "uses," "is a type of," or "is more efficient than."

Graph Structure: The overall arrangement of nodes and edges forms the graph structure, which can be used to represent complex systems and hierarchies. The structure allows for the exploration of connections and the discovery of patterns or insights.

Semantic Meaning: The relationships in a knowledge graph carry semantic meaning, which is crucial for understanding the context and implications of the connections between entities.

Scalability and Extensibility: Knowledge graphs are designed to be scalable and extensible, allowing for the addition of new entities and relationships as the domain of interest grows or evolves.

Understanding these basic concepts is essential for effectively constructing and utilizing a knowledge graph in the context of the "Data Structures and Algorithms" course, or any other domain of knowledge.

2.2 Knowledge Graph Construction Technology

The construction of a knowledge graph primarily encompasses key technologies such as entity recognition, entity linking, and relationship extraction between entities. On the

Superstar platform, the technology for constructing a knowledge graph mainly includes the following aspects:

1. Data Collection and Preprocessing: Initially, the platform collects data from various channels, including text, images, videos, etc. Then, these data undergo preprocessing, such as deduplication, cleaning, and format conversion, laying the groundwork for subsequent knowledge extraction and integration.
2. Knowledge Extraction: After preprocessing, natural language processing (NLP) and information extraction techniques are utilized to extract key information such as entities, relationships, and attributes. This extracted information serves as the fundamental units of the knowledge graph.
3. Knowledge Fusion: Data from different sources and in various formats are integrated to build a complete and accurate knowledge graph. During the fusion process, it is essential to consider the credibility of data sources and conflicts between data to ensure the high quality of the integrated knowledge graph.
4. Knowledge Representation and Storage: The knowledge extracted and fused is represented in the form of a graph and stored using efficient graph databases or relational databases. Additionally, to facilitate user queries and analysis, knowledge indexing and query optimization are also necessary.
5. Knowledge Update and Maintenance: As data is continuously updated and changes, the knowledge graph also requires ongoing updates and maintenance. The Superstar platform provides a variety of tools for updating and maintaining the knowledge graph, making it easy to add, delete, and modify the graph, ensuring its timeliness and accuracy.

Furthermore, the knowledge graph construction technology on the Superstar platform also features:

(1)Visual Presentation: The knowledge graph is displayed through a graphical interface, allowing users to intuitively understand the relationships and attributes between various entities.

(2) Intelligent Analysis: Based on the knowledge graph, the platform can conduct intelligent analyses, such as relationship mining, path analysis, and trend forecasting, providing users with in-depth information analysis and decision support.

(3) Customized Services: The platform supports the customization of knowledge graph construction and analysis services according to user needs, catering to the requirements of different industries and scenarios.

2.3 Knowledge Graph Construction Method Based on the Superstar Platform

In the "Data Structures and Algorithms" course, entities mainly include concepts, methods, and algorithms; entity linking is the process of associating the identified entities with entities in the knowledge base, such as learning videos, assignments, question banks, course materials, online resources, etc.; entity relationship extraction is determining the relationships between entities, such as inheritance, dependency, containment, etc.

(1) Define Key Nodes: Identify key knowledge points and algorithms in the course, such as arrays, linked lists, stacks, queues, trees, graphs, and algorithms like sorting, searching, dynamic programming, graph algorithms, etc. These will become the main nodes of the knowledge graph.

(2) Determine Relationships: Determine the relationships between these nodes. For example, some data structures (such as stacks and queues) may be implemented based on arrays or linked lists; some algorithms (such as depth-first search and breadth-first search) may be used to handle graph data structures.

(3) Construct the Knowledge Graph: Using the Superstar knowledge graph template, determine the primary, secondary, and tertiary knowledge points and their respective prerequisite and post-requisite relationships and associations, add detailed attributes and information for each node, such as tags, categories, cognitive dimensions, etc. After completing the template, import it into the Superstar platform to generate the knowledge graph.

(4) Associate Knowledge Points: Associate course resources on the Superstar platform, such as online course video resources, question banks, assignments, etc., with knowledge points.

(5) Optimize and Expand: Continuously optimize and expand the knowledge graph based on teaching needs and student feedback. New nodes and relationships can be added to cover more knowledge points and algorithms; existing nodes and relationships can also be adjusted to better present the associations and hierarchical structure between knowledge.

(6) Integrate into Teaching: Integrate the constructed knowledge graph into the teaching of the "Data Structures and Algorithms" course. It can be used as supplementary teaching materials for students to learn and refer to in class or after class; it can also be used as a teaching demonstration tool to help teachers more intuitively display course content and explain difficult points.

3 Constructing a Knowledge Graph for the Course "Data Structures and Algorithms"

A knowledge graph is a semantic network represented by a graph data structure composed of entity nodes, entity attributes, and relationships between entities. It is a foundational technology for cognitive intelligence. The knowledge graph abstracts real-world entities as nodes and constructs a vast network structure through the relationships between these nodes. In a knowledge graph, nodes represent entities, which can be anything from the real world, such as people, objects, events, etc.; edges represent the relationships between entities.

In the "Data Structures and Algorithms" course, entities mainly include concepts, methods, algorithms, and so on; entity linking associates identified entities with entities in a knowledge base, such as linking learning videos, assignments, question banks, course materials, online resources, etc.; entity relationship extraction determines the relationships between entities, such as inheritance relationships, dependency relationships, containment relationships, etc.

This text outlines the process of organizing the knowledge points and their relationships in the "Data Structures and Algorithms" course[3], combining the syllabus and textbook content to construct a knowledge graph for the course (as shown in Figure 1). This knowledge graph aims to provide students with AI-based personalized learning path recommendations. Steps to Construct the Knowledge Graph as follow:

(1)Identify Entities

Concepts: Such as data structures, algorithms, time complexity, space complexity, etc.

Methods: Such as sorting algorithms, search algorithms, graph algorithms, etc.

Algorithms: Such as quicksort, binary search, Dijkstra's algorithm, etc.

(2)Entity Linking

Associate identified entities with entities in the knowledge base. For example, linking the "quicksort" algorithm to related teaching videos, assignments, question banks, course materials, online resources, etc.

(3)Entity Relationship Extraction

Determine the relationships between entities, such as:

Inheritance Relationships: For example, "sorting algorithms" inherit from "algorithms."

Dependency Relationships: For example, "binary search" depends on "sorted arrays."

Containment Relationships: For example, "data structures" contain "arrays," "linked lists," "trees," etc.

Constructing a knowledge graph for the "Data Structures and Algorithms" course helps students understand and master the course content better. It also enables the provision of AI-based personalized learning path recommendations. For instance, while studying a particular knowledge point, the system can recommend related learning materials and practice problems to help students learn more efficiently[4].

Fig. 1. Knowledge Graph for Linear table

4 Application of Knowledge Graphs in the "Data Structures and Algorithms" Course

By constructing a knowledge graph for the "Data Structures and Algorithms" course[5]and integrating it into the teaching process, several significant benefits can be realized.

4.1 Supporting Instruction

In the "Data Structures and Algorithms" course, the numerous and interconnected knowledge points can be challenging to clearly present using traditional teaching methods. A knowledge graph, however, can graphically and intuitively display these knowledge points and their relationships. Thus, a knowledge graph can serve as a supplementary teaching tool for the course.

Teachers can use the knowledge graph to show students the relationships between algorithms and data structures, as well as their applications to real-world problems, helping students better understand and master the knowledge points. For example, by constructing a knowledge graph that includes various data structures (such as arrays, linked lists, trees, graphs, etc.) and their basic operations (such as insertion, deletion, searching, etc.), the hierarchical structure and dependencies among them can be displayed.

4.2 Personalized Learning

The course adopts a blended learning approach, requiring students to engage in self-directed learning both before and after classes, as well as online. However, due to the multitude of interconnected knowledge points, students often struggle to find suitable learning paths during independent study. Knowledge graphs can recommend personalized learning pathways based on students' mastery of the subject matter[6]. For instance, when a student chooses to study sequential lists, the system will recommend learning paths and resources based on the student's mastery of prerequisite and related knowledge points thus aiding students in systematically mastering the relevant knowledge. Additionally, knowledge graphs can track students' learning progress and performance, providing feedback and suggestions to help students adjust their learning strategies in a timely manner.

4.3 Promoting Teacher-Student Interaction

Establishing an online course on the Chaoxing platform enables blended teaching, combining online and offline methods, and shifts the focus from teacher-centered to student-centered learning. Teachers can post teaching resources, assign learning tasks, and answer questions online before class. Students can use the platform for online learning, submitting assignments, and asking questions before and after class.

This mode of online and offline interaction allows teachers to manage teaching resources and monitor students' learning progress more conveniently while encouraging students to participate more actively in the teaching activities. Additionally, teachers can utilize the knowledge graph feature on the Chaoxing platform to conduct statistical analysis of students' learning conditions. This helps teachers better understand students' learning needs and problems, providing data support for improving teaching methods.

4.4 Deepening Course Understanding and Application

The course focuses on cultivating students' ability to innovate through practical application. This paper employs case-driven teaching to stimulate students' interest in learning and guide them in the in-depth analysis of case problems, clarifying the input, output, and constraints of the problems to determine the required data structures and algorithms. For example, when studying graph theory[7], a knowledge graph of graph-related application cases can be constructed. For the shortest path problem in path planning, teachers can build a knowledge graph encompassing various graph application scenarios, helping students understand the advantages and limitations of these algorithms in solving real-world problems. This approach enables students to gain a deeper understanding of the importance of data structures and algorithms and to apply the knowledge learned more flexibly in practical situations.

5 Application Effects

Compared to traditional teaching methods, after implementing reforms based on knowledge graphs in the data structures and algorithms course, significant improvements have been achieved in the following aspects:

Implementation of the data structures and algorithms course reform based on knowledge graphs has led to noticeable advancements in student learning outcomes. During the teaching process of the data structures and algorithms course, the utilization of knowledge graphs not only showcased the knowledge structure within the field of web programming but also presented the key points and challenging aspects of the course in a more intuitive and comprehensive manner. This aided students in clearly understanding the interrelationships among different pieces of knowledge, enabling them to focus on key and challenging content and attain a more comprehensive understanding of the subject matter in a systematic and scientific manner.

The adoption of teaching methods based on knowledge graphs has enhanced both student learning efficiency and teaching effectiveness. This approach eliminated the isolation and lack of logical continuity in teaching content. Instead, it facilitated the seamless connection and collaboration of knowledge points across chapters, assisting students in establishing a cohesive knowledge framework[8]. This, in turn, enabled students to better apply the acquired knowledge, fostering their creativity and enthusiasm for learning.

Teaching practices have indicated that students' programming skills and algorithmic thinking have been expanded and enhanced. During practical training, the use of

knowledge graphs significantly reduced the time required for problem retrieval. Moreover, students were able to synthesize solutions from multiple knowledge points, approaching problems from various perspectives. This improvement in practical abilities was achieved while consolidating and advancing theoretical knowledge.

Therefore, it is evident that the adoption of teaching methods based on knowledge graphs has yielded the anticipated application effects in teaching practice, not only promoting optimization in classroom teaching but also significantly enhancing learning outcomes.

6 Conclusion

In the process of reforming the teaching of data structures and algorithms in the Internet of Things engineering major, a set of integrated dual-skilled training programs, namely "Training-Certification-Competition," has been established in the talent cultivation model. In terms of application capability cultivation, "multi-time period" training measures are mainly adopted during the teaching process, along with encouraging students to obtain certifications based on the characteristics of the profession to enhance their application capabilities. In terms of innovation capability cultivation, participation in academic competitions is emphasized to stimulate students' innovation consciousness and improve their innovation and practical application abilities, aiming to cultivate software talents with application innovation capabilities for society[9].

Since 2021, students have accumulated more than 40 provincial-level awards in the National Software and Information Technology Professionals Competition closely related to the curriculum. Students have undertaken 74 innovative training projects, including 8 national-level projects, 14 provincial-level (key) projects, and 52 university-level projects. The project approval rate has reached a record high year by year, ranking first in the university. Students have published 21 related scientific papers, applied for 18 patents, and applied for 6 software copyrights. The pass rate of students participating in the National Computer Level 2 Examination has reached 60%.

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