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GRAPH USER INTERFACES FOR ENHANCING EXPLORATORY LEARNING: AN OVERVIEW

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Abstract. *Exploratory learning is a key methodology in education. This text highlights the role of Graph User Interfaces (Graph UI) in enhancing exploratory learning by providing interactive, graph-structured data representations. Tracing from Euler's work to modern applications, graph structures simplify complex data, aiding cognitive engagement and navigational abilities. Studies show that Graph UI can optimize educational processes, enhancing knowledge acquisition and innovative application through an intuitive, visually structured learning environment. The promising future of exploratory learning through Graph UI invites more research and development to unlock its potential for insightful and accessible learning experiences.*

Key words: *exploratory learning, graphs, graph user interfaces*

Introduction

Exploratory learning, driven by our natural curiosity, grows in a changing world. As said in [1], exploratory learning often leads to unexpected discoveries. In today's digital world, Graph User Interfaces (Graph UI) have become a key tool, linking interactive, graph-like data presentations with self-driven learning. By changing complex data into visual, easy-to-follow structures, Graph UI boosts exploratory learning, creating a space where learners can easily dive into connected information. This article starts from the basics of Graph UI to its big impact on how we learn, highlighting the promise and the urgent need to dig deeper to unlock its full potential for a strong, insightful learning experience.

Exploratory learning

Exploratory learning is an essential approach for humans for learning new concepts. In terms of human-computer interaction, exploratory learning is a common approach for learning the systems as it is natural for human beings to explore something and try to understand concepts usually on their own [2]. Sometimes the learning can be supervised, but usually that is an autonomous process. That is often regarded to be the most popular approach to systems learning as well.

Exploratory learning is very effective with the visual representation of information [3]. In data analysis, exploratory data analysis would be an important phase of the conducted research, as it allows us to start to build hypotheses and get familiar with the data specifics [4]. As a rule, this step of the analysis is heavily backed by the means of the visual representation of the data. That fact highlights the importance of visuals for human learning.

Graphs and information visualization

The information can be structured or unstructured. When we think about learning a subject, we would want to refer to the structured information which can be visually represented. Often this structured information can be represented with graphs. Graphs are the graphical data that consists of nodes and relation between them. The examples of graphs are trees (Figure 1), organizational charts, data flow and entity relationship diagrams [5]. They provide support for the learning, as well as can be used as a tool for knowledge systematization.

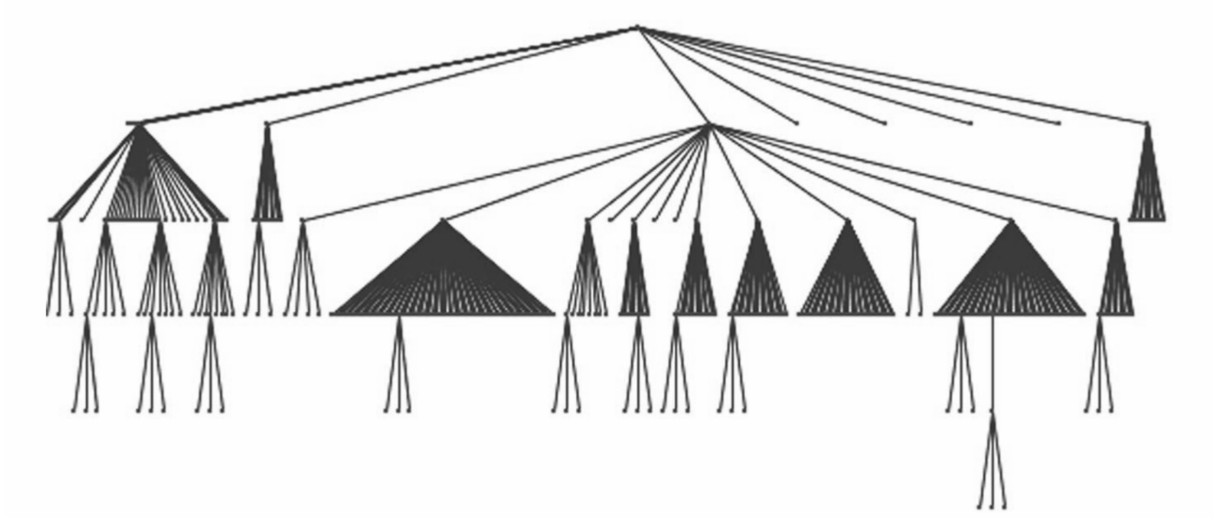

Figure 1 - A tree layout for a moderately large graph

A source: [5]

The fundamental challenge of graph drawing involves determining node positions and edge curves given a set of nodes and their relations (or edges). This issue has persistently existed because graph definitions often rely on their drawings, as demonstrated by Euler's 1736 resolution of the “Königsberg Bridge Problem” using a visual representation [5]. The problem revolved around the city of Königsberg in Prussia, where seven bridges connected various land masses [6]. The challenge was to devise a walk through the city that would cross each bridge once and only once. Euler proved that such a walk was impossible, introducing the concept of an Eulerian path in the process. His innovative approach, which involved representing the land masses as nodes and the bridges as edges between them, created a new, abstracted way of thinking about the problem and marked the genesis of graph theory [7]. In fact, the solution to the problem did not rely on bridges, islands, or people, as well as the whole geography of the city didn’t influence the solutions, making the only thing that was important the connection itself [8].

Numerous papers, compiled by Battista et al., explore the complexities of defining a proper graph drawing, necessitating the establishment of properties and classification of layouts suitable for various graph types [9]. For example, they discuss various graph-drawing algorithms, each with different computational complexities and applicabilities to different types of graphs, managing large-scale graphs and adhering to specific aesthetic criteria, various heuristics and optimizations investigations. They also argue that sometimes, determining what constitutes a "good" drawing might involve user studies to understand which layouts are more intuitive or readable for humans.

Using Euler's ideas, mathematicians have looked at many ways to show connections between points, or nodes, with links, called relationships. Some allow the links to have a start and end point, while others just connect points without direction.

Some types, like hypergraphs, let links join several points at once. However, there's no single good solution for all the cases of how the structured information can be represented in graphs, so different models have to be used [8]. The graphs have been extensively applied in various domains, including computer science, bioinformatics, and social network analysis, as well as in education. The practical application of graphs is also presented by concept maps, which are visual instruments used to arrange and display relationships between ideas, symbolized by a line joining two concepts. Words placed on a line act as connection phrases, specifying the relationship between the linked concepts [10]. The concept maps arose from a prevailing necessity in educational psychology to develop a concept of meaningful learning which was first described by Ausubel [11]. This underscores the significance of organizing and associating new information with pre-existing knowledge during the learning process [12].

Another similar visual tool that can be used in learning is a mind map, which centers around a key concept and typically spreads out like a tree from that central idea. While it usually shows a clear hierarchy, it can also weave in additional links among various elements to capture more complex relationships. Its radial layout has made it a go-to format for showcasing how information is structured [12].

Graph User Interfaces and Learning Systems

The rise of accessible digital devices empowers users to interact with data in new ways, enabling a many user interfaces (UI) to facilitate unique experiences. A distinctive approach to this endeavor is represented by Graph User Interfaces (Graph UI), where information is modeled and interacted with through graph-structured representations. As was discussed earlier, graph UI embodies a visualization method where data points (nodes) and their interrelationships (edges) are visibly represented, offering users an interface to navigate, manipulate, and explore interconnected information, thus facilitating exploratory learning.

There are experiments providing evidence that information presented with the graphs can enhance cognitive engagements. Puntambekar et al. examined the navigation patterns of students and discovered that the maps assisted students in maintaining focus on their objectives, compared to a version of the system that used an index [13]. Feedback from students via an attitude survey revealed that they perceived the maps as beneficial for locating information pertinent to their objectives. The concept maps acted as a visual aid, facilitating students in making logical transitions between concepts. The map's connections and the fisheye visualization of concepts pointed towards additional information relevant to their ongoing reading, and students appeared to exhibit a positive attitude towards these elements.

There have been approaches to constitute a system that could build graphs specifically for educational purposes. It brings its own unique challenges which have to be solved and connected with ontological modeling. Chen et. al. [14]. discesses such systems as well as describe practical approaches for it. Their system, developed in response to the growing demands in the educational sector, automatically constructs educational knowledge graphs utilizing heterogeneous data like pedagogical and learning assessment data. Through neural sequence labeling algorithms, it extracts educational concepts from pedagogical data and employs probabilistic association rule mining on assessment data to ascertain crucial educational relations between concepts.

Another approach is discussed in [15] where it has been highlighted the significance and methodology of employing graphical visualizations, specifically concept maps, in the context of ontologically oriented information and educational web systems. In an effort to enhance the educational process and knowledge acquisition, the article underscores the need to integrate visualizations like interactive concept maps, which depict the structure of concepts and their interconnections into educational web environments. These maps, based on didactic ontology and a concept-thesis model, not only aim to improve navigation and facilitate a better understanding of subject areas but also to boost user engagement and learning effectiveness by presenting data in a visually intuitive manner [15].

The main goal is to develop a method for the automated construction of interactive concept maps within web systems and to enhance the functionality of the information and educational web environment, so a Graph UI will be created at the end [15]. The approach involves formalizing content based on the concept-thesis model, analyzing types of conceptual maps, and adapting models and algorithms according to identified needs and shortcomings. The system encapsulates server modules and client components for generating graph data and interfacing components, utilizing the Vis.js library for graph visualization, while also allowing for user interaction and convenient data display [15].

While the method presented promises clarity and interactivity in presenting educational content, ongoing research and development in the system seek to further optimize algorithms and minimize server and client load when building and utilizing interactive concept maps [15]. The automated creation of these knowledge graphs might enhance online education platforms by providing personalized teaching and adaptive learning solutions.

Summary and conclusions

Exploratory learning greatly benefits from Graph UI advancements, which turn complex data into visual, interactive models, fueling curiosity and innovative problem-solving. Many researchers have explored and explained the benefits that graphs can provide. These aren't merely visual tools but catalysts for cognitive engagement, creating an intuitive and efficient learning environment.

Automating educational knowledge graph creation may significantly boost learning engagement and innovative application of information. While its integration with educational tech continues evolving, future innovations are poised to further enrich interactive learning, with a multidisciplinary approach ensuring it meets both tech and pedagogical demands.

The discussed case studies underline the transformative potential of Graph UI on educational technologies, particularly in automating the creation of educational knowledge graphs, thereby enhancing exploratory learning. This shift not only reshapes how information is absorbed and engaged with but also how it's innovatively applied. The process of refining Graph UI and aligning it with exploratory learning is ongoing. The automated creation of these knowledge graphs could potentially improve the process of learning in digital environments.

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