DS-Hacker: Teaching Data Structures and Algorithms Through Analogical Representations in the Game Environment and Game Challenges

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EXTENDED ABSTRACT

Data structures and algorithms are a fundamental area of study in Computer Science, and they are extensively employed in the software industry. Data structures and algorithms are important because their correct application considerably improves the efficiency of computational systems (Sedgewick and Wayne 2014). However, for beginning students, developing a deep understanding of advanced data structures and their algorithms is a difficult task because they are abstract and difficult to relate to familiar knowledge (Becker and Beacham 2000).

According to the meaningful learning theory, learning and understanding a new topic, such as data structures and algorithms, requires the creation of connections to previously acquired knowledge (Aubusson, Harrison, and Ritchie 2006). From a constructivist stance, learning is a "re-learning" process (Kolb 2014), and to create new knowledge, it is necessary to use our previous experiences, beliefs, and knowledge. An approach to linking new information and familiar knowledge is using analogies. Analogies are comparisons of structures between two domains; those structures must share symmetrical relations among their components (Duit 1991). In educational environments, analogies are utilized extensively to create relations between non-intuitive concepts and familiar concepts. In view of this theoretical background, serious games can serve as an educational tool to introduce data structures and algorithms (Dicheva and Hodge 2018). Serious game games can borrow game elements from popular game genres to teach new knowledge and build analogies to facilitate the understanding of complex and abstract topics.

This research proposes to use serious games and analogies to facilitate the creation of connections between familiar knowledge and new information. Specifically, the project aims to use the game environment as a symmetrical model of the Binary Search Tree (BST) data structure and the game challenges as a representation of the BST algorithms. Furthermore, our research emphasizes the relationship between the game elements

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(environment and challenges) and the BST structure and its algorithms through analogies delivered by the game story. We anticipate that this approach will facilitate linking the abstract topics of the BST data structure with familiar knowledge of the game elements. Additionally, the player will be able to visualize the data structure arrangement and practice the concepts reinforcing the new acquired information.

To prove our concept, we created a serious game called *DS-Hacker* (Data Structure Hacker), a 3D action-adventure PC game developed in Unity. *DS-Hacker* possesses sci-fi aesthetics and intends to introduce factual and conceptual knowledge about BST data structure to college students. The topics covered by the game are BST's basic elements, the BST property, and its algorithms (e.g., the get algorithm and the in-order tree traversal algorithm). In the game, the player takes the role of a robotic hacker who must extract information from a corrupt corporation. To achieve this objective, the player should pay attention to the game story that contains the BST concepts and the analogies between data structure and the game elements. Then, the player should complete the game challenges. During the challenges, the player should traverse the game environment (a maze) that consists of elements that represent the basic elements of a BST and are organized as the data structure. For instance, each level has a maze that is composed of linked chambers, and each chamber possesses a comparable key, some stored data, and links to a maximum of two other chambers. Additionally, the chambers are organized following the BST property. While traversing the maze, the player can visualize the structure of the BST and its components. Additionally, the challenges consist of tasks or puzzles that the player should solve using BST concepts and algorithms. For instance, in the first levels, the player must find the basic components of the BST represented by the game elements. In the final levels, the player must apply the get algorithm using the comparable keys of each chamber in order to find the information stored in a specific chamber. The following link contains a video of the gameplay of *DS-Hacker*: https://www.dropbox.com/s/8vavy0e7b9uywx6/DS-Hacker_Level1%26Level2.mp4?dl=1. Figure 1 shows a screenshot of the game.

Figure 1: Screenshot of the first level of *DS-Hacker*.

DS-Hacker is currently at a stage of evaluation involving a trial with participants in order to measure the game's effect on the participants' learning gains and intrinsic motivation. The study will follow a pre-test post-test design with an experimental group and control group, and we will use a calibrated test to measure the BST knowledge and the Intrinsic Motivation Inventory (Ryan 1982) to measure the player motivation. Our sample will consist of undergraduate students, and we will use ANCOVA to analyze the collected data. We expect the results to provide insights to support the game's approach or the subsequent examination and correction of the game's areas that contain

flaws. Additionally, the results obtained will support the development of guidelines that could be used to implement further serious games based on analogies.

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