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Visualize and Learn Sorting Algorithms in Data Structure Subject in a **Game-based Learning**

Wee Han Lim¹

Singapore University of Social Sciences, Singapore Yiyu Cai²

Nanyang Technological University, Singapore

Dezhong Yao³

Huazhong University of Science and Technology, China Qi Cao^{4*}

University of Glasgow, United Kingdom

Learning of sorting algorithms is an essential topic in the Data Structure course for Computing Science students in universities [1]. Novice students usually find it challenging to understand the topics and relevant algorithms. This could be attributed to the values of elements in data structures which are dynamically modified through the sequences of program flow [2]. There are various types of sorting algorithms, each of which has own unique features. To use the more suitable sorting algorithm to solve a specific problem, students need to understand the concept of various sorting algorithms to be able to make the right choice based on complexity of the algorithm to be employed. Concepts in programming are abstract not easy to understand because it is not easy to correctly imagine the steps in their mind. It is a challenge for some of students to understand the working steps and process the sequences [3]. There is often confusion between the various sorting algorithms when students initially touch base with the Data Structure subject.

As technologies advance, learning animations and videos are made readily available to illustrate the working steps and sequences. Visual aids such as animations could help to bridge the gap between abstract concepts and actual situation by helping the students to visualise and help them understand, which improves the learning process [4][5]. A portal of interactive animations and visualizations is introduced with card sorting animations for five animations of sorting algorithms, such as simple exchange sort, bubble sort, etc. [6]. But at times, they may not be engaging enough, as it lacks interactivity with students when they are watching such learning aids. An approach of "Direct, Purposeful Experiences" which is an effective method of learning could be referenced to a study method of learning could be referenced to a study [7], that couches the method of learning through constructivism, where students create visualisation storyboards to refine and present their ideas of the sorting algorithms they have learnt. Positive feedback is received from the leaners.

Through learning pedagogies such as Active Learning, students take part in the learning process rather than the conventional methods of learning of unidirectional lessons delivered by lecturers. Research has shown that students are able to learn more from active learnings as compared to the conventional learnings [8]. Game-based learning can increase learners' engagement and can increase learners' engagement and participations in prior studies [9-11]. Literature

ABSTRACT

The Data Structure subject is an essential Computer Science subject. Sorting algorithms are important topics in Data Structure where students are expected to learn how various sorting algorithms work and their time complexities. Some sorting algorithms may easily cause confusions to novice students, as they usually find it challenging to understand and memorize these algorithms. There is a need to find a means of technology enhanced learning to improve the learning process of students. Game based learning is a pedagogy where students learn through game playing. This mode of learning could effectively engage students to focus on the learning topics more efficiently. The study uses a sorting algorithm serious game to allow students to learn four types of sorting algorithms: Bubble sort, Selection sort, Insertion sort and Quick sort. The students would carry out self-directed learning lecture materials in the serious game, followed by refreshing their learning using a visualizer, and lastly reinforce their learning through playing a sorting serious game. Two groups of students participate in the experiment, a control group and an experiment group. The experiment group that sues the sorting algorithm games achieves better results, compared to the control group who learns without the serious game. Gamebased learning provides a positive learning experience to the students that could improve the learning effectiveness. Coupled with technology such as VR headsets as a future upgrade, it would be a niche factor that would create an immersive learning experience to engage the students and enhance their learning in a virtual environment.

Keywords: Game-based learning, data structure, sorting algorithms, learning efficiency, serious game.

1 INTRODUCTION

Sorting Algorithm is a software process that arranges elements of a list in a specific order.

¹e-mail: whlim014@suss.edu.sg

²e-mail: myycai@ntu.edu.sg

³e-mail: dyao@hust.edu.cn

^{4*}e-mail: qi.cao@glasgow.ac.uk

review has revealed that the level of engagement affects learning and motivation. There are observations that learning games can engage students to learn better [12][13]. For cognitive engagement, knowledge acquisition is the first step followed by practicing and processing which would lead to skills acquisition through the application of knowledge.

The use of learning games as education activities to augment the teaching of topics on algorithms and Data Structure course has been found to be effective in improving the understanding of the learners [14]. The educational games are reported for teaching the sorting algorithms: quicksort and heapsort with 23 applications of the games in the Data Structures course [1]. An online game for simulation of the execution steps is presented to teach the Heapsort sorting algorithm in the data structure course [15]. A learning game, Sort Attack, simulates the execution processes of three types of sorting algorithms: insertion sort, selection sort, and bubble sort [16]. Virtual reality (VR) technology is able to provide immersive learning experiences with interactions and engagement with players [17]. It has good potential to help students provide further learning experience in acquiring the knowledge of sorting algorithms. One implementation of using VR for sorting algorithm is introduced [18], where a learning game for the bubble sort algorithm using VR technology is created. The game uses numbered balls as target objects for the players to choose and perform the sorting. To ensure that the learning objective of the game is met, only the correct balls could be selected, such that the players would never go wrong in the sorting sequence. In this paper, the game-based learning method is proposed to teach and compare four types of sorting algorithms: Bubble sort, Selection sort, Insertion sort and Quick sort. It aims to provide a better learning approach to the students of Data Structure course. The learning game is designed to provide multiple ways of interactions for the learners on different computing platforms, including computers, mobile phones, and tables.

The paper organization is as follow. After the introduction in Section 1, Section 2 presents the designed learning game and the game design flow. Section 3 introduces the experiment results and analysis. Section 4 concludes the paper.

2 METHODOLOGY

To develop the game-based learning for the sorting algorithms, Unity3D tool is chosen as the main development platform, to create the virtual game scenes. Unity3D is a popular content creation platform for developers which offers tutorials and tools for game creation on a wide range of devices, such as Laptops, Xbox, Play Station, head mounted devices (HMD), and Mobile devices for both Android and Apple iOS operating systems. Unity uses C Sharp (C#) for source code programming. They are an essential part to determine how the programme reacts or objects are defined within the game scenes. In this project, another software tool, Microsoft Visual Studio is used to develop the source codes for the learning game.



Figure 1: Design flow for the learning game of sorting algorithms.

To ensure that there is a logical sequence for the learning game, a design flow chart on how the learning game would behave based on the user inputs need to be drafted. A game flow design is created to allow correct mapping of the game sequence so that the game would respond correctly. Having this design flow chart would allow the programmer to plan how the game would sequence and how the scenes of the game to link together. Figure 1 shows the flow chart of the learning game for sorting algorithms.

There are two modes in the learning game: tutorial mode and game mode. The theory knowledge and animation demonstrations of the four sorting algorithms are presented in the tutorial mode for the players' self-learning at their own time and own pace. Players can then practice their knowledge in the game mode, for each sorting algorithm according to the selection of the players. There are the tutorial room scenes for the tutorial mode, and game room scenes for the game mode, that the player can walk around in different scenes in the learning game of sorting algorithms.

2.1 Game Control

There is an avatar robot controlled by the player to explore round in the learning game. The Robot Sphere that is downloaded from Unity Asset Store, to animate the movements of players using the keyboard inputs. To ensure that the avatar has a moving animation when the player moves the controls, the script is developed to include additional inputs so that the avatar would have the required walking animation.

The control of the robot avatar is via the mobile joystick on the display screen for touchscreen inputs. In this learning game, a mobile controller is created where there are two joysticks, the left joystick is for avatar movement control, while the right joystick is for camera angle control as shown in Fig. 2. Their scripts in Unity have also been customised to suit the gameplay for this learning game of sorting algorithms.



Figure 2: Robot avatar with joystick control.

One important function is how the player moves based on the user inputs with the joysticks. The first-person controller is developed. Its script is embedded to the camera to adjust the view to simulate the avatar movements based on the inputs of the player. With it, the touchscreen controls are enabled, and the command inputs can be registered, and resultant changes being applied to the camera.

There is a need to transfer the avatar between different locations within the learning game when the avatar moves to certain spots in the game scene. Two scripts are created to enable this function to transit within the locations or transfer to another game scene for a different game function. A C# script is written to enable the avatar to "teleport" to another location in the map within the same scene or the different scenes, like moving from the main entry room in the game, which the gameplay starts to the tutorial room or the games room.

2.2 Tutorial Mode

There are four sorting algorithms in this learning game. In the tutorial mode, a set of teaching slide show with explanations to present the theory how these four sorting algorithms work is added into the learning game. Control functions are added for the touch screen detection inputs or keyboard arrow keys. It enables players to navigate the slide show for self-learning of theories with the teaching notes using touchscreen or keyboard keys.

After the self-learning on the slide show, visualisation animations are created to explain the sorting process using bar movements which could help the students to visualise how the sorting process works according to different sorting algorithms. These visualisation animations are incorporated as a part of the learning materials to help the students understand better on top of the slide show. An example of visualiser animation for bubble sort algorithm is shown in Fig. 3.

The visualiser animation of each sorting algorithm is programmed using two C# scripts, one for the menu to allow the player to start, reset or go back to the main game scene. While the other script is to initialize and start the visualiser animation once the start button on the main menu is activated.



Figure 3: A visualiser animation for Bubble sort.

2.3 Game Mode

In each game scene of the game mode, there is a group of robots with different numbers associated with them. The tasks for players are to sort these robots correctly according to the process of each sort algorithm. The sorting of the robots is done by selecting two robots to sort, followed by clicking on the "Swap" button. When the robots are selected, they will animate and curl up to become a ball to differentiate with the other unselected robots. The learning game will require the robots to be sorted in sequence based on the algorithm logic. The game point system is implemented in the game. Once completed, a display would show how well the player performs. An example game scene in the Selection sort algorithm is shown in Fig. 4.



Figure 4: An example scene in the game mode.

3 EVALUATIONS

There is a need to evaluate and measure the effectiveness of the learning game of sorting algorithms. Therefore, a set of quiz questions is created. 10 university students are invited to the experiments, who are divided into two groups equally. These participants are 18 years of age or older, with the same level of tertiary education background. The first group of students conduct their self-directed learning on the sorting algorithms using textbooks and teaching notes. While the second group use the game-based learning for the sorting algorithm game as the learning approach. After completion of their learning, all of the students attempt a test consisting

of eight questions, to test their understanding of the sorting algorithm knowledge. The results and time being spent are recorded for each student.

The results from the experiment are analysed with positive responses from the students who participate using the game-based learning. It is observed from Fig. 5, students with game-based learning manage to compete the test in a shorter average time, compared to those who do their own self-directed learning. Students with game-based learning also manage to achieve a better average score, as shown in Fig. 6. This proves that the learning game of the sorting algorithms is effective in making students learn the sorting algorithms better.



Figure 5: Average time to complete quiz.



Figure 6: Average scores for the test.

A survey is carried out to solicitate feedbacks from the five participants who played the learning game of the sorting algorithms to gather their responses. The survey responses are rated using a five-point Likert scale with (1) Strongly Disagree, (2) Disagree, (3) Neutral, (4) Agree, (5) Strongly Agree.

The feedback gathered from the participants receives positive responses. They agree that the game-based learning is fun and improves their understanding of the sorting algorithms. The learning game provides them a means to test their understanding to reinforce what they have learnt. This is an indication that the game makes learning of sorting algorithms more engaging and efficiently motivate the players. But there is common feedback from participants is that the learning game has slow response. It could be attributed to the WebGL hosting, as the developed learning game is hosted on a web portal. The reason is that some participants are not comfortable to install the learning game into their own computers or mobile platforms in the experiments. The WebGL hosting enables the learning game to be assessable by all participants as long as there is an internet connection and browser access.

4 CONCLUSION

The learning of sorting algorithms in the Data Structure course is not easy, due to the lack of process visualization. In this paper, a learning game is developed for four types of sorting algorithms: Bubble sort, Selection sort, Insertion sort and Quick sort. Players can learn the theory in the tutorial mode and practice in the game mode. A robot avatar is used in the gameplay, with a group of robots being employed to examine the knowledge of the players how to perform the sorting of robots according to the sorting logic of each algorithm. A group of 10 university students are invited to the experiments to evaluate the game-based learning effectiveness. Positive outcomes are obtained in the experiments of the developed learning game. The methodology of using game-based learning on various topics is an alternative mode of teaching that is effective to enhance the learning of the students especially with the newer tech savvy generation of learners.

The learning game of sorting algorithms could be converted to become a part of gamification of group learning for the Data Structure course, where player registration and scores tally could be done when players complete all four sorting games. The scores could then be displayed on a leaderboard to induce students to challenge one another to perform better.

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