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Development of AR Content for Algorithm Learning

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Abstract

Coding education and algorithm education are essential in the era of the fourth industrial revolution. Text-oriented algorithm textbooks are perceived as difficult by students who are new to coding and algorithms. There is a need to develop educational content so that students can easily understand the principles of complex algorithms. This paper has implemented basic sorting algorithms as augmented reality contents for students who are new to algorithm education. To make it easier to understand the concept and principles of sorting algorithms, sorting data was expressed as a 3D box and the comparison of values according to the algorithms and the movement of values were produced as augmented reality contents in the form of 3D animations. In order to help with the understanding of sorting algorithms in C language, the change of variable values and the exchange of data were shown as animations according to the execution order of the code and the flow of the loop. Students can conveniently use contents through a smart phone without special equipment by being produced in a marker-based manner. Interest and immersion, as well as understanding of classes of sorting algorithms can be increased through educational augmented reality-based educational contents.

Keywords*: AR (Augmented Reality), Educational Content, Algorithm Learning, 3D animation*

1. Introduction

Software education is being reinforced from elementary schools to high schools in order to nurture outstanding SW talents who will lead future societies. Universities are also gradually expanding coding education for non-major classes as well as major classes. Elementary schools are focusing on problem solving, algorithm experience, and programming experience with the goal of cultivating basic SW knowledge. Middle schools and high schools are teaching algorithms and simple program development. Because algorithms are the core of software education, it is a topic that must be dealt with in software education. However, text-based algorithm education is perceived as difficult by students who are new to software education.

There is a need to teach the complex principles of algorithms by visualizing them, and there are studies that

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show that learning effects may be increased by doing so [1]. Existing studies have generally visualized algorithms into 2D animation form.

This paper intends to develop contents supporting augmented reality-based algorithm education by going one step further from simple visualization and two-dimensional animation of algorithms. Augmented reality, unlike virtual reality, provides virtual information in the real world, and thus, further increases a sense of realism and presence. Augmented reality is being used in various fields, such as medicine, architecture, advertising, games, manufacturing, and digital contents, and is also widely used as educational contents [2-4]. In view of the characteristics of augmented reality as educational content, it can generate interest in the learner because it adds and shows three-dimensionalized information in the real world. This has the advantage of increasing the understanding of learners and allowing them to further immerse in the content [5]. In the case of experiments that are dangerous or difficult due to a lack of environments in which the experiments may be conducted, the understanding of the students may be helped with a greater sense of reality. Also, text-based education, such as algorithm education, provides interest and immersion in areas that are difficult for students to grasp, thereby enhancing students' understanding.

This paper produced augmented reality contents to assist in helping the students who are new to coding and algorithms to understand basic sorting algorithms. The learning contents were largely composed of 4 parts. First, the concept and principle of each sorting algorithm are produced as contents using text and graphics. Second, the code that implements each sorting algorithm in C language is presented and the operation of the codes is explained. Third, a change in the variable values is displayed as an animation according to the execution order of the code and the flow of the loop for students who find it difficult to understand the detailed operation of codes in C language. Fourth, the data to be sorted is expressed in the form of a three-dimensional box, and the animation in which a comparison and place exchange are performed according to each sorting method is expressed in augmented reality to increase the interest, immersion, and understanding of students.

The composition of this paper is as follows. In Chapter 2, a study on augmented reality-based educational contents is detailed. In Chapter 3, contents for augmented reality-based algorithm education are produced, in Chapter 4, the implementation results are displayed, and in Chapter 5, the conclusion is given.

2. Related studies

In relation to this paper, algorithm visualization studies and augmented reality-based educational contents were researched. In the paper, "Pedagogical effectiveness of algorithm visualizations in teaching the data structures and algorithms in elementary schools," the algorithm was produced as an animation-type PowerPoint presentation and the teaching effects were evaluated [1]. The evaluation cores of the students were 22.2% higher in animation-based lectures compared to text-based PowerPoint presentation.

The paper, "A Case Study of Developing the Educational Contents Using Augmented Reality," analyzed educational content development cases using augmented reality and proposed the means of applying augmented reality in digital textbooks [5]. The paper analyzed the cases in which earth and topography in geography, water travel in science, the solar system, atoms and molecules, three-dimensional figures and equations in mathematics, and picture books in Korean language were implemented in augmented reality. As a result of the analysis, it was proposed that augmented reality should be actively applied to experiencing learning, such as science, and the compatibility of display technologies in various environments, such as smart phones and PC, should be enabled.

The paper, "Development of Augmented Reality Based Electronic Circuit Education System," used augmented reality in electronic circuit education [6]. The function of sending a message to an augmented reality app is provided when the circuit in an electronic circuit education has been incorrectly configured, to

enabled easy circuit debugging. The disadvantages of existing electronic circuit education methods were supplemented by developing an augmented reality-based educational content.

The paper "Effect of Augmented Reality Contents Based Instruction on Academic Achievement, Interest and Flow of Learning" analyzed the effect of augmented reality-based classes on academic achievement, learning interest, and immersion [7]. The result of the of the study demonstrated that augmented reality classes were more effective than textbook-centered classes in terms of academic achievement, and augmented reality classes increased interest in the class itself and higher levels of immersion.

"Study on the Effect of Augmented Reality Contents-Based Instruction for Adult Learners on Academic Achievement, Interest and Flow" measured the effect of education using augmented reality contents for adult learners completing professional IT education courses [8]. The result displayed a higher level of learning interest and immersion than existing textbooks. Augmented reality is also used as a means of increasing educational effects on the intellectually disabled [9].

3. Augmented Reality Content Design for Sorting Algorithm Training

By analyzing the related studies, it can be ascertained that interest, immersion and understanding in classes increased when classes were taught using augmented reality contents compared to the existing method of text and image-based two-dimensional textbooks. Augmented reality contents were devised to help students who are new to coding and algorithms to understand sorting algorithms, a topic that is found to be particularly difficult. Most textbooks and teaching plans for existing sorting algorithms were text-oriented and focused on explaining program codes. This paper intends to increase understanding by producing changes in the variables and execution sequence of codes, which are difficult to understand based only on existing textbooks, in the form of animation. Furthermore, augmented reality contents in the form of 3D animation are produced to assist with the understanding of sorting algorithm. The numbers to be sorted are visualized and expressed in the form of a three-dimensional box, and the sorting process is expressed as augmented reality animation according to each sorting algorithm to increase the students' understanding, interest and immersion. The system was devised to display augmented reality contents when the students project a marker using a PC camera or a smartphone during classes without the use of separate augmented reality equipment. Figure 1 displays the entire structure of augmented reality contents for sorting algorithm education.

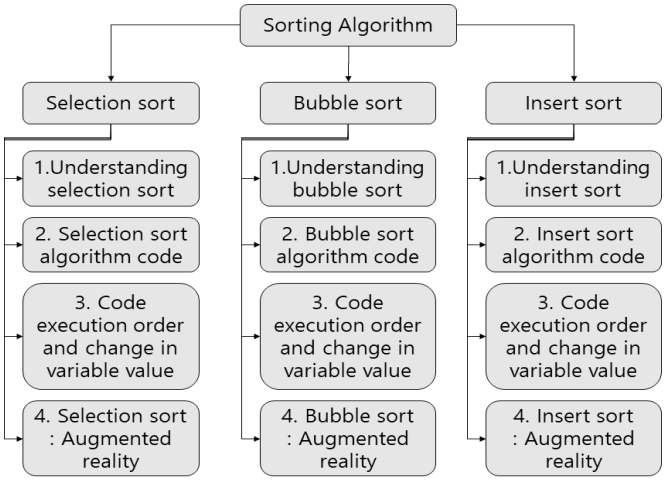

Figure 1. Augmented Reality-based Sorting Algorithm Educational Content Structure

Augmented reality contents were designed to educate students on selection sorting, bubble sorting, and insertion sorting. Each sorting algorithm unit is formed of 4 parts. The first part was designed to teach the concept and principle of each sorting algorithm. In the second part, the students learn about codes implementing each sorting algorithm in C language. In the third part, changes in the execution sequence and variables of codes are presented in each step to help the students who find it difficult to understand codes in C language. The fourth part displays the operation of the sorting algorithm implemented in three-dimensional augmented reality using a smartphone. Through which, it was intended to increase the understanding, interest and immersion of sorting algorithms.

Next, the content covered in each learning step and the media type to compose the content are defined in Table 1. First, text and two-dimensional graphics are used to explain the concept and operational process of each sorting algorithm. Second, algorithm codes are expressed in C language and explained in code. Third, changes in the variables according to the execution sequence of C language codes are displayed in the form of two-dimensional animation to help students who find it difficult to understand sorting algorithm codes. Fourth, contents are created to allow the students to view the operation of sorting algorithm on a smartphone using augmented reality. The data to be sorted is created as a box in the form of a 3D graphics, and the comparison and place movement of the values according to the algorithm at each step is produced and displayed in the form of 3D augmented reality animation.

Table 1. Designing Contents and Media Elements to be Covered in the Learning Step

Learning stage	Contents	Media type
Understanding Sorting Algorithm	The concept, sorting method, and process of each sorting algorithm are introduced to be easily understood using text and 2D graphics.	Text, 2D graphics
Algorithm code	Each sorting algorithm is displayed in C language codes and the operation of codes is explained.	Text
Code execution order and change in variable value	The changes in variables at each sorting step is displayed in the form of 2D animation in C language code to help the students clearly understand the details of sorting algorithm.	Text, 2D graphics, 2D animation
Augmented reality contents	The data to be sorted is expressed in the form of a 3D box, and data in the form of a 3D box is moved at each step according to each sorting algorithm. A comparison and movement of data expressed in the form of a 3D box are implemented as animation and a smartphone is used to implement it in 3D augmented reality.	Text, 3D graphics, 3D animation, Augmented reality

Figure 2 displays the process of producing augmented reality contents. First, an object for augmented reality content production is modelled in 3D. The data to be sorted is modelled in the form of a box. Text is used to display the value on the box as a number, and the minimum value and scope of comparison of values are also displayed. Second, the material is applied. Third, the process of exchanging the place of data to be sorted according to each sorting algorithm is produced as an animation. Fourth, augmented reality content is generated. A two-dimensional marker provided in an augmented reality production program is prepared. The augmented reality app is opened to project a smartphone on the prepared marker, which produces a three-dimensional

sorting algorithm animation to be displayed as augmented reality content.

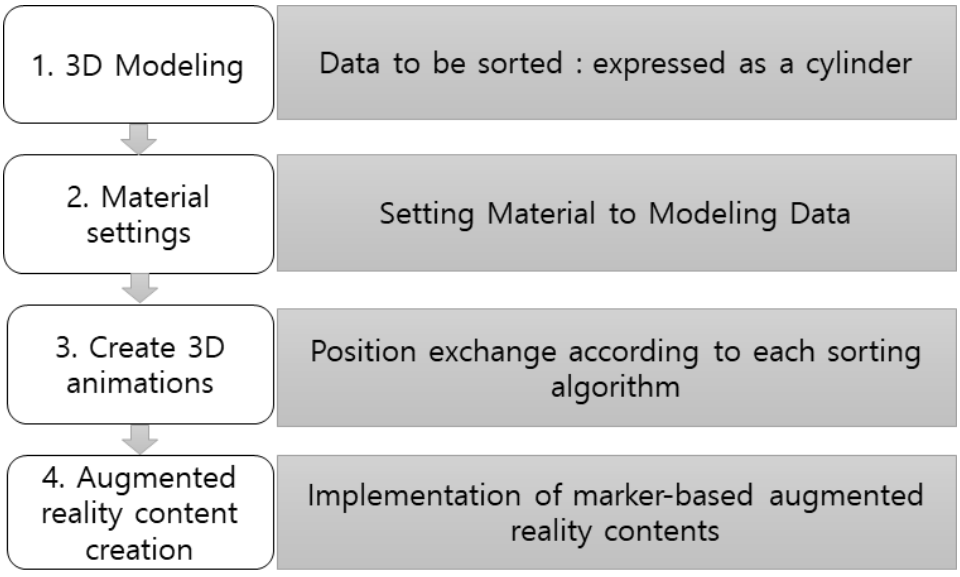

Figure 2. Process of producing Augmented Reality Contents

4. Development and Evaluation of Sorting Algorithm Educational Augmented Reality Content

The tools used in this paper to produce AR contents for algorithm learning are as follows. 3D MAX, which is commonly used for architectural or educational purposes, was used for 3D object modeling. Among various augmented reality production programs, the augmented reality production program used in this paper was Cospaces. Cospaces is an educational 3D programming language produced to execute VR screens, AR screens, and 3D screens by running Cospaces apps on a smartphone after producing a three-dimensional space using a 3D object, such as 3D and moving animation. The production process is as follows. First, the required 3D objects, such as a 3D data box to display numbers needed in sorting, a sorting area display bar, and arrows to display whether the data has been replaced, were formed in 3D MAX. By applying different colored materials to the data box, the production of the 3D object needed in the augmented reality content is completed. To store as augmented reality production tool files, each object is selected and exported as an FBX extension. To produce AR contents for algorithm learning, Cospaces is used to upload the 3D objects produced in 3D MAX. To apply the sorting process of 3D objects uploaded to Cospaces, the straight path menu in the special menu of the library is inserted, then the moving animation path is set in accordance with the sorting sequence. When the path setting is completed, the screen moves to the code screen to complete the animation code, in which the animation coding is written.

Figure 3 displays the result of implementing and executing a selection algorithm using Cospaces. The process of selecting and sorting the list[5]={15, 10, 8, 13, 10} composed of 5 values was produced in augmented reality. The 5 values are modelled in the form of a box and the values on the box were displayed as numbers. The smallest value from the five values in figure 3(a) is found first. The smallest value is 7. In figure 3(b), the value in the first digit, which is the reference position, and the smallest value will be exchanged with the position of 7. In figure 3(c), the second digit is determined as the reference position, and the minimum

value is found by comparing the 2nd element to the last element. In figure 3(d), the second digit, which is the reference position, and the position of 8, which is the minimum value, will be exchanged. This process is repeated to complete selection sorting.

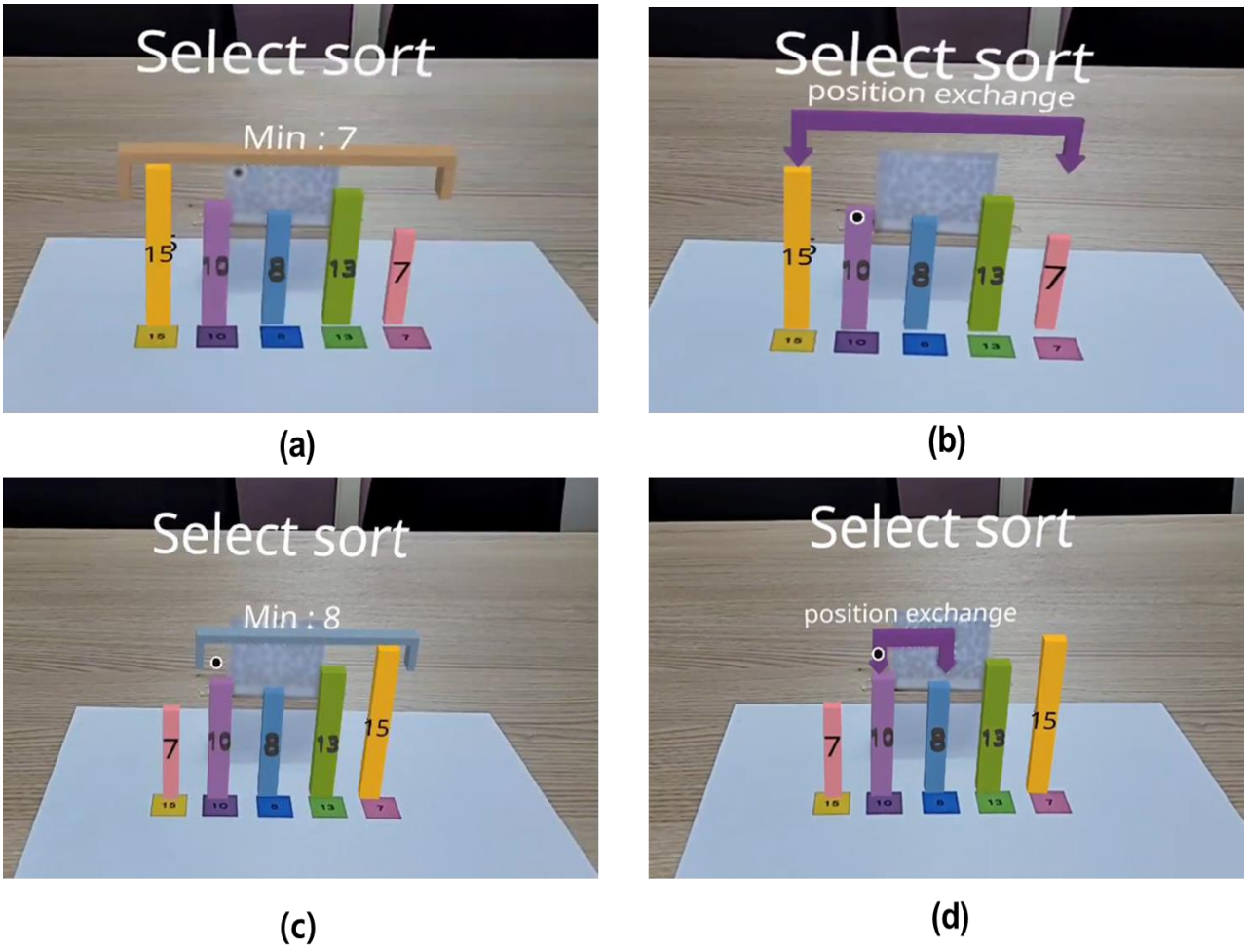

Figure 3. Producing Selection Sorting in Augmented Reality

The advantages of augmented reality contents for sorting algorithm education are as follows.
First, because it displays a comparison of sorted values and the movement of positions according to each sorting algorithm using augmented reality contents, the sorting process can be easily understood. Second, the changes in variables according to executing C language codes are provided as an animation to assist in the understanding of sorting algorithm in C language. Third, textbook screens or textbook printouts may be viewed on the computer or the smartphone to execute augmented reality contents, which allows its use in both online and offline education. Fourth, because augmented reality contents can be viewed using a smartphone without any special augmented reality equipment, students are able to conveniently use the system. Fifth, interest and immersion in classes were enhanced through augmented reality contents in the form of three-dimensional animation.

5. Conclusion

To help students who are new to coding take an interest in coding learning and understand sorting algorithms, augmented reality-based sorting algorithm educational contents were produced. The concept and the process of operation of sorting algorithms were expressed in text and graphics. Sorting algorithm programming codes were written in C language, and after explaining the codes, changes in the variables according to the sequence and the operation sequence of the codes were produced in 2D animation. For students who are new to coding, it may be difficult to understand changes in the variables according to the execution of flow of the loop, and thus, the lessons were produced in animation so that they may be repeated until understood. The values to be sorted were displayed in the form of a box, and the reference position, scope of position, minimum value, and place exchange, etc. according to each sorting algorithm were produced in three-dimensional animation. Lastly, three-dimensional animation is displayed in the form of augmented reality by projecting the marker on the teaching screen. The augmented reality learning contents proposed in this paper are expected to increase students' interest, participation and understanding in classes compared to existing text-based algorithm textbooks, and is expected to be applied in expressing various algorithms and data structures in the same manner, in addition to sorting algorithms.

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