Chen, W. et al. (Eds.) (2017). Proceedings of the 25th International Conference on Computers in Education.
New Zealand: Asia-Pacific Society for Computers in Education

Augmented Reality based Learning Support System for Mental Rotation

Midori NAKANO*, Yukihiro MATSUBARA, Masaru OKAMOTO & Noriyuki IWANE
Graduate School of Information Sciences, Hiroshima City University, Japan
*lnakano@lake.info.hiroshima-cu.ac.jp

Abstract: In the field of figure, it is said that learners' subjective "manipulation" enhances the learners' interest in mathematics and improves the degree of learning. In addition, spatial cognitive and mental rotation abilities can be considered necessary to solve the questions on spatial figures. This research constructs a system that enables learners to manipulate marker and learn mental rotation questions. The proposed system realizes learners' subjective manipulation by freely manipulating stereoscopic markers. This system makes it possible to confirm spatial figures from various angles by using stereoscopic Augmented Reality markers.

Keywords: Mental rotation, Augmented Reality, spatial figures

1. Introduction

Spatial cognitive and mental rotation abilities can be considered fundamental to solve the questions on spatial figures. Mental rotation ability can be acquired by learning using stereoscopic objects. It is said that subjective "manipulation" by learners enhances learners' interest in mathematics and improves the degree of learning (Yuki, Shota and Tokuji, 2013). In many cases, learning is performed using paper media such as textbooks, while learning via a three-dimensional object is not performed very often. In order to address this issue, Kei and Nobuyuki (2014) conducted learning support on the mental rotation questions. The system they propose can virtually observe three-dimensional figures using Augmented Reality (we will abbreviate it as AR hereafter). However, since Kei and Nobuyuki's system recognizes the AR marker affixed to the desk, it seems difficult for the learner to move hands on a subjective manipulation.

This research constructs a system that enables learners to learn the space figure by operating the marker themselves. By using stereoscopic AR markers, this system realizes the learners' subjective manipulation, making it possible to see figures from various angles. In the proposed system, a state in which a learner manipulates two types of markers is recorded by a smartphone; then, the CG of the three-dimensional object is superimposed on the image and displayed on the smartphone screen.

2. Proposed System

The proposed system is constructed using a smartphone and a marker. The right side of Figure 1 shows the appearance of the proposed system. The left side of Figure 1 shows the screen of the system. On the smartphone screen, a virtual object corresponding to the recognized control marker is displayed as shown on the right side of Figure 1. Figure 2 shows markers used in the proposed system. Since this system is for Japanese learners, the character of the marker is displayed in Japanese. There are two types of markers. One is a marker to select a question, while another is a control marker that manipulates a virtual object. The virtual object acts as teaching material for mental rotation learning. The control marker is a cubic marker. When the learner rotates the control marker, a stereoscopic marker, it is possible to rotate the virtual object displayed on the screen of the smartphone. The select marker is prepared for 20 titles. The learner can switch the question by moving the select marker closer to the control marker. Figure 3 shows how the system screen looks when the question is presented. The red arrow is the reference arrow and the three straight lines form the axis. The learner thinks about which arrow among the five blue arrows

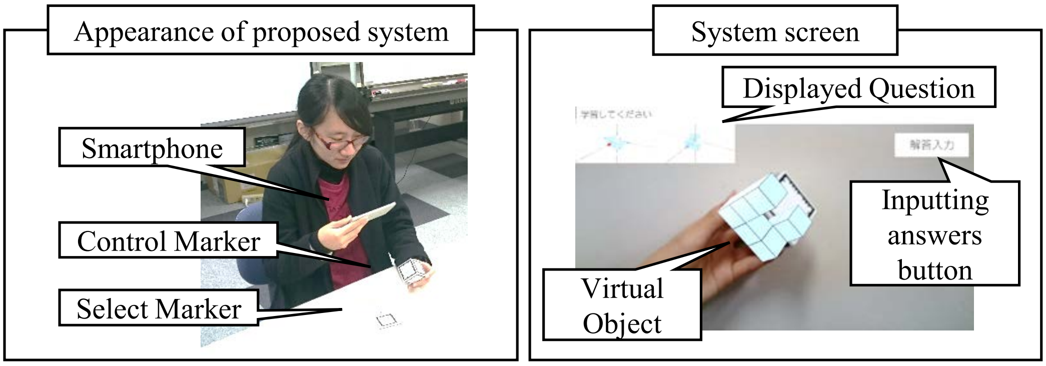

Figure 1. The appearance of the proposed system and the screen of the system

(a) Control Marker (b) Select Marker

Figure 2. Markers used in the proposed system

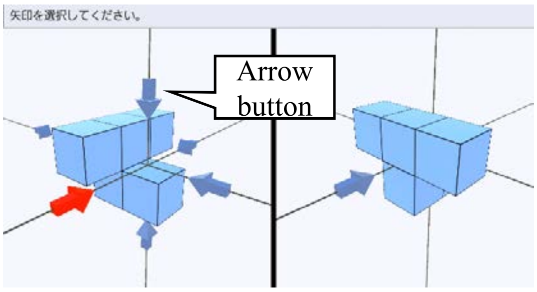

Figure 3. The system screen when the question is presented

displayed on the left corresponds to the arrow displayed on the right side of the screen. The proposed system uses two buttons in the proposed system. “Inputting answers button” is used for learning graphics using the system and transitioning to the screen to input answers. “Arrow button” is used for answering directions when entering forecast and answer. The buttons are displayed in Japanese. The learner can input the forecast of the solution to the question by selecting the arrow on the screen. After inputting the forecast, the questions are displayed in the upper left side of the screen. The learner considers his or her answer while confirming the question and the virtual object displayed on the screen. If the learner answers correctly, the system finalizes the solution to that question and the learner can move on to the next question. In case of an incorrect answer, the learner returns to input the forecast. By using their markers, the learner can learn with subjective “operation”.

3. Preliminary Experiment

In the experiment, in order to confirm the operability of this system, we instructed and evaluated learning using the proposed system. The subjects were six university students (A to F), among them three subjects A, B, and C formed Group 1 (the experiment group) and used the proposed system. The other three subjects (D, E, and F) formed Group 2 (the control group) and used a system that presents the question and performs correct/incorrect judgment. The system used by Group 2 displays a question on the screen, and when the learner answers the question, “correct answer” or “incorrect answer” is displayed for the subjects. This feedback is also offered in Japanese.

During the verification, the learners first answer the questions on mental rotation as part of a preliminary test comprising 20 questions. The subjects then learn using the system assigned to each group. After learning using the system, learners solved the same questions that were posed in the preliminary test again, after which a post-test questionnaire was carried out. Table 1 shows the number of correct answers on each subject’s pre-test and post-test. Because questions are too easy, there was no significant difference in the number of correct answers between the two groups, as shown in Table 1.

Table 1: Number of correct answers on each subject’s pre-test and post-test.

Group	Subject	Pre-test	Post-test
1 (experiment group)	A	20	19
	B	19	19
	C	20	19
2 (control group)	D	20	19
	E	20	20
	F	18	18

The post-test questionnaires show that it was easy to grasp the shape of the figure using the proposed system, and the subject could be confirmed answers by using system. It also shows that subjects could understand the questions by learning what they could not understand at first and that the system is simple to operate. On the contrary, there are opinions such as “when the marker is hidden with the finger, the recognition is interrupted and the figure is not displayed” and “It is inconvenient that one hand cannot be used.” Therefore, the subjects faced problems using the stereoscopic AR markers.

4. Summary and Future Challenges

Spatial cognitive and mental rotation abilities are considered fundamental to solve the questions on spatial figures. In the conventional system that requires learners to answer questions on spatial figures using AR, it is difficult to grasp the shape of the surface behind the marker. Therefore, in this research, we proposed a system that allows learners to answer questions on mental rotation using a smartphone and AR markers. In the proposed system, it is possible for the learner to grasp the shape of the figure from all directions while operating the cube marker.

During the preliminary experiment, we compared and verified operability of proposed system. The experimental results did not reveal any significant difference in the results from using the proposed system; however, from the post-test questionnaire, it was confirmed that the proposed system could enable learners to grasp the shape of the figure and confirm the solution better. Also, learners had opinions like, “I did not know what to solve because I did not understand knowing the intention of the question” and “There was a place where it was difficult for the arrow to tap when answering.” Therefore, in the future research, improvement of the user interface such as that for manipulation using AR marker. In addition, we consider the difficulty level of the problem and the subjects, conduct experiment which can verify the learning effect by involving subjective manipulation.

A part of this research has been made possible through Grant-in-aid for Scientific Research C (No.15K01084) from MEXT Japan.

References

Yuki, K., Shota, W., Tokuji, H. (2013). Teaching practice aimed at improving learners' subjective. *Japan Society of Educational Information,* (29), 408-409

Kei, N., Nobuyuki, W. (2014). Effect of the presentation of three−dimensional object using the Augmented Reality technology on the performance of mental rotation tasks, *The Institute of Electronics, Information and Communication Engineers Technical Report, 113*(462), 39-44