Gaze-measurement-technology-based evaluation of a vegetation-succession learning system

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Sponsoring Information:

This work was supported by JSPS KAKENHI Grant numbers JP26282061, JP26560129, JP15H02936, JP16H03059, and JP16H01814. The experiment was supported by Kobe University, Association to Plant Beech and Forest Volunteer Liaison Council. We would like to thank Editage (www.editage.jp) for English language editing.

Abstract

Several forest problems must be resolved to move toward a sustainable society. Therefore, it is very important to educate people, especially children, about forest problems. Although schools have conventionally educated children through textbooks, children are not expected to actively learn about forest problems only through textbooks. Therefore, we developed a game-type learning-support teaching material that learns the actual vegetation succession while practicing forest management and focuses on the complex mechanism of vegetation succession and the problem of forest. In this research, we aim to evaluate such learning support material by using a gaze-measurement technology. For this, we asked experienced and inexperienced users in *SATOYAMA* management to experience games. The results show that the subjects managed to learn by using the learning support function of the system. In addition, we found that *SATOYAMA* management in this system can express actual *SATOYAMA* management, suggesting this systems suitability as a learning support material.

Keywords

Environmental Problem, Education, EMR-9, Forest Management Game

1 Introduction

The past years have seen an increase in the environmental problems on a global scale. Therefore, the real-world understanding and experience of changes in the natural environment is important; however, this is relatively difficult. Learning with the help of teachers and textbooks does not provide real-world experience. Therefore, to acquire practical knowledge of environmental problems, the countryside of *SATOYAMA* has attracted the attention of researchers. *SATOYAMA* is a forest which has been used by humans, between nature and a village. An important concept for understanding *SATOYAMA* is vegetation succession through a complicated mechanism. However, the practical knowledge of these concepts cannot be obtained simply by reading textbooks or watching movies. Furthermore, as actual vegetation succession occurs on a large time scale, such as over decades to hundreds of years, it cannot be experienced completely by the outdoor learning in *SATOYAMA*. Therefore, vegetation succession is difficult to understand in a realistic way. To overcome these problems, the development of a learning tool, such as a game enabling students to learn vegetation succession, is important. Applied research on the use of games as learning support has attracted attention recently, for which several studies have been conducted (Squire and Klopfer, 2007). These studies revealed that the simulation provided in the game can support acquisition of knowledge in macroscopic and microscopic worlds and skills necessary for scientific research. However, in this research, we tackled the subject matter of vegetation succession in *SATOYAMA* as an environmental problem-learning strategy.

The authors developed “*SATOYAMA* management game” to manage *SATOYAMA* as a simulation game for learners to tackle environmental problems closest to them. In this game, 10 kinds of plants, which increase/decrease according to 3 types of influences (competition among plants, management by humans, and insect damage) were learned through 6 management methods (leaf cutting, evergreen tree cutting, afforestation, control, deer disinfection, and by not doing anything). A *SATOYAMA* is scored with the ideal state (high plant diversity) of 100 points. In addition, as it is difficult for unsatisfied managers to manage *SATOYAMA*, some functions have been provided to assist learners in discovering the state of an ideal *SATOYAMA*.

Students of the elementary school attached at Kobe University and those of Tokyo University of Science participated in the experiments, and the game was evaluated as follows.

- Questionnaire
- Interview
- Change in score every time the game is repeated
- EDA

The results showed that experiencing "*SATOYAMA*" increased the motivation for learning and deepened the understanding of the necessity of *SATOYAMA* management and complicated vegetation succession (Kawaguchi, et al., 2017, Kawaguchi, et al., 2017, Kawaguchi, et al., 2018).

However, with these evaluation methods, it is not possible to judge whether the learner can actually manage *SATOYAMA* by using the learning support function. They cannot judge whether the visualized *SATOYAMA* is valid. Also experienced the developed "*SATOYAMA*" was limited to *SATOYAMA* management inexperienced person. Therefore, the following issues were recognized.

- Determination of a learner's gaze movements during "*SATOYAMA*" experience;
- Determination of the types of results that would be obtained by experts in *SATOYAMA* management

To solve these problems, in this research, we solved the problem of this game inexperience through the experience of *SATOYAMA* management and compared the movement of gaze of both. This paper shows the details of implementation of the game and preliminary experiments conducted in the game.

2 Vegetation Succession Learning Support System

In this research, the authors developed a game called "*SATOYAMA*" to learn complex mechanisms, such as vegetation succession and the actual state of inheritance while maintaining interest in forest problems. In the developed game, you can manage one forest in the virtual environment for approximately 300 years. As this game can be played on a personal computer, it can be used not only in school classrooms but also in various places. In this game, 10 types of trees are planted in the forest, divided into early-, middle-, and late-stage species. The learner improves the forest so that it reaches the ideal state (environment rich in biodiversity) from an unfavorable environment (environments with poor biodiversity = large-stage species, which includes plants with a biodiversity = many vegetation). Figure 1 shows the screen of the game. As each tree has different sizes and growth rates, a dominant relationship exists between the trees. In addition, some deer and insects exist that eat specific trees. Therefore, it is necessary to consider the damage inflicted by these deer and insects. The learner was suggested to use six management methods: clear-cut logging, evergreen tree cutting, afforestation, pesticide control, deer removal, and do nothing). Vegetation changes due to superiority/inferiority relation among plants, damage by deer and insects, and human influence. If the learner chooses a management method within 20 s per turn, the game proceeds to the next turn and changes are made corresponding to the action in the forest. This is repeated 20 times.

The managed forests are scored 100 points for an ideal state. As evergreen trees constantly increase, short trees cannot be planted and the forest biodiversity would be low. In other words, if forest management is inefficient, the score will eventually be 0. In this way, through trial and error, a learner can learn to manage forest changes due to various factors, and thus improve forests. Simultaneously, the learner can learn about complex mechanisms such as vegetation succession and actual inheritance situation.

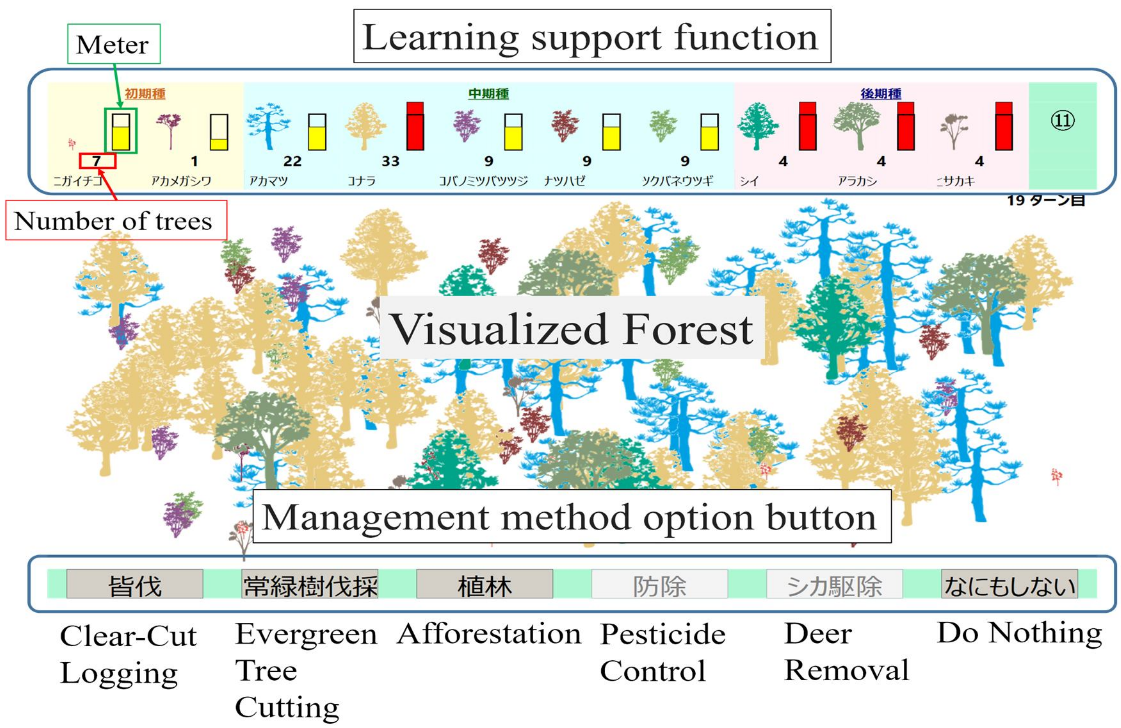

Figure 1: The screen of the game.

Several functions were added in the game to allow learners to judge or discover the aforementioned factors, i.e., the influence of superiority/inferiority relation among plants, influence of deer and insect damage, influence of human management, and the ideal number of plants vegetation in the forest. As shown in Figure 1, the number of plants is displayed. In addition, a state meter was used to compare the current number of plants with the ideal number to determine the ideal number for each plant. As the ideal number varies for each plant, there is a meter for each plant. When the meter is full, an ideal number is said to be reached, and when the limit is exceeded, it implies that the forest has more trees than necessary. These functions support learners' forest-management skills.

3 Experiment

3.1 Objective

In this research, we focused on forest management in a virtual environment and developed a system to learn about vegetation succession and the complicated mechanism of inheritance while maintaining interest in forest problems. However, it is impossible to judge whether a student actually manages the *SATOYAMA* by using the learning support function, the visualized *SATOYAMA* is valid, or actual *SATOYAMA* management can be reproduced. Therefore, we measured the gaze of the inexperienced and experienced users in *SATOYAMA* management, examined their gaze movement, and determined the result of the user who managed the *SATOYAMA*. We compared the gazes of the experienced and inexperienced users by using an eye-mark recorder. By using this method, we aimed to evaluate the usefulness of our system.

3.2 Measuring Device

Eye movement was measured using an EMR-9 (Nac Imaging Technology, Inc., Japan); other commercial eye-movement-measuring equipment are also available. The update rate of the EMR-9 is 60 Hz and the resolution is 0.1 degree in both the horizontal and vertical directions (Kikuchi, et al., 2014), as shown in Figure 2 and 3.

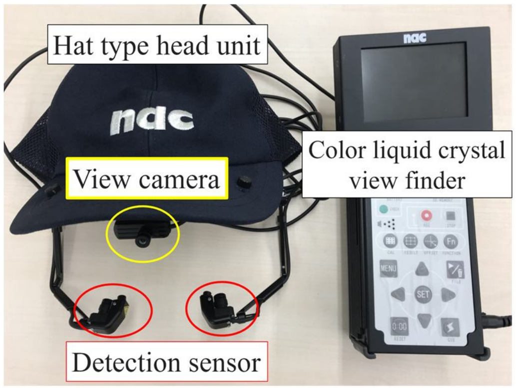

Figure 2: EMR-9.

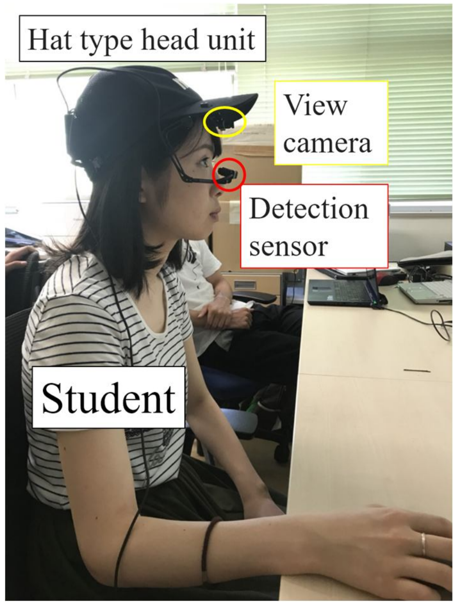

Figure 3: Subject wearing the device.

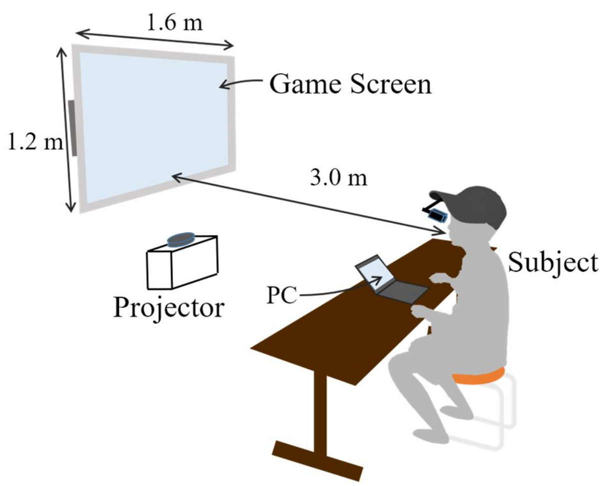

Figure 4: Experiment environment.

3.3 Experimental Method

Three people belonging to the association managing *SATOYAMA* were considered as the experienced users in this study. Some of them have conducted *SATOYAMA* management for 38 years. The inexperienced users comprised 10 students of Kobe University. In this experiment, we measured and examined the gaze directions of all the participants, and determined the result of *SATOYAMA* management by experienced users.

The gaze data of the experienced users and students wearing EMR-9 were collected while implementing "*SATOYAMA*." Subjects played the game six times. Figure 4 and 5 and 6 show the experimental environment.

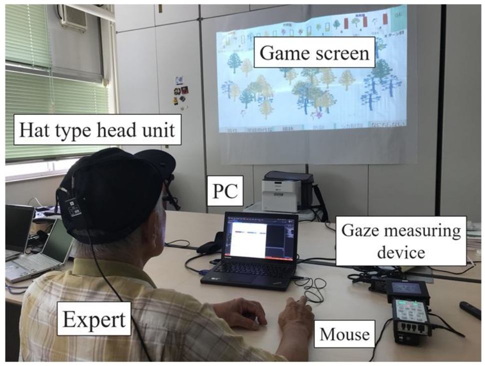

Figure 5: Experiment environment of the experienced managers.

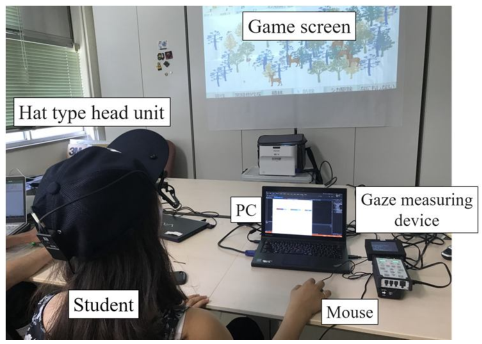

Figure 6: Experiment environment of student.

3.4 Evaluation Method

Of the data recorded through EMR-9, the gaze data per turn was analyzed. Stop-point trajectory analysis was performed using the EMR-9 analysis software. Regarding the line-of-sight trajectory, data “from the beginning of each turn” and “until subjects selected a management method” were picked. We compared the locus of stationary points of students with those of the experienced users for each turn.

3.5 Result

First, we focused on the stationary point trajectory. Figure 7 and 8 shows the experimental result of one of the experienced managers. Figure 9 and 10 shows the experimental result of one student. The green and red lines represent the lines-of-sight of the right and left eyes, respectively. The yellow circle represents a stationary point. The comparison showed that the experienced users were able to manage *SATOYAMA* without looking at the learning support function at the top of the game screen. Therefore, users can manage the *SATOYAMA* if you look at the visualized *SATOYAMA*. In addition, the students could manage *SATOYAMA* by using the learning support function at the top of the game screen, suggesting the function efficiency in helping students learn *SATOYAMA* management. And other things were confirmed. Experienced users have noticeable retention to deer and pests and tend to focus on evergreen trees.

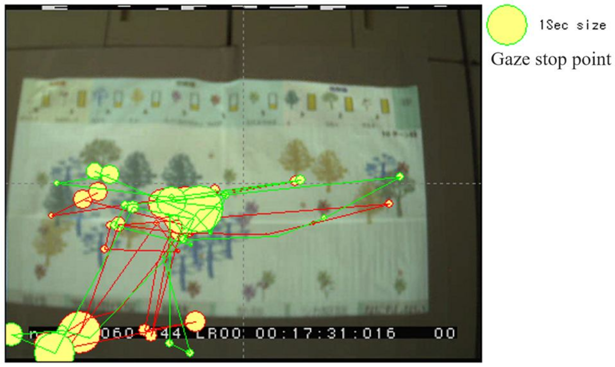

Figure 7: The experimental result of one of the experienced managers①.

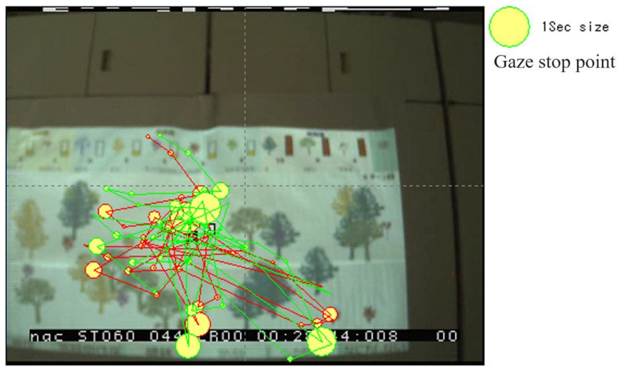

Figure 8: The experimental result of one of the experienced managers②.

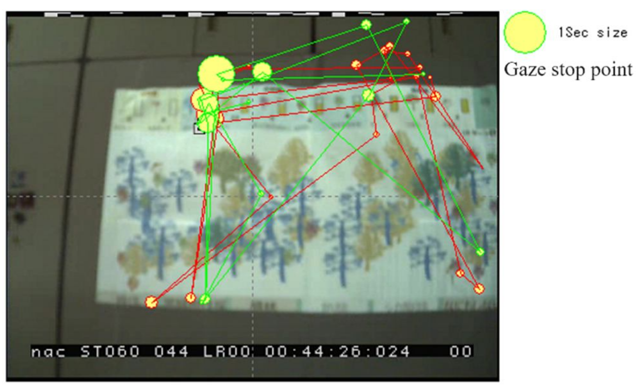

Figure 9: The experimental result of one of student①.

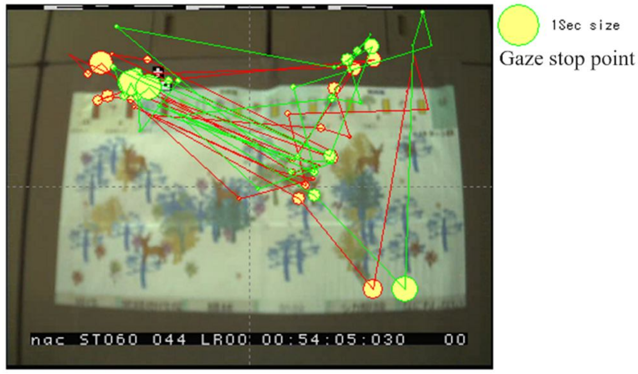

Figure 10: The experimental result of one student②.

	The Experienced Managers	Student
Average Points of All	70 points	52 points
Average Points of First Time	74 points	44 points
Average Points of 6 th Time	69 points	66 points

Table 1: Average point of the game

Next, the authors focused on the final score of the *SATOYAMA* managed by the experienced and inexperienced users. Table 1 shows the average points of the six times and the average points of the first and sixth times. The results show that the experienced person was able to achieve a high score by using the knowledge learned in actual *SATOYAMA* management. This indicates that the *SATOYAMA* management in "*SATOYAMA*" is the same mechanism used in actual *SATOYAMA* management.

4 Conclusion

This paper described the proposed vegetation-succession learning support system and the gaze-measurement experiment conducted to evaluate it. We gathered gaze data during the implementation of "*SATOYAMA*" and evaluated the learning support function of the system by comparing *SATOYAMA* management methods among experienced and inexperienced users. Thus, we confirmed that an inexperienced person can manage the *SATOYAMA* well by using the learning support function. In addition, an experienced user can manage it by only using the visualized *SATOYAMA*. This suggests that learning using this system is effective, and that the visualized *SATOYAMA* is effective.

The final scores were compared and confirmed that an experienced user can achieve a high score from the beginning, suggesting that the system-based *SATOYAMA* management can simulate actual *SATOYAMA* management.

The following problems were recognized in this preliminary experiment. Longer eyelashes prevent the accurate measurement of a user's line of sight. If the user's face moves during the experiment, an error occurs. Future research will focus on solving these problems and increasing the number of users to conduct experiments.

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