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SATOYAMA: Simulating and Teaching Game Optimal for Young Children to Learn Vegetation Succession as Management of an Actual Forest

Shuya KAWAGUCHI[a*], Hiroshi MIZOGUCHI[a], Ryohei EGUSA[b, c], Yoshiaki TAKEDA[c], Etsuji YAMAGUCHI[c], Shigenori INAGAKI[c], Fusako KUSUNOKI[d], Hideo FUNAOI[e] & Masanori SUGIMOTO[f]
[a]*Department of Mechanical Engineering, Tokyo University of Science, Japan*
[b]*Research Fellow of Japan Society for the Promotion of Science, Japan*
[c]*Graduate School of Human Development and Environment, Kobe University, Japan*
[d]*Department of Information Design, Tama Art University, Japan*
[e]*Faculty of Education, Soka University, Japan*
[f]*Graduate School of Information Science and Technology, Hokkaido University, Japan*
[*]bdashshuya@gmail.com

Abstract: Global environmental problems have worsened in the recent years. Children need to cope with this situation by learning about global environmental issues in a realistic manner. For children to understand more about global environmental issues, it is important for them to learn from textbooks and teachers and also actually experience these learned things. However, phenomena occurring in a large time scale are difficult to experience in reality. One of them is vegetation succession. Vegetation succession occurs in a large time scale. Hence, it is difficult for children to experience changes in vegetation even if they do field work. In this study, the authors try to solve the abovementioned problem by developing a game that can support children's learning of the vegetation succession in Japan. Children can simulate the management of SATOYAMA when they play this game. SATOYAMA is a forest which has been used by humans, between nature and a village. When a player selects an action within a predetermined time, a change caused by the action occurs in SATOYAMA. The status of the managed SATOYAMA compared with the ideal SATOYAMA state is scored at the end of the game. By doing so, children can intuitively understand the state of the SATOYAMA they managed. The results obtained from 38 children, who participated in this experiment, suggested that this game would make children interested in vegetation succession and encourage learning.

Keywords: Vegetation succession, game, management, education, environmental problem, learning support

1. Introduction

Environmental problems have worsened on a global scale in the recent years. In such a situation, children must understand and experience the change of the natural environments through a realistic method. However, one of the difficulties of this trial is the fact that theoretical learning about the subject (as taught by teachers and textbooks) does not provide a real experience of the real world. As a result, the country's natural zone, which is referred to as the SATOYAMA, has attracted attention as a place for acquiring practical knowledge of environmental problems. The important concept in understanding SATOYAMA is accompanied by a complicated mechanism about the real situation of vegetation succession. However, practical knowledge on these concepts is not provided only by merely reading textbooks and watching movies. Children cannot completely experience the real vegetation succession in the SATOYAMA-based fieldwork because it has a large time scale (e.g., several decades and several hundred years). Therefore, understanding the vegetation succession through a realistic method is difficult. A learning tool, such as a game where a child would learn about vegetation succession without being limited by the large time scale, is important to overcome these problems. Many studies have been conducted on using a game for learning (Facer and others, 2004, Squire and Klopfer, 2007). These early studies clarified that the simulation provided by a game helped a student obtain the ability to understand the microscopic and macroscopic world. However, our educational initiative is the only one that focuses on learning an environmental problem using the vegetation succession of the SATOYAMA.

The authors developed "Human SUGOROKU," with the maintenance of the SATOYAMA as an exercise for a learner to work on an imminent environmental problem. In this game, the change of the superiority of the indicator plant by the environmental disturbance factor (e.g., felling, landslide, precipitation, etc.) is expressed in SUGOROKU form. In addition, we perform the high study of a learning document visualizing the vegetation succession of the SATOYAMA through animation (Deguchi et al., 2010; Deguchi et al., 2012). Consequently, the game raised learning will and deepened the understanding of the complicated vegetation succession. The game also improved the player's ability of solving the problem in conjunction with the vegetation succession (Adachi, et al., 2013, Nakayama, et al., 2014, Yoshida, et al., 2015). However, the scene, where the game was set, was limited to a specific area. Large-scale ultrasonic sensors were used in this game, and learners worked on the squares arranged in the virtual world disguised as indicator plants, but this merely realized restricted immersion. Therefore, the following four observations were made:

- The competitive relationship between plants and environmental disturbance factors in various areas could not be expressed.
- The propagation of this game was difficult because of the large-scale devices used in it and its lack of portability.
- Restricted embodiment could not provide the learners with the experience of complete immersion in the virtual world.
- The game contents are not adaptable to the learners' intelligence.

Therefore, the authors decided on the following objectives for the current study to deepen understanding and improve the problem-solving abilities of the learners in the area of vegetation succession:

- developing a wide range of contents, including main vegetation succession, in each area of Japan;
- making a portable game using mobile devices; and
- making the contents of the game adaptable to the intelligence of learners.

As the first step in this endeavor, this study presents the details of the current implementation of the game and the experiments conducted with it.

2. Current Game Implementation

2.1 *Game Content*

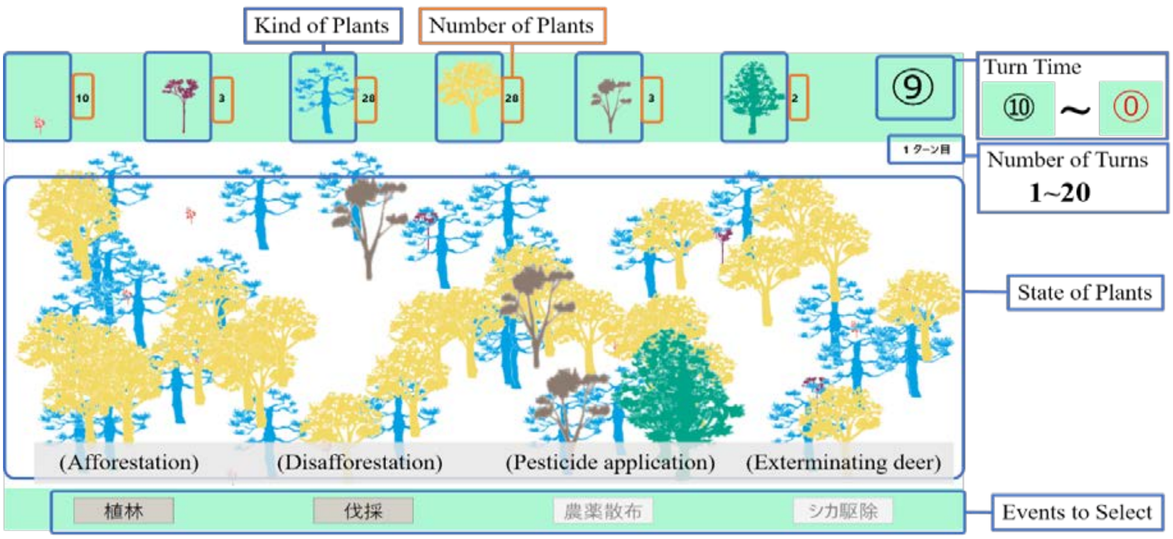


Figure 1. SATOYAMA Management Game Screen.

This study introduces a game, called the SATOYAMA Management Game. SATOYAMA is a forest used by humans. The SATOYAMA Management Game can simulate a player's environmental management. Figure 1 shows a game screen, where six kinds of plants arranged on the screen grow.

- small plants: *Rubus microphyllus* and *Mallotus japonicas*
- medium-sized plants: *Pinus densiflora* and *Quercus serrata*
- tall plants: *Ilex peduncIosa* and *Castanopsis* spp.

Competition exists between plants and occurs when two or more plants grow in the same place. For example, when taller and smaller plants grow in the same dense forest area, taller plants get the sunlight they need to grow, but small plants do not because the sunlight does not reach them. A deer and a pine longicorn that eat plants are used in the SATOYAMA Management Game. While adjusting the number of plants, players must prevent the plants from being devoured by the deer and the pine longicorn and manage the environment. The player must select one of the following actions within 10 s of turn to do that:

- Afforestation,
- Deforestation,
- Pesticide Application, and
- Removing Deer.

However, the player can leave it unselected. The SATOYAMA vegetation varies according to the selected action. The players manage it for 20 turns. We set it to be managed for 300 years as 15 years pass per turn. The players can experience vegetation successions in a realistic manner at the end of the game by scaling the final state of the SATOYAMA compared with the ideal environment. An ideal environment is an environment, where many medium plants grow. An ideal environment (100 points state) is used at the start of the game.

The player first clicks the start button, then the countdown begins. The vegetation change is displayed when the timer reaches 0 s. Increasing plants are surrounded by red circles, and decreasing plants turn gray. The SATOYAMA after 15 years will then be displayed. The score after repeating this circle for 20 turns is displayed at the end. Points are deductive, and SATOYAMA's vegetation will only comprise tall plants if people do not manage it well. We set the condition at a 0 point.

The players can visually understand the state of vegetation inheritance through the SATOYAMA Management Game. Therefore, students playing this game can easily understand the interactions that occur between plants, the effect of different events in SATOYAMA, and the management of SATOYAMA. The vegetation succession is represented by the relative relationship of each plant.

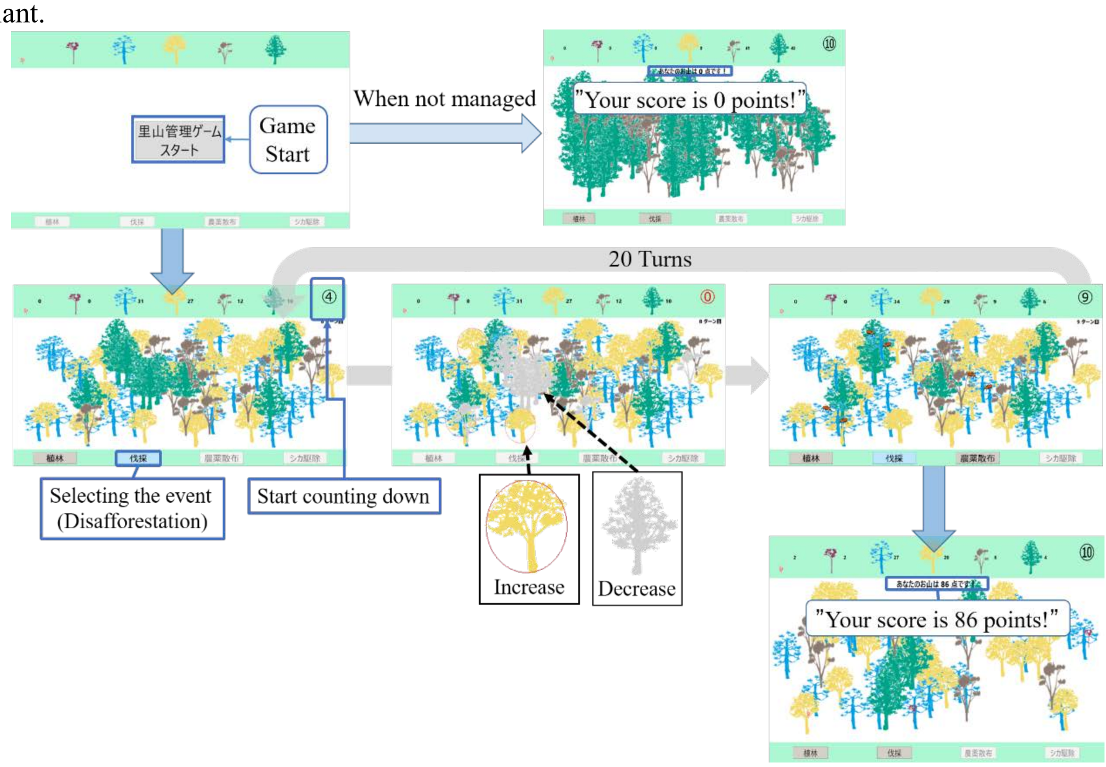


Figure 2. Game Flow.

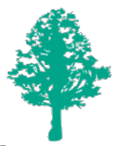
2.2 System Configuration

The system consisted of a screen, a single focal projector, a personal computer, and a mouse. A corresponding vegetation change occurs in the SATOYAMA when a player chooses the action on the screen with a mouse. These operation and control were implemented using the C# program that we developed using Visual Studio 2013. We can optionally increase and decrease the number of each plant using this program.

Table 1 shows each phenomenon and relation with the increase and decrease of the number of plants. Beginning with an ideal state, every turn changes the SATOYAMA. Medium-sized plants increase when a player chooses “Afforestation.” The number of tall plants decreases when they choose “Deforestation.” Meanwhile, the pine longicorn appears when the number of *P. densiflora* is above six. A deer appears when the number of *R. microphyllus* is above three. The outbreak is random. The influence on vegetation caused by the two creatures depends on the plant characteristic. *P. densiflora* markedly decreases when pine longicorn appears. In contrast, the number of small plants increases because that of medium-sized plants decreases. The player can prevent a decrease in *P. densiflora* when they choose “Pesticide Application.” The deer eats all kinds of plants, but likes a small plant and seedlings. Therefore, the number of small plant decreases compared to other plants when a deer appears. Meanwhile, the number of small plants increase compared to that of the other plants when a player chooses “Removing Deer.” The tall plants grow regardless of the player’s choice of action. Furthermore, the numbers of small- and medium-sized plants decrease in competition of the growing tall plants.

The gameplay is scored from the difference between the ideal and final states of the managed SATOYAMA. A penalty point method is set from 100 points and 0 point for the vegetation of the tall plants without management.

Table 1: Change of vegetation in each phenomenon.

Plants / **Events**	*R. microphyllus*	 *M. japonicus*	 *P. densiflora*	 *Q. serrata*	 *I. pedunclosa*	 *Castanopsis* spp.
Afforestation			Increase by 4	Increase by 3		
Deforestation			Increase by 5	Increase by 4	Decrease by 5	Decrease by 6
 **Pine longicorn**	Increase by 2	Increase by 3	Decrease by 7			
Pesticide Application	Increase by 5	Increase by 4	Increase by 6			
 **Deer**	Decrease by 3	Decrease by 3	Decrease by 2	Decrease by 2	Decrease by 1	Decrease by 1
Removing Deer	Increase by 3	Increase by 3	Increase by 2	Increase by 2	Increase by 1	Increase by 1
There are tall plants	Decrease by 3	Decrease by 3	Decrease by 2	Decrease by 2		

3. Experiment

3.1 Method

Thirty-eight 6th grade students from an elementary school in Kobe, Japan, participated in the experiment. The game, which simulated the management of undeveloped woodlands near populated areas, was played thrice by each participant. The game was played by one participant at a time. Each participant was asked to consider a strategy before the commencement of each game. After playing three rounds, the participants were asked to evaluate their gaming experience by rating their response to two types of multiple-choice statements.
The survey was conducted from December 19 to 22, 2016. Figure 3 shows the experiment environment.

3.2 Result

Figure 3 shows the experiment environment. The positive answer in the questionnaire result exceeded the neutral/negative answer. The number of responses showed a significant difference. This result denoted that the participants played the SATOYAMA Management Game with enthusiasm (Kawaguchi et al., 2017).
Let us now pay attention to the game score results of 36 people. Figure 4 shows a histogram showing the distribution of the first, second, and third game scores. The distribution of 36 participants in the first round was gentle, whereas the percentage of participants in the second distribution sharply increased because the game scores exceeded 50 points. The number of participants with a game score of 60 or more in the first round were 19 people, whereas the number of participants with a game score of 60 or more in the second round were 29 people. In addition, the number of participants with a game score of 90 to 99 points increased in the third time compared with the first and second times. The third-time scatter scores were larger than those of the second time but we think that it was the result of the participants performing various analysis.

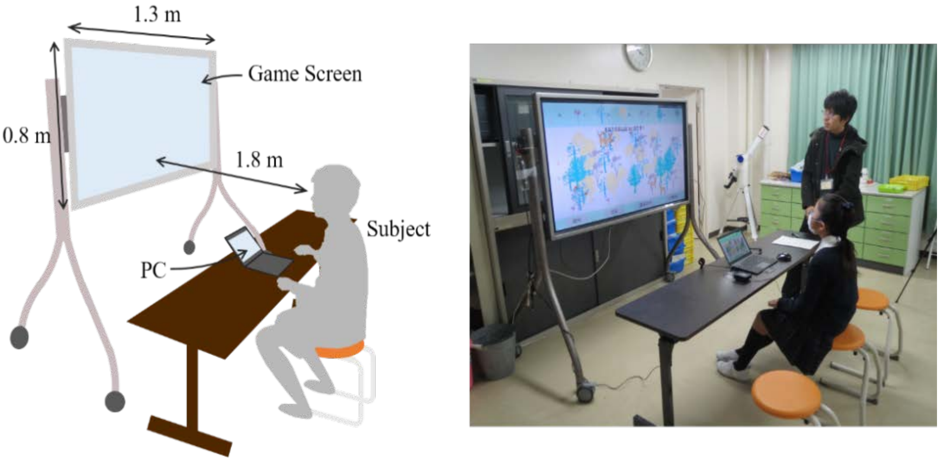


Figure 3. Experiment Environment.

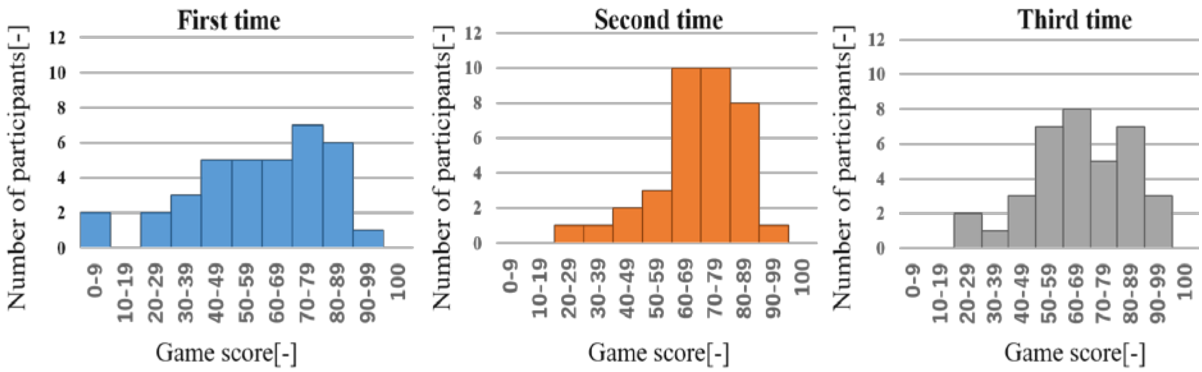


Figure 4. Game Score Histogram.

4. Conclusions

This study develops and evaluates a game that simulates the management of undeveloped woodlands near populated areas. The game provides practical training by simulating a woodland management experience. The questionnaire results implied that positive opinions outnumbered neutral/negative opinions. The difference between the numbers of responses was significant. Furthermore, the score of the game shows that the number of people who take high scores increases as participants repeatedly play the game.

These results showed that the participants played the woodland management game with enthusiasm. The findings also denoted that the participants placed considerable thought into the game strategies pertaining to the simulated changes in the woodlands. We found that the game could encourage learning.

Acknowledgments

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