Life-size Board Game "Human SUGOROKU" To Teach Children about Vegetation Succession

Application of Human Sensing Technology to Embodied Education

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Abstract: In this paper, we propose and develop a full-body interaction system and simulation game called "Human SUGOROKU," which helps elementary school students learn about vegetation succession while having fun. We found that the students became more involved in the game because they were required to play it using their body movements. An experiment conducted with students verified that the participants became immersed in the virtual world of vegetation succession while playing Human SUGOROKU. This paper describes the structure of our game and the results of its evaluation.

1 INTRODUCTION

Elementary school students often have difficulty in understanding environmental issues because they cannot easily experience the relevant knowledge that they gain in school. In light of this, we aim to collaborate with elementary schools to effectively educate students regarding environmental problems.

In previous research, we developed a simulated tablet game, based on the Digital SUGOROKU board game, involving vegetation succession (Toshizaki Matsumura, 2010; Akiko Deguchi, 2010; Akiko Deguchi, 2009). Vegetation succession is the observed process of change in the plant life in an ecosystem, such as the kinds of trees and plants found in mountains and their patterns of distribution in the last several thousand years. Vegetation succession is a crucial concept for the conservation of mountains. The word "SUGOROKU" means "board game" in Japanese. Multiple players can participate in a game of Digital SUGOROKU. The board is divided into grids, and each player moves a piece on it. Players move their pieces on the grid according to event cards, with the aim of securing the most advanced piece. In our game, a piece corresponded to a plant and grids corresponded to its succession phases. In other words, the children played the role of plants in the simulation. Experiments revealed that our game effectively stimulated interest among students and helped them learn (Toshizaki Matsumura, 2010; Akiko Deguchi, 2010; Akiko Deguchi, 2009).

However, one drawback of the game was that it was digital and, hence, was played on a computer screen. We found that the virtual world did not suitably approximate to the real world. Our experimental evaluations suggested that rendering the virtual world more immersive would not only further motivate the students, but would also enhance their understanding. In order to evoke greater interest in the digital game among students, we focus on implementing operations through players' body movements. Accordingly, we have developed a new learning support system called "Human SUGOROKU" (Figure 1) (Tomohiro Nakayama, 2014). The original tablet game uses a touch panel interface, and players move pieces using a mouse or a touch pen. By contrast, in order to make Human SUGOROKU more interesting, we replaced the touch panel interface with a full-body

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interaction interface developed by combining a human detector interface, which measures each player's movement, with the game's digital core. In Human SUGOROKU, the students move on a life-size board.

In this paper, we determine whether Human SUGOROKU caused participants to be immersed in the virtual world of vegetation succession. Unlike Nakayama et al., who gathered data by interviewing players once they had played Human SUGOROKU, we tracked participants' states in real time to determine whether they were immersed in the system, and analyzed their remarks while playing Human SUGOROKU. In this paper, we describe the structure of Human SUGOROKU as well as the evaluation experiment.

2 HUMAN SUGOROKU

2.1 Structure

In Human SUGOROKU, players operate as pieces by moving on a replica of the SUGOROKU board drawn on the floor. In order to implement this operation, technologies that can measure a player's position and identify the players in the room are needed. The technology to calculate a player's three-dimensional (3D) position through attached ultrasonic sensors has already been developed (Yoshifumi Nishida, 2003; Akifumi Nishitani, 2005). Accordingly, we used ultrasonic sensors as our human detector interface.

Figure 2 shows the structure of Human SUGOROKU. The system is composed of ultrasonic sensors, two computers, and a projector. Receivers are placed on the ceiling and transmitters are attached to the players moving on the grid drawn on the floor. The digital game core runs on a computer and is shown on a projector, so that players can visually absorb the state of the game. A server is connected to the ultrasonic sensors, which calculate players' 3D position information and send it over the network. Another client computer runs the digital game.

2.2 Digital Game Core

The digital game core is written in ActionScript CS5.5, and the game simulates the forested area of Mt. Rokko in Japan. Figure 3 shows a screenshot of the game. The plant pieces represent the characteristic plants that grow on Mt. Rokko.

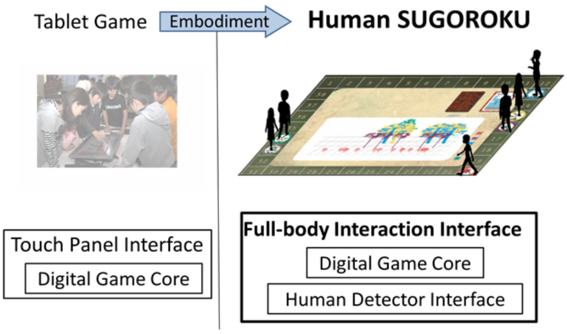

Figure 1: Human SUGOROKU full-body interaction system.

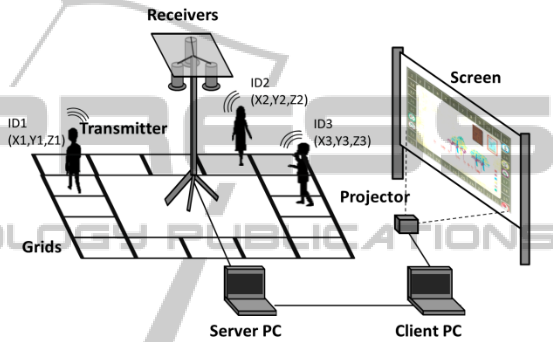

Figure 2: Structure of Human SUGOROKU.

Figure 3: Screenshot of digital game.

The surrounding part is the grid area. The event cards either disrupt or promote plant growth. The cards are turned over by operating the keyboard, and the pieces accordingly move on the grid. A visualization window represents vegetation succession according to the progression of the game.

In the digital game, there are six types of plant pieces: Rubus Microphyllus, Mallotus Japonicas, Quercus Serrata, Pinus Densiflora, Castanopsis, and Llex Pedunculosa. These plants have varying growth rates and sizes. Rubus Microphyllus and Mallotus Japonicas are rapidly growing small plants, Quercus Serrate and Pinus Densiflora are medium-size plants that grow at a moderate rate, and Castanopsis and

Llex Pedunculosa are slow-growing tall plants. There are six types of event cards: sunny, rainy, wild boar, insects, landslides, and felling. The extent of a disturbance depends on the characteristics of each event card and affects plant breeding. The sunny and rainy cards are classified as “no disturbance,” wild boar and insects are classified as “small disturbances,” and landslides and felling are classed as “large disturbances.” For example if no disturbance occurs, small plants, such as Rubus Microphyllus, decline and tall plants breed. On the other hand, if a large disturbance occurs, the forest shows very little vegetation. Therefore, the number of rapidly growing plants increases and the number of slow-growing plants decreases significantly. Moreover, there is mutual action between plants. This mutual action occurs when two plants grow in the same place. For example, if a tall plant and a small plant grow in the same densely forested area, the tall plant can obtain the sunlight it needs to grow but the small plant cannot. Therefore, the number of small plants will decrease. Players can visually understand the state of vegetation succession through the visualization window. Thus, students playing the game can easily understand the scale and effect of the disturbances on each species of plant. Vegetation succession is expressed by the relative progress of each plant piece.

2.3 Human Detector Interface

Figure 4 shows the system configuration of the human detector interface. To calculate the position of the players and identify them in the room, we use ultrasonic sensors consisting of transmitters, receivers, and a control unit. The receivers receive ultrasonic waves emitted from the transmitters, whereas the control unit calculates the 3D position of the transmitters using the time difference between successively received ultrasonic waves from the same transmitter. Because each transmitter has a unique identifier associated with it, the ultrasonic sensors can locate the positions of the players using the transmitters and identify them. Therefore, by setting transmitters that correspond to a type of plant piece in advance, we can understand the type of plant and the position of the associated learner.

In the tablet game, players use a mouse or a touch pen. They can move a piece on the grid by dragging it on the computer screen, and can place a piece on the grid by releasing it. To make the players’ pieces, it is necessary not only to measure their position, but also to determine their situation: whether they are moving or stationary. The system determines whether players are standing or sitting based on the position of their heads.

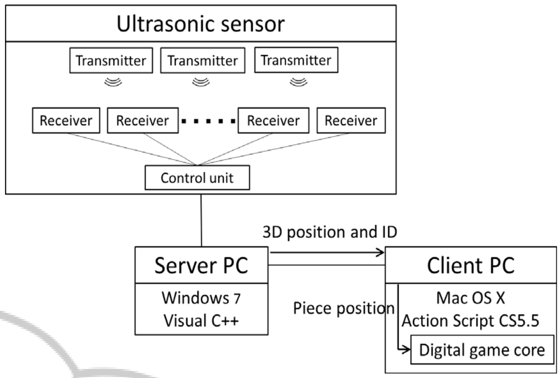

Figure 4: System configuration of human detector interface.

Figure 5: Playing Human SUGOROKU.

3 EVALUATION

3.1 Evaluation Method

The purpose of our experiment was to determine whether the participants were immersed in the virtual world of vegetation succession while playing Human SUGOROKU. For this, we recorded participants’ comments as they played the game and investigated whether these were sufficient to judge their level of interest. When a participant's comment suggested that he/she felt like he/she had completely become a plant, we concluded that the person was immersed in the virtual world of vegetation succession.

The participants were 36 sixth-grade primary school students (ages 11-12 years) in Japan. The participants were divided into six groups of six participants each. The members of each group played two rounds of Human SUGOROKU. The first round consisted of nine event cards and the second of 10. The types of cards that appeared during the first and the second rounds of play had previously been decided to ensure that the participants would experience multiple patterns of vegetation succession. Many first round event cards included smaller disturbances, whereas several second round event cards affected larger disturbances.

The first and second rounds of play lasted for a total of 30 minutes. We randomly selected five of the 36 participants and recorded their comments during the game to serve as our data source. The comments were recorded using a video camera, and we collected approximately 30 minutes of sound data per person.

We first transcribed the recorded comments. Then, with each event card acting as a unit, we divided the audio data accordingly, and further divided participants' comments in each unit every time there was a change in the speaker. We classified the comments into two categories: (1) comments indicating that the participant was immersed in the virtual world of vegetation succession, and (2) comments unrelated to immersion. We then counted the total number of comments for each category.

A few comments indicated that the participants were immersed in the game. For instance, a participant playing the role of Castanopsis said during the deforestation event, "No, don't cut me down," or "It feels so sad to be cut down!" Examples of comments unrelated to immersion included an instance when a participant, who noticed that another participant was moving to an incorrect square, said, "That's not the square (you should be moving to)."

Table 1: Number of comments indicating immersion, and comments unrelated to immersion.

		Unit (1st round of play)									Unit (2nd round of play)										
		1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	10	Total
P1	○	8	1	6	2	6	6	6	7	9	3	6	5	4	3	6	15	7	6	5	111
	×	3	3	1	2	2	1	2	1	4	5	1	8	1	3	0	4	0	2	1	44
P2	○	7	7	5	3	3	6	8	7	3	5	6	0	2	4	0	3	0	4	5	78
	×	1	1	8	4	2	1	0	2	2	5	4	5	0	2	3	1	5	4	2	52
P3	○	9	6	6	3	7	4	9	5	10	6	9	8	7	5	7	5	5	5	9	125
	×	4	2	4	2	1	1	2	2	2	4	1	3	1	1	2	4	3	0	2	41
P4	○	4	5	8	5	0	5	3	10	6	4	6	0	7	7	0	2	8	3	7	90
	×	0	1	1	0	7	2	2	3	1	3	1	6	0	0	3	1	1	3	1	36
P5	○	9	7	9	6	5	6	5	12	3	2	6	6	0	3	8	5	0	6	2	100
	×	5	0	1	3	3	2	3	5	0	2	2	2	1	1	1	4	3	1	0	39

Note: The numbers indicate the number of comments. ○: comments indicating immersion, ×: comments unrelated to immersion, P1: Participant 1, P2: Participant 2, P3: Participant 3, P4: Participant 4, P5: Participant 5.

Table 2: Comments made by participant P3 regarding an event card.

01	P3	: I want a large disturbance. I want a landslide! Landslide!
02	Other (Castanopsis)	: I want a rainy or a sunny day.
03	P3	: So, Castanopsis can move forward when it is rainy or sunny.
04	Other	: No landslide, please.
05	Moderator	: I'm going to turn over the event card now.
06	Other	: Oh no, it's a landslide! That's terrible! I have to move back four squares.
07	P3	: This is really interesting.

Note. P3: Participant 3

Table 3: Comments made by participant P5 regarding a mutual action.

01	Moderator	: Next, let's turn over the event card.
02	P5	: It's a rainy day!
03	Other (Pinus Densiflora)	: Great! I can move forward three squares!
04	P5	: I can't move much.
05	Other	: Just one square?
06	P5	: Yes.
07	Other	: One, two, three (*counts squares*). I've really moved ahead.
08	P5	: [*Mutual action with Pinus Densiflora occurs.*] Wait a minute. Now I have to move back two squares. You're the worst!
Note. P5: Participant 5		

3.2 Results

Table 1 shows the number of comments that indicated immersion as well as the number of comments unrelated to immersion. More than 70% of the total comments made by P1, P3, P4, and P5 indicated immersion, and more than 60% of the total comments made by P2 indicated the same.

Table 2 shows P3's comments relating to an event card. P3 was hoping for a large disturbance, so that the plant (Mallotus Japonicus), the role of which he played, could move forward [01]. At the same time, the participant playing the role of Castanopsis was hoping for a sunny day or a rainy day event card, so that her plant could move forward [02]. When the event card indicated a landslide, the participant playing the role of Castanopsis was disappointed as she had to move back four squares [06], while P3 was happy at being able to move forward [07].

Table 3 shows P5's comments relating to a mutual action. When a rainy day event card appeared, the participant playing the role of Pinus Densiflora was happy to be able to move forward three squares [03], while P5 was unhappy at only being able to move forward by a square [04]. Due to the movements of each plant, Rubus Microphyllus and Pinus Densiflora arrived at the same square, resulting in a mutual action. Consequently, Rubus Microphyllus had to move back two squares, and expressed anger toward the player playing Pinus Densiflora [08].

4 CONCLUSIONS

In this paper, we proposed and tested a movement-based "Human SUGOROKU" game designed to educate students about vegetation succession while having fun. The results of our evaluation, based on participants' comments during the game, indicated that the participants were thoroughly immersed in the game. We surmise that there are two reasons for this result: (1) The participants were able to experience fondness for the plant they played, since the participants themselves were the pieces in the SUGOROKU game. (2) Because the participants had to move forward or backward according to whether the plants flourished or decayed, respectively, they felt as if they were the actual plants.

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