Science Education Enhancement within a Museum using Computer-human Interaction Technology

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Abstract: We are developing an immersive learning support system for paleontological environments in museums. The system measures the physical movement of the learner using a Kinect sensor, and provides a sense of immersion in the paleontological environment by adapting the surroundings according to these movements. As the first step toward realizing an immersive learning support system for museums, Yoshida et al. developed and evaluated a prototype system. However, their system cannot learn about certain paleontological features such as the names of extinct animals and their characteristics. Therefore, we developed an improved version of this system that allows for an enriched knowledge of paleontological environments, focusing in particular on extinct animals and plants and the ecological environment. Here, we evaluate the system's learning assistant and immersive features insofar as they are directed toward children in primary school. This paper summarizes the current system and describes the evaluation results.

1 INTRODUCTION

Museums are important places for children to learn about science (Falk and Dierking, 2012). They also operate as centers for informal education in connection with schools, and they enhance the effectiveness of scientific education (Stocklmayer et al., 2010). However, because the main learning method within museums is the study of the specimens on display and their explanations, there are few chances for learners to observe or experience the environment about which they are learning. In particular, it is impossible to experience a paleontological environment, which includes extinct animals and plants and their ecological environment (Adachi et al., 2013). It is difficult for children to learn about such environments merely with fossils and commentary. Overcoming this problem would qualitatively improve scientific learning within museums.

One solution to this problem would be some sort of booth and video content that reproduced the paleontological environment artificially. However, issues pertaining to space and cost mean that most museums cannot accommodate such an exhibit.

Hence, we are developing an immersive learning system that will enable learners to explore a virtual paleontological environment at any museum. This "Body Experience and Sense of Immersion in a Digital paleontological Environment" (or BESIDE) system acquires information regarding the learner's movement using a Kinect sensor, and operates according to this information. The system uses multiple screens spread across the learner's entire field of vision. By being projected into this virtual space, the learner can adopt physical movements as observational actions. We expect that this will engender a sense of immersion in the virtual space. Because BESIDE comprises only a commercial image sensor, projector, and control PC, we can provide a low-cost immersive learning experience within a small space.

As the first step toward realizing an immersive learning support system for museums, Yoshida et al.

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developed and evaluated a prototype system (Yoshida et al., 2015).

Their system allows the learner to experience the paleontological environment. By being projected in such a paleontological environment, the learner can adopt physical movements as observational actions. This engenders a sense of immersion in the paleontological environment. However, their system is limited insofar as users cannot learn about these paleontological environments, including the extinct animals and plants and their ecological environment. Because of this limitation, we developed an improved version of the system developed by Yoshida et al. With our proposed system, learners can develop a richer knowledge of paleontological environments, including extinct animals and plants and the ecological environment.

In this paper, we summarize our improved version of the system developed by Yoshida et al., and we describe an evaluation of its learning support and immersion.

2 IMMERSIVE LEARNING SUPPORT SYSTEM

2.1 BESIDE

We are developing "BESIDE" as an immersive learning system that enables learners to explore a virtual paleontological environment at any museum. BESIDE consists of various sensors and digital learning content. The sensors measure the learners' location, pose, and actions, and the learning content is then controlled according to these measurements. Figure 1 illustrates the concept of BESIDE.

Figure 1: Concept of BESIDE.

Learners walk around a space containing a screen that displays a virtual environment, and observable objects such as animals move in synchronization with them. In this way, learners feel immersed in the paleontological environment. Synchronizing the movement of the paleontological animals with that of the learner makes it possible to consider the animals "real" in some sense, rather than imaginary.

Furthermore, by introducing near-real activities, such as "approaching the observable object" or "diving into water," the level of interest and learning effects are more enhanced than they would be by merely attending a typical exhibition or watching a video.

2.2 Current System

We are developing a system that includes a figure of the learner in a virtual environment displayed on the screen, allowing the learner to experience the paleontological environment and learn about extinct animals and plants and the ecological environment. Figure 2 shows the setup of the current system.

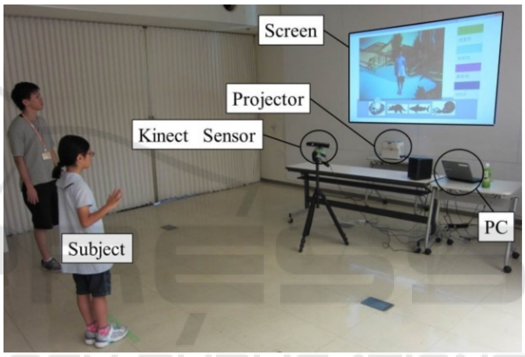


Figure 2: Setup of the current system.

In the system, the learner first stands in front of the screen, and a camera image of the learner is displayed with the background removed. Learners can change the background by moving their hands and interacting with the content. The system then allows learners to select animals appropriate for different geologic eras, and these are then displayed on the screen. Furthermore, the animal's characteristics are displayed in the screen. Learners use their hands to select the animal's name and then interact with the content.

The system must be able to acquire real-time data regarding the learner's location and movements. Thus, we utilize Microsoft's Kinect sensor, a range-image sensor originally developed as a home videogame device. Although it is inexpensive, the sensor can record sophisticated measurements regarding the user's location (Shotton, J., 2011). Additionally, this sensor can recognize humans and the human skeleton using the library in Kinect's software development kit for Windows. Kinect can measure the location of human body parts such as hands and legs, and it can identify the user's pose or status with this function and the location information. We use these functions to recognize humans and detect the human skeleton.

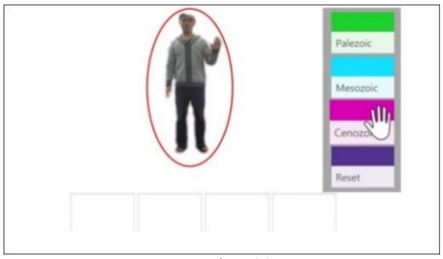
The system reproduces a paleontological environment by placing a suitable animal from one of three geologic eras (viz., Paleozoic, Mesozoic, and Cenozoic) into the display. The animals appropriate to each era are listed in Table 1. We also prepared three kinds of fossils that are typical of these animals—i.e., fossils that can be found at the museum. Furthermore, we prepared animals' names and characteristics. With this system, information regarding the frames and depth are measured with the Kinect sensor. The measurements are sent to the PC, and various images are displayed on the screen. The system has the following functions:

(a) Displays images based on sensor information;
(b) Operates using the learner's body motion;
(c) Enables observations of animals as GIF animations.
(d) Teaches animal names and characteristics

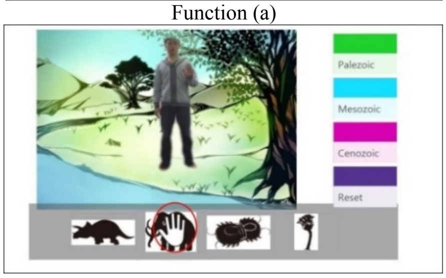
Table 1: Details of animals.

Paleozoic	Mesozoic	Cenozoic
Elrathiakingi (Trilobite)	Perisphinctina (Ammonoidea)	Mammoth
Orthoceras	Triceratops	Merycoidodon
Crinoidea	Mosasaurus	Shark

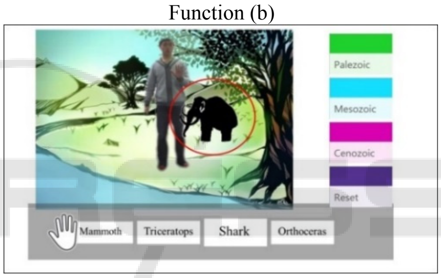
Function (a) displays the user on the screen by recognizing the user's outline. Accordingly, the user is placed into the paleontological environment. Function (b) allows the system to operate according to the user's hand movements. The learner can click a button by pushing his/her hand toward the Kinect sensor. The learner then chooses one of the three geologic eras, and the screen is replaced with an image appropriate to that era. Icons of the animals are displayed at the bottom the screen. If the learner selects an animal from that geologic era, the animal is displayed on the screen. If the selected animal is from a different era, a warning sounds and the learner is asked to choose again. This enables the system to teach the learner about which animals lived in each era, in addition to providing a sense of immersion. Function (c) enables the displayed animal to move around the screen as a GIF animation. By means of this, learners can observe extinct animals as though they were real. Function (d) displays animals' names at the bottom the screen. If the learner selects the correct name of the animal, its characteristics are displayed on the screen. If the selected animal is from the wrong era, a warning sounds and the learner is asked to choose again. By means of this, the user learns about paleontological environments, including extinct animals and plants and their ecological environment. Figure 3 shows a learner using the current systems' functions.



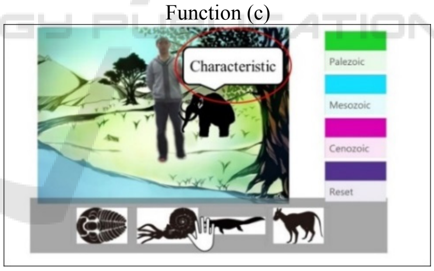
Function (a)



Function (b)



Function (c)



Function (d)

Figure 3: Functions of the current system.

Figure 4: Using the current system.

3 EVALUATION

3.1 Method

Participants: The participants comprised 27 students (age: 10–11 years) from an elementary school in Kobe, Japan (12 boys and 15 girls).

Process: The participants were organized into groups of 3–4, and were instructed to observe selected fossils on display at the museum. These fossils were from organisms available in the prototype system.

Participants used the system, one by one. The participants were able to select the geologic era relevant to the fossils they studied—viz., Paleozoic, Mesozoic, and Cenozoic—and the paleoecology of the era was then simulated. We prepared three silhouette quizzes and three quizzes regarding animal names for each geologic era. Each of the participants spent approximately five minutes interacting with the system. Finally, the participants evaluated the system.

Evaluation: A questionnaire was used to evaluate two features of the system: learning assistance and immersion. The questionnaire consisted of 12 items. The learning assistance provided by the system was evaluated with five questions regarding changes in the understanding and interests of the participants after experiencing the paleoecological simulation.

Immersion was evaluated with seven questions (based on Player Experience of Need Satisfaction Physical/Emotional/Narrative Presence Scale) regarding the effectiveness of the system at enhancing the immersive experience of the paleoecological simulation and the learner's projection into the scenery. For each question, participants answered, "strongly agree," "agree," "agree somewhat," "neutral," "disagree," "disagree somewhat," or "strongly disagree."

Date of Experiment: July 25, 2015

Location: Natural Science Museum, Hyogo Prefecture.

3.2 Results

The average scores for each quiz were as follows: the silhouette quizzes resulted in an average of 2.68, and the quizzes regarding animal names resulted in an average of 2.82.

Data obtained from the questionnaire was divided into two groups—positive evaluations ("strongly agree," "agree," and "agree somewhat"), and neutral or negative evaluations ("neutral," "disagree," "disagree somewhat," and "strongly disagree")—and the results for the two groups were totaled. The difference between the positive and neutral/negative evaluations was computed using Fisher's Exact Test (1 x 2).

Table 2: Results of evaluation about learning assistance.

Item	7	6	5	4	3	2	1
When I accomplished all the quizzes in the system, I experienced genuine pride.**	17	5	6	0	0	0	0
When I read the explanations of the ancient organisms provided by the system, I believed that they were effective at improving the learning experience at the museum.**	15	6	5	1	0	1	0
Using body motion in order to complete the quizzes was fun.**	20	5	3	0	0	0	0
The silhouette quizzes were effective at improving the learning experience at the museum. **	19	6	2	1	0	0	0
The quizzes regarding animal names were effective at improving the learning experience at the museum.**	21	4	2	1	0	0	0
N=28 7:Strongly Agree, 6:Agree, 5:Agree Somewhat, 4:No Option, 3:Disagree Somewhat, 2:Disagree, 1:Strongly Disagree **P<0.01							

Table 3: Results from the Evaluation of the Proposed System's Immersion.

Item	7	6	5	4	3	2	1
When I used the system, I felt transported to another time and place.**	11	8	8	0	1	0	0
Observing an ancient era felt like taking an actual trip to a new place.**	12	5	7	2	2	0	0
When I moved entities with the system, I felt as though I was actually there.**	12	4	7	3	2	0	0
I was not impacted emotionally by the events in the system. (-)	3	2	5	3	3	4	8
I experienced feelings as deeply in the system as I have in real life.**	16	7	4	1	0	0	0
When I used the system, I felt as though I was part of the ancient era. **	10	3	77	77	10	1	0
I reacted to the ancient environments and organisms in the system as though they were real.	8	5	7	4	3	1	0
N=28 (-): reverse item 7:Strongly Agree, 6:Agree, 5:Agree Somewhat, 4:No Option, 3:Disagree Somewhat, 2:Disagree, 1:Strongly Disagree **P<0.01							

Table 2 shows the results for the questionnaire regarding the system's ability to assist in learning. A significant difference was observed for all the items regarding the system's learning assistance, in which the neutral/negative group outnumbered the positive group. This result implies that the participants believed that the system helped them to learn about ancient organisms and the eras in which they existed.

Table 3 shows the results for the questionnaire regarding immersion. "I was not impacted emotionally by events in the system" is a reverse item. Therefore, we transferred the scores "strongly agree" to "strongly disagree," "agree" to "disagree," and so on. A significant difference was observed in six items from this questionnaire, in which the neutral/negative group outnumbered the positive group. A significant difference was not detected in only one item, namely "I was not impacted emotionally by the events in the system." These results imply that the participants believed that the proposed system facilitated an immersive paleoecological experience. However, participants require more interactive and stimulating events in order to be emotionally impacted by the environment.

4 CONCLUSIONS

This paper summarized and evaluated an improved version of the system developed by Yoshida et al. The proposed system allows users to enrich their understanding of paleontology, including extinct animals and plants and their ecological environment. We evaluated the proposed system in terms of its ability to assist primary-school children learning about such environments in museums, and in terms of its potential to facilitate an immersed experience. The results showed that the neutral/negative group outnumbered the positive group. The results also suggest that the proposed system helps users to learn about ancient organisms and the eras in which they existed and that it facilitated an immersive paleoecological experience. In future work, we intend to enhance the immersive experience of users in the paleontological environment using a technique that modifies the background according to the movements of the learner.

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