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Learning Support System for Museum exhibits using Complex Body Movements --Enhancing Sense of Immersion in Paleontological Environment

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Abstract: This paper presents a support system to assist learning in museums. Museums are important places for children to learn about science. At present, the main learning methods in museums involve the study of various displays and their explanations. The opportunities for user to observe or experience the environment about which they are learning are limited. It is difficult for children to learn and comprehend paleontological environments. Therefore, in this study, we work towards the development of a body experience-based learning support system that is applicable to museums. In an initial step toward realizing an immersive learning support system in museums, Yoshida et al. proposed a prototype system. However, users carry out all the learning with that same body movement. On the other hand, in our proposed system, users can learn about paleontology using various body movements and complicated body movements that are characteristic to paleontology. This enhances the sense of immersion in the paleontological environment by incorporating body movement as an observation behavior of paleontology. In addition, the user's involvement in learning and motivation to participate are improved, and the effectiveness of the individuals' learning process is improved because they can comprehend the various body movements of extinct animals. In this study, proposed immersive learning support system is applied to the fossil exhibition at a museum. In addition, the evaluation of user questionnaires were conducted with the objective of clarifying whether the proposed system can provide learners with a realistic paleontological observation experience.

Keywords: Kinect v2 sensor, Immersive, Learning Support System, Body Movements, Game

1. Introduction

Museums play an important part in the learning experience of children in the field of science and history. (Falk, 2012). However, because the primary learning methods in the museum include research on display and explanations, the opportunities to observe or experience the environment for learners are limited. In particular, it is impossible to experience paleontological environments including extinct animals and plants and their ecology (Adachi, 2013). Watching fossils and listening to explanations is insufficient for helping children to learn about such environments. In addition, children cannot actively learn with interest only with the aid of displays or verbal explanation. Overcoming these problems will qualitatively improve the scientific learning environment in museums. With regard to these problems, a system that simulates paleontological environments and transitions, which otherwise cannot be experienced in reality, will solve these problems. The system should also enhance the sense of immersion of the learners.

In order to enhance the sense of immersion, a full body interaction interface, wherein the movement of the whole body is linked to the operation of the system was previously shown to be effective (Klemmer, 2006). Yoshida et al. (2015) also developed a system that attempted to realize a full body interaction interface; however, the system could only be operated using one simple body movement such as raising of hands. Users were required to perform all actions using the same body movements. Therefore, it is difficult for individual learning contents to leave an impression on the users. Moreover, improving the involvement and motivation of users to participate is difficult because of the repetitive body movements.

We developed an immersive learning support system, called "BELONG". BELONG supports complex body movements that are characteristic to paleontology, which will aid users to learn about paleontology. The system is designed to enhance the user's sense of immersion in the paleontological environment by incorporating body movement as an observation behavior of paleontology. In addition, the user's involvement in learning and motivation to participate are improved; thereby improving the effectiveness of an individual's learning experience.

In this paper, we describe an immersive learning support system for the fossil exhibitions in museums. In addition, we also describe the results of our questionnaire-based experimental evaluation with the aim of clarifying whether the proposed system can provide learners with a realistic paleontological observation experience.

2. Learning Support System

2.1 BELONG

The proposed BELONG system accepts the user's body movements as input for observational behavior. The system uses different body movements for different extinct species. The movements of the user's whole body and the system operation are linked; thereby, enhancing the user's sense of immersion in a paleontological environment. Learners can actively learn while having fun. A user's sense of immersion can be improved if the system is operated in conjunction with complicated body movements, as compared to the case wherein the system is operated using simple body movements. The complicated body movement of this system is big body movement of the individual difference. For example, running and jumping are (Sakai, 2016).

The recognition of complicated body movements and various body movements should not involve attaching expensive sensors or devices on the user's body, particularly when the application is intended for a museum environment. In this system, we utilize Microsoft's Kinect v2 sensor, which is a range-image sensor. BELONG consists of a Kinect v2 sensor, projector, and control PC; therefore, it enables the provision of a low-cost immersive learning experience in confined spaces. The advantage of this arrangement is that it is possible to easily modify the learning content as required.

2.2 Configuration of the System

BELONG simulates paleontological environments and transitions that are otherwise impossible to experience in reality. As a first step towards the realization of this system, we are developing a system to simulate paleoecology, which particularly deals with the study of dinosaurs, based on experiences that simulate a paleontological excavation. This was based on our assumption that learners' interest would be improved when they are allowed to virtually excavate the fossils included in the current museum exhibit.

In this section, we describe the Kinect v2 sensor used to recognize the body movements of the users. Microsoft's Kinect v2 sensor is a range-image sensor originally developed as part of indoor video-gaming system. Although it is inexpensive, the sensor can take sophisticated measurements and adjudge the user's location. In addition, this sensor can recognize humans and the human skeleton using the library in Kinect's software development kit for Windows. Kinect can measure the three-dimensional skeletal location of 25 points on the human body, including hands and legs, and it can identify the user's pose or status based on these functions. This skeletal information makes it possible to recognize various body movements. Moreover, Kinect Studio and Visual Gesture Builder are used to recognize the complicated body movements captured by the Kinect sensor (Tokuoka, 2017). Therefore, it is possible to develop a discriminator that registers the body movements we want to recognize and can accurately recognize body movements using machine learning. In this study, we adopted the movements associated with performing excavation activities at an excavation site.

Figure 1 shows the overview of this system; it comprises a Kinect v2 sensor, a control PC, and a projector. Figure 2 shows a situation while a user is experiencing the proposed system.

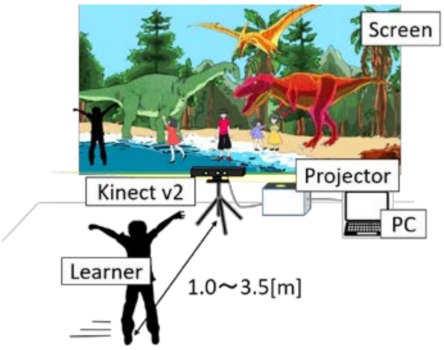

Figure 1. Setup of BELONG

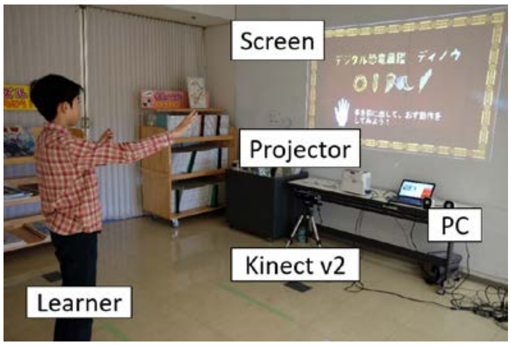

Figure 2. Situation during a System Experience

In the current system, leaners can learn about five dinosaurs; Tyrannosaurs, Tambaryu, Archeopteryx, Pteranodon, and Ichthyosaurus. The system initializes operation when users stand in front of the screen. First, they select the dinosaur fossil with which they want to play by using a "pushing motion"; the users move their palm in the direction of the screen. After selection, the users begin excavation of the corresponding dinosaur fossil. In this step, the Kinect v2 sensor is used to recognize movements of the user. When the excavation movements are performed at full power and excavation is successful, a video is displayed that shows the characteristics of the excavated dinosaur. The video shows the dinosaur's habitat and size. We determined that the excavation movement will be recognized when massive and accurate movement is done at full power. If the user makes small movements, the movements are not recognized as excavation movements. However, when the users are more enthusiastic and move their body towards the screen, their sense of immersion in the paleontological environment is enhanced. In the museum, fossils are mere sightings. However, they felt virtual excavation enhanced their participation by visualizing the virtual world.

After the users successfully complete the excavation movements, separate learning for the five dinosaurs can be conducted, wherein the five contents and recognition methods are explained to the users. Figure 3 shows the recognition methods for each of the contents.

1. **Tyrannosaurs.** Users can answer quizzes about Tyrannosaurs by pushing their palm in the direction of the screen. A video commentary is provided after users answer the quiz correctly. In the event that an incorrect is given by the user, the system allows learners to make another selection. By learning about dinosaurs in a quiz-based format, the users' willingness to participate can be enhanced.
   Next, we describe the recognition method used in the system. First, the skeletal information and coordinates of the hand are acquired by using the Kinect sensor. When the co-ordinates of the hand change with respect to the screen, the system regards it as a click. Therefore, the users can answer the questions of the quiz using body movements.

2. **Tambaryu**. Tambaryu moves in correspondence with the user's movement. If users stop moving, Tambaryu also will stop moving. This is made possible by estimating the speed of the user's motion. The users can learn about the size of Tambaryu and its walking speed while having fun at the same time.
   Next, we describe the recognition method. First, the skeletal information including the coordinates of the spine are acquired. The speed and direction of the user's walking movement are estimated based on the changes in the pixel coordinates of the user's spine on the screen between each measurement sample. Information such as the position at this time and the speed and direction of walking of a person are transmitted to the control PC, thereby making it possible for the on-screen dinosaur to follow the user's movement.

3. **Archeopteryx**. Users can feed an Archeopteryx by using the action of gripping and opening their fists. First, they can select the bait for the Archeopteryx, which is displayed on the screen, by using a gripping action. Then, they can move this bait toward the mouth of the Archeopteryx and open their hands, and the Archeopteryx eats the bait. In this manner, they can virtually experience feeding an Archeopteryx and remember what they fed it. Next, we describe the recognition method. First, skeletal information and coordinates of the hand are acquired. When the hand coordinates are dense, the system recognizes it as an opening action. When the hand coordinates are dispersed, the system regards it as a gripping action. By combining these actions, it is possible realize virtual gripping and movements.
4. **Pteranodon**. When users wave their hands in an animated fashion, a Pteranodon approaches the screen. A video of the Pteranodon approaching is displayed, and users feel like they are attacked by it. However, in the video, the Pteranodon does not have sufficient muscular strength to drag the users away. This will enable users to learn about the physical features of dinosaurs. This feature uses the Kinect's gesture recognition function (Tokuoka, 2017).
5. **Ichthyosaurus**. When learners move forward and backward, they can learn about the physical features of the Ichthyosaurus. When they approach the screen, a video showing the state of the stomach is displayed. When they retreat away from the screen, the video shows the full appearance of the Ichthyosaurus body. Thus, their sense of distance changes in conjunction with action of moving forward and backward. This enables the users to learn about the size and shape of the Ichthyosaurus. Next, we describe the recognition method. First, the skeletal information and coordinates of the spine are acquired. We assume that when the three-dimensional coordinates of the spine go beyond a certain the threshold (determined by the distance from the screen), the dinosaur approaches the screen. When that condition is satisfied, the image that approaches the dinosaur body flows. On the other hand, suppose that the three-dimensional coordinates of the spine exceed another threshold distance away from the screen, it is assumed that it is far from the screen. When that condition is satisfied, the image is switched to the image away from the dinosaur. In this way, the positions of the users are correlated with the screen.

By enabling the users to perform various complex body movements, we were able to develop a full-body interactive interface that is more immersive.

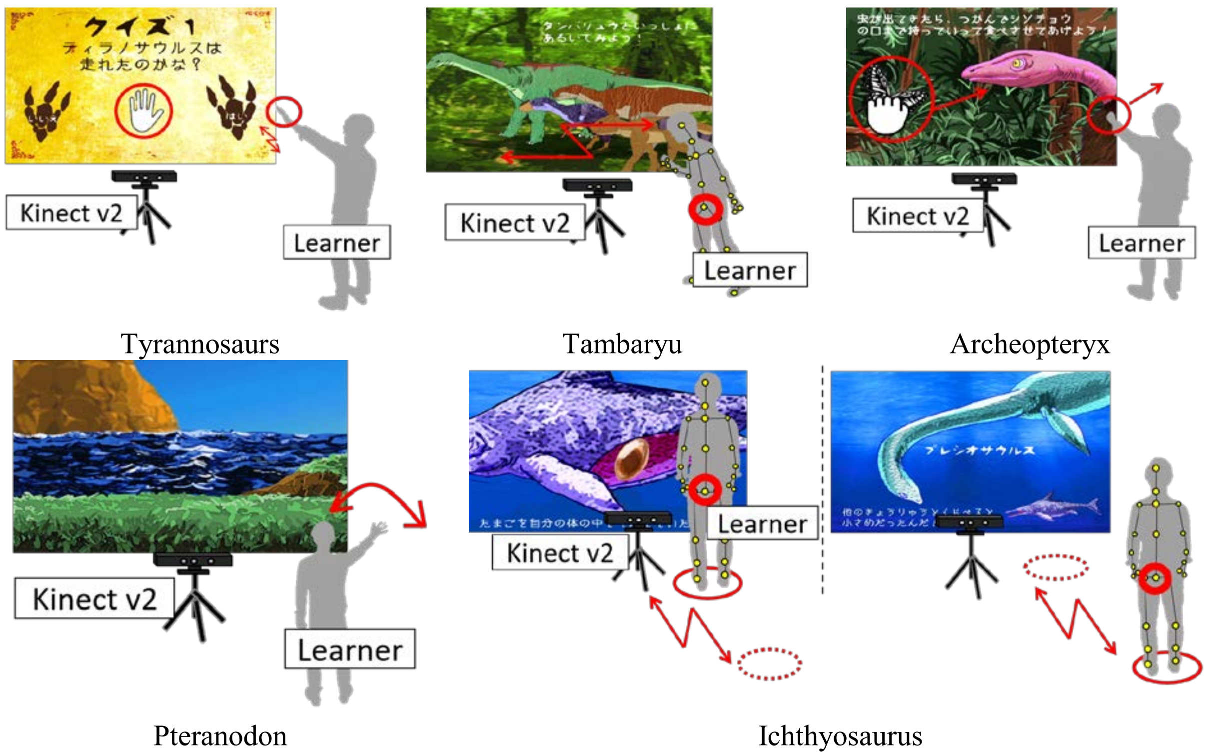

Figure 3. Various Body Movements

3. Evaluation Experiment

3.1 Methods

Thirty-five participants from 5th-grade elementary school, were used as the subjects of the study. The experiments were conducted at the Tokyo University of Science.
The subjects experienced the system in a sequential manner. As mentioned earlier, five types of contents pertaining extinct species of dinosaurs were prepared. The subjects began the experiments by selecting dinosaurs in the order of their interest. The number selected for each content is as follow; Tyrannosaurs: nine, Tambaryu: five, Archeopteryx: six, Pteranodon: nine, Ichthyosaurus: six.
Finally, we evaluated the system using survey questionnaires. There were four question items pertaining the experience of physical movement. Each question was scored on a scale of one to four, where four corresponded to "strongly agree" and one corresponds to "completely disagree."

3.2 Results

First, we classified the responses into positive responses of "strongly agree" and "agree," and negative responses of "disagree" and "completely disagree." We then analyzed the number of positive replies and neutral and negative replies using directly established calculation: 1 x 2 population rate inequality. Table 1 summarizes the results of the evaluation for the physical movement experience. For all types of contents, the number of positive responses for "I enjoyed the fact that I was moving my body," "I feel attached to extinct animal I selected," "I found it easy to use the system with my body movements," and "I want to know about other extinct animals from the paleontological era through the system experience" exceeded the number of neutral and negative responses. In addition, a significant deviation was observed between the number of responses.

Table 1: Evaluation of the overall system experienced.

Questions	Tyrannosaurs		Tambaryu		Archeopteryx		Pteranodon		Ichthyosaurus	
	P	N	P	N	P	N	P	N	P	N
I enjoyed the fact that I was moving my body.	9※※	0	5※※	0	6※※	0	9※※	0	6※※	0
I feel attached to extinct animal I selected.	9※※	0	4※※	1	6※※	0	8※※	0	6※※	0
I found it easy to use the system with my body movements.	9※※	0	5※※	0	6※※	0	8※※	0	6※※	0
I want to know about other extinct animals from the paleontological era through the system experience.	9※※	0	5※※	0	6※※	0	9※※	0	6※※	0
N=35 P: number of positive responses N: number of negative responses ※※$P < 0.01$										

4. Conclusion

In this paper, we proposed a prototype of "BELONG" as the first step of realizing an immersive learning support system for the fossil exhibits in museums. In this system, users can learn about paleontology by using various complex body movements that are characteristic of paleontology. A number of children used the proposed system and answered a questionnaire survey. The results suggest that the children were enthusiastic about the system and had fun while learning. The children experienced a further desire to learn more, and their motivation to learn increased. Therefore, by using BELONG, virtual observation of the behaviors of paleontological species based on various body movements enabled learners to experience reality.

This indicates that BELONG is effective a method for providing a place of observation to learn about aspects of paleontology, such as dinosaurs, where a direct observational experience would have been impossible.

Acknowledgements

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