Experience-based Learning using Game with Gesture Recognition and EDA-based Evaluation of the Physiological Response

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Abstract

This paper presents an educational game to assist learning in museums. Museums are important places for children to learn about science. The opportunities for a 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 toward the development of an experience-based learning support game that is applicable to museums. In our proposed system, users can learn about paleontology using various body movements, including complicated body movements that are specific to paleontology. This enhances the sense of immersion in the paleontological environment by incorporating body movement as a method for behavior observation in paleontology. We evaluated the effectiveness of this game by using electrodermal activity as the physiological indicator. In this paper, we describe the current game and its evaluation results.

Keywords

Kinect Sensor, Science Education, Full Body Interaction, Paleontology

1 Introduction

Museums play an important role in the learning experience of children in the field of science and history (Falk & Dierking, 2012). However, the mode of learning currently adopted in museums is passive. Because the primary learning methods in the museum include researching on the display items and verbal explanations, the opportunities for learners to observe or experience the environment are limited. In particular, it is impossible to experience paleontological environments, including extinct animals and plants and their ecology (Adachi et al., 2013). Watching fossils and listening to verbal explanations are insufficient in helping children learn about such environments. In addition, children cannot actively learn with interest with the aid of only displays or verbal explanation. Overcoming these problems will qualitatively improve the scientific learning environment in museums. A system that simulates paleontological environments and transitions, which otherwise cannot be experienced in reality, will address these problems. The ability to virtually experience paleontological environments, including extinct animals and plants and their ecology, delivers an immersive experience to the user, which enables the user to learn efficiently and with great interest. In order to realize efficient learning, it is necessary to improve the virtual and immersive experience delivered to the user.

A full body interaction interface, wherein the movement of the entire body was linked to the operation of the system, was previously shown to be effective in enhancing the immersive experience (Klemmer, Hartmann, & Takayama, 2006). Yoshida et al. (2015) developed a full-body interaction interface to improve passive learning; 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 was difficult for individual learning contents to provide a distinct experience to users. Moreover, the repetitive body movements made it difficult to increase the involvement of users and motivate them to participate in the learning. Thus, the system was inadequate as a learning solution.

To address the abovementioned shortcomings of conventional learning interfaces, we developed an immersive learning support game called "BELONG". BELONG supports complex body movements that are characteristic to paleontology, which will aid users to learn about paleontology.

This game aims to improve the immersive experience and normalize the learner's interest by facilitating learning using complicated physical movements. In addition, this system can simulate the paleontological environment and transitions, which cannot be experienced in reality.

In this paper, we describe the abovementioned immersive learning support game for fossil exhibits in museums. We evaluated the usability of the game by monitoring the electrodermal activity (EDA) as the physiological indicator (Yoshida et al., 2014) and quantitatively evaluating the learning interest of users in paleontology.

2 Learning Support Game

2.1 BELONG Game Overview

We are in the process of developing the immersive learning support game BELONG to simulate the paleontological environment and transitions that cannot be experienced by users. Our aim is to improve the

efficiency of environmental learning at museums to improve the motivation for users to participate in learning.
We emphasize on "active participation" as an element of the game, where the human body is used as the controller for learning. Active participation involves incorporating various body movements for behavior observation. By operating the game in conjunction with these body movements, it is possible to enhance the user's sense of immersion in the paleontological environment. Compared with the case where the game involves only simple operations, active participation with variety of body movements, including complicated body movements, enhances the sense of immersion and increases the perception of the experience. This makes the learning more interesting to users and enhances the learning effectiveness. Considering that the game is intended for use in a museum, it is infeasible to employ an expensive device or sensor to attach to the user for recognizing the various simple and complicated movements. Therefore, BELONG uses the Kinect V2 sensor, which is a commercially available three-dimensional ranged image sensor (Shotton et al., 2013). Our system combines human recognition, position measurement with the Kinect V2 sensor, and gesture recognition with machine learning.

2.2 Current Game

We are developing games that incorporate various body movements, including complicated movements, for users to enjoy while learning about paleontology and paleoecology. Figure 1 shows the overview of this system; it comprises a Kinect v2 sensor, a control PC, and a projector.

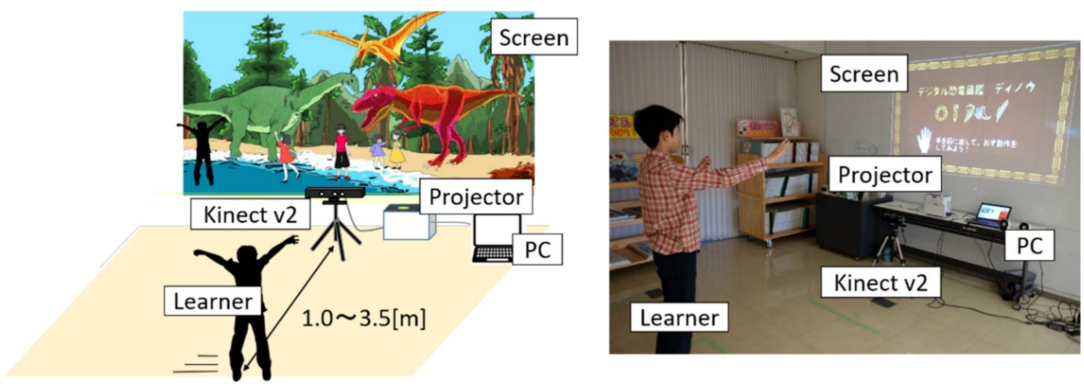

Figure 1: System overview

In the current game, users can play games with five dinosaurs, namely, Tyrannosaurus, Tambaryu, Archaeopteryx, Pteranodon, and Ichthyosaurus. Figure 2 shows the flowchart of the game.

Figure 2: System flow

First, users operate the game using their hands as the interface. They select the fossil they want to learn about by pushing their palm towards its image on the screen After selection, they excavate the fossil. The excavation operation is recognized by the system by means of the Kinect v2 sensor. Users perform the excavation activities at full power; if the excavation succeeds, images pop up showing the dinosaur characteristics such as its habitat and size. GIFs of the dinosaur excavation scene are projected on the screen so that the user can experience a virtual excavation.

After the users successfully complete the excavation movements, separate learning contents for the five dinosaurs can be accessed, wherein the five contents and recognition methods are explained to the users.

1.Tyrannosaurs. Users can answer a quiz on Tyrannosaurs by pushing their palm in the direction of the screen. The quiz has the following questions: "Is Tyrannosaurus capable of running?" "Does Tyrannosaurus have hair?" "Does Tyrannosaurus eat grass?" A video commentary is provided after a user answers the quiz correctly. If an incorrect answer is given by the user, the system allows the user to answer the question again. The user’s willingness to participate is enhanced by allowing them to learn about dinosaurs in a quiz-based format.

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. Figure 3 illustrates the operation of the system.

Figure 3: Tyrannosaurs. Users can answer a quiz on Tyrannosaurs by pushing their palm in the direction of the screen.

2.Tambaryu. Tambaryu moves in correspondence with the user’s movement. Tambaryu stops moving when the user stops moving.

The learner can experience the size of the Tambaryu dragon and its walking speed.

This is made possible by estimating the speed of the user’s motion. Thus, the users can learn about the size of Tambaryu and its walking speed in an enjoyable manner. Next, we describe the method for recognizing the user movement. 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 two consecutive measurement samples. Information such as the user position at this time and the speed and direction of walking of the user is transmitted to the control PC, thereby enabling the on-screen dinosaur to follow the user’s movement. Figure 4 illustrates the operation of the system.

Figure 4: Tambaryu. The dinosaur Tambaryu moves in correspondence with the user’s movement. It stops moving when the user stops moving.

3.Archaeopteryx. Users can feed an Archaeopteryx by using the action of gripping and opening their fists. First, they can select the bait for the Archaeopteryx from the selections displayed on the screen by using a gripping action. Then, they can move this bait toward the mouth of the Archaeopteryx and open their hands to feed the Archaeopteryx. In this manner, they can virtually experience feeding an Archaeopteryx and remember what they fed it.

Thus, users can learn about the diet of the Archaeopteryx.

Next, we describe the method for recognizing the user movement. First, the 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 to realize a virtual gripping action and other movements. Figure 5 illustrates the operation of the system.

Figure 5: Archaeopteryx. Users can feed an Archaeopteryx by using the action of gripping and opening their fists.

4. Pteranodon. When users wave their hands in an animated fashion, a Pteranodon approaches the front of the screen. A video of the Pteranodon approaching is displayed, which makes the users feel as if they are about to be attacked by it. However, in the video, the Pteranodon does not have sufficient muscular strength to drag the users away. The opportunity to view the Pteranodon from a close range enables users to learn about its physical features. This feature uses the Kinect's gesture recognition function (Tokuoka et al, 2017). Figure 6 illustrates the operation of the system.

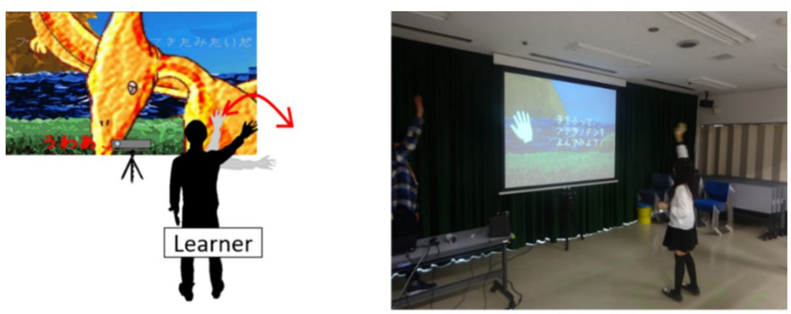

Figure 6: Pteranodon. When users wave their hands in an animated fashion, a Pteranodon approaches the front of the screen.

5. Ichthyosaurus. When learners move forward and backward, they are shown the physical features of the Ichthyosaurus. When they approach the screen, a video showing the state of its 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 from the Ichthyosaurus changes in conjunction with the action of moving forward and backward. This enables the users to learn about the size and shape of the Ichthyosaurus. Next, we describe the method for recognizing the user movement. First, the skeletal information and coordinates of the spine are acquired. We assume that the user is close to the screen when the three-dimensional coordinates of the spine go beyond a certain

threshold (determined by the distance from the screen). When this condition is satisfied, a close-up image of the dinosaur is displayed. On the other hand, the user is assumed to be far from the screen when the three-dimensional coordinates of the spine exceed another threshold distance away from the screen. When this condition is satisfied, the image of the dinosaur is switched to an image that is away from the front of the screen. In this way, the position of the user is correlated with the image on the screen. Figure 7 illustrates the operation of the system.

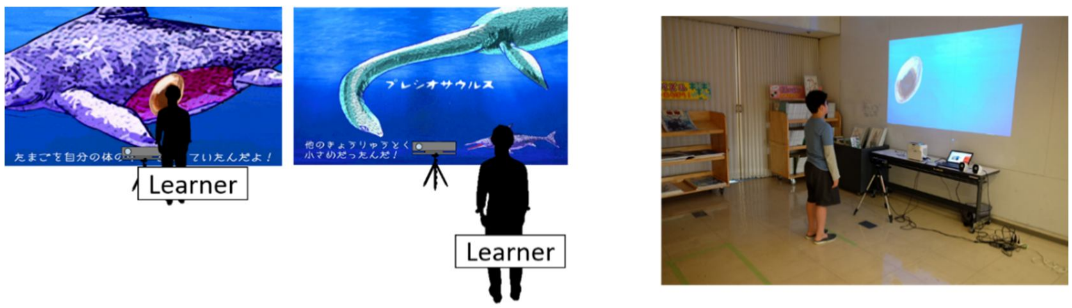

Figure 7: Ichthyosaurus. Users can learn about the physical features of the Ichthyosaurus by moving forward and backward.

3 Experiment

We quantitatively evaluated the interest of users in learning about the paleontological environment through games using body movements and by experiencing the learning. We evaluated the usability of the game by considering electro-dermal activity (EDA) as the physiological indicator.

3.1 EDA

We used EDA to confirm the presence or absence of interest in children. EDA is the change in the electrical properties of the surface of the skin due to sweating caused by excitation or tension. The method of measuring the apparent resistance by passing electricity through the skin is called the energization method. The sustained activity measured thereby is called the skin conductance level (SCL). Transient activity is referred to as the skin conductance response (SCR). The brain's limbic system is comprised of the cingulate gyrus, hippocampus, and amygdala. Recent studies have demonstrated that the limbic system is activated when a person is interested. In addition, this system is known to have a close relationship with emotion (Boucsein, 2012). When people are visually interested in a subject, they experience a pleasant feeling and an increase in arousal, which changes the electrical activity of the skin and produces an SCR (Yoshida et al., 2014). Figure 8 shows that if interest is generated, the SCL and SCR reaction values can be measured from variations in the electrical activity over relatively long and short periods, respectively. A reaction appears when a user shows interest. In contrast, no reaction appears when there is no interest. Therefore, we judge the presence or absence of interest in the proposed system using EDA.

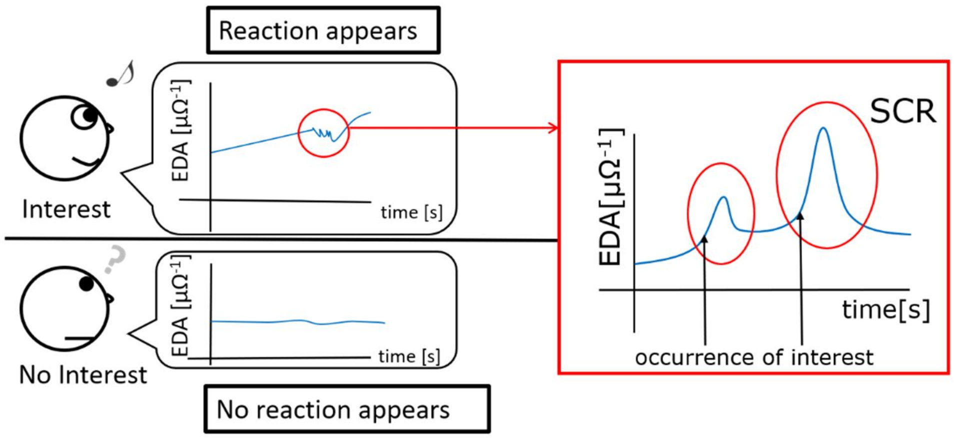

Figure 8: EDA

3.2 Methods

Participants: The subjects were 30 college students (21–25 years old).

Purpose: Our aim was to compare the effectiveness of the video being shown in the museum with that of the proposed system.

Location: The experiment was performed at the Tokyo University of Science in Chiba, Japan.

Evaluation method: In the experiment, we compared the effect of the explanatory video of the dinosaur used in the museum with that of the proposed system. We evaluated the usability of the game by using electro-dermal activity (EDA) as the physiological indicator.

Procedure: We attached an electrode that measures the EDA to the fingertips on the right hand of each subject, as shown in Figure 9.

Figure 9: Subject wearing the electrodes for measuring the EDA.

First, the learner watches the explanatory video about the dinosaur. The learner's EDA is measured at this time. Then, the learner accesses the learning items related to all five dinosaurs in the proposed system. The EDA is measured again while learning with the proposed system. Thus, we can compare whether the experience delivered by the proposed learning system is effective in generating learning interest in the user.

4 Results

We describe the results of the evaluation experiment. Figure 10 shows the change in EDA while the subject played the game, and Figure 11 shows the change in EDA when the subject was watching the explanatory video about the dinosaur. EDA can be evaluated by the number of reactions that occur in the user. The reaction in Figure 8 shows the occurrence of interest (Yoshida et al., 2014).

The figure proves that the user finds the learning item interesting when experiencing the system, whereas there is a lack of interest when the learner is watching the movie with commentary. From these results, it was confirmed that the learner's interest was aroused through the experience gained with the proposed system. Next, we will describe the results for all subjects. Table 1 shows the number of reactions in the EDA of each subject when experiencing the system and watching the explanatory video.

Statistical tests were conducted on the EDA results in the two scenarios, and a t-test analyzing the difference between the average EDA produced a result of $p < 0.01$, which corresponds to a significant difference. This result confirmed that all subjects were interested in experience-based learning through the proposed system.

The above results quantitatively clarified that interest in learning increases as learners receive an immersive experience in the virtual environment.

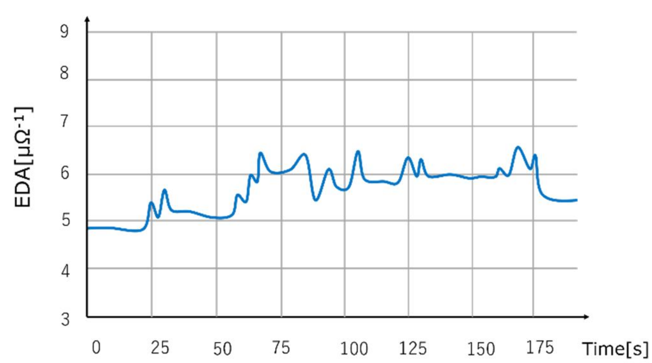

Figure 10: Change in EDA while the subject played the game.

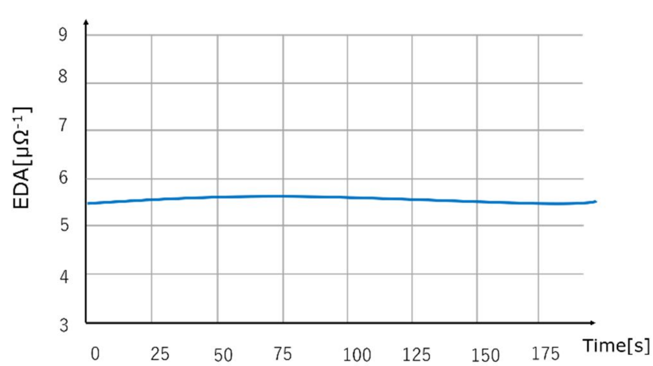

Figure 11: Change in EDA when the subject was watching the explanatory video about the dinosaur.

Subject number	1	2	3	4	5	6	7	8	9	10
EDA while experiencing the system[-]	13	9	13	16	16	21	21	15	18	11
EDA while watching the video[-]	0	2	5	3	5	3	2	5	8	2

Subject Number	11	12	13	14	15	16	17	18	19	20
EDA while experiencing the system[-]	18	11	25	14	14	21	17	15	8	16
EDA while watching the video[-]	7	3	13	2	5	9	7	4	2	8

Subject number	21	22	23	24	25	26	27	28	29	30
EDA while experiencing the system[-]	17	12	17	12	18	9	19	12	13	15
EDA while watching the video[-]	2	8	3	6	5	1	10	3	9	0

Table 1: Results of all subjects.

5 Observations and future issues

In this paper, we proposed a museum learning support game called BELONG as a first step toward increasing the interest and motivation of users to learn in museums. We described the evaluation results of the current game using EDA. The evaluation results suggested that learning with various body movements helps increase the user's interest and improves the immersive experience in the paleontological environment.

In the future, we will aim to have multiple users manipulate multiple paleontological exhibits at the same time. We will measure the interest shown by different users at the same time as they respond to multiple images on the screen. With this, we aim to promote learning in paleontology by improving the immersive experience of learners in a paleontological environment.

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