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IMMERSIVE LEARNING SUPPORT SYSTEM BASED ON KINECT SENSOR FOR CHILDREN TO LEARN ABOUT PALEONTOLOGICAL ENVIRONMENTS

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Abstract- This paper proposes a simulation-based environmental learning support system, based on Kinect sensors, which is currently under development. Our system animates paleontological animals and their habitats on a display in synchronization with learners' actions, immersing learners in a real-life paleontological environment. We evaluated the system by recording real-time measurements of

learners' movements, and controlled the animation based on sensor output. Participants were subsequently interviewed to assess their sense of immersion. The system was found to provide a near-real experience of a defunct environment and the results confirmed that learners felt a sense of immersion and experienced an enhanced interest.

Index terms: **Kinect sensor; virtual environment; simulated experience; environmental learning; synchronized animation; learner experience; assessment interview; animation control; interactive animation; socket communication; near-infrared sensing; human movement.**

I. INTRODUCTION

In general, when studying past environments and life forms that no longer exist (e.g., a paleontological environment), we do not have the opportunity to make direct observations. Thus, it is difficult, especially for children, to develop a genuine understanding and interest in the past environment. This problem may be solved by finding a method to promote the learners' sense of immersion and interest in these past environments and to motivate their observation of these life forms.

This study focuses on body experience in learning [1, 2] by proposing an immersive learning environment based on a system using Kinect sensors. The proposed system animates the environment and the animals featured in the display in synchronization with learners' actions, enabling them to interact with "live" animals in a detailed, realistic world. The aim of the system is to provide a simulated experience of environments that have since become extinct and to promote interest and encourage closer observation of these environments. Further, we aim to evaluate whether the proposed system is capable of providing learners with the feeling that they are experiencing the environment.

II. IMMERSIVE ENVIRONMENTAL LEARNING SYSTEM

a. Introduction of body experience into learning

In general, children's environmental learning can be enhanced through real life experiences such as fieldwork, in addition to books, exhibits, and computer contents. However, when learning about environments that no longer exist, learners cannot watch or experience the environment, and have to rely on previously documented material, such as books. Thus, it is difficult for them to experience a sense of immersion into the environment due to their interest is not isufficiently stimulated. They may not develop the desired understanding. In this regard, the difficulties associated with immersing a user in the learning environment (i.e., the learning target) are considered. This is due a lack of body experience in learning [3, 4]. When learning through books, exhibits, and computer content [5, 6, 7], the body experience of the learner is limited to experiencing the environment through audio-visual perception from the outside. They are not fully immersed in the environment.

With the aim of providing a near-real experience, we are developing an immersive learning support system that permits a physical experience (Figure 1) . This system involves an animation of extinct animals and their environments, which is projected onto a large-scale display. Paleontological animals from 30 million years ago are animated on the screen, which displays information about the animals in synchronization with learners' actions. Learners can move the animals or environment, thereby obtaining knowledge by performing physical movements with their bodies. In this manner, learners feel more of a body experience and sense that they have entered the virtual environment by changing the animations in this environment using body actions. This physical experience provides a deeper sense of immersion than merely watching exhibits or videos, and it will help improve the interest and motivation for observing the content.

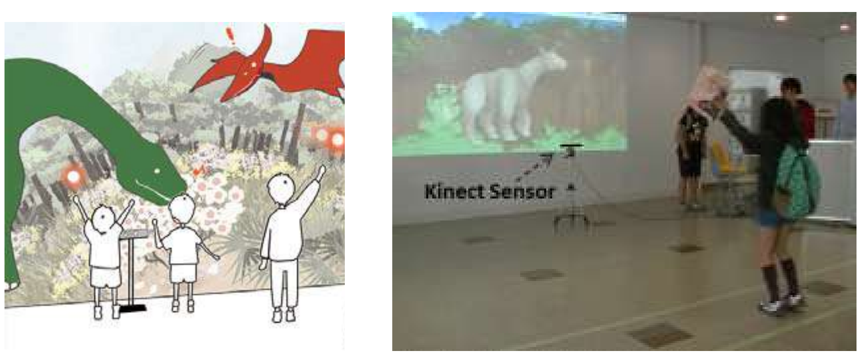

Figure 1. Immersive Environment Learning Support System

b. Configuration of the system

The system should be able to control the animation in synchronization with human movement, which requires real-time knowledge of the human's location and actions. We utilized Microsoft's Kinect sensor (Figure 2) for this purpose. The diagram in Figure 3 shows the configuration of the system.

The Kinect sensor is a range image sensor originally developed as a home video-game device. Although it does not cost much, the sensor can record advanced measurements of the location of an object. By projecting special near-infrared light patterns, followed by the detection of subsequent distortions in the pattern, this sensor can measure the distance to a subject. Further, this sensor can recognize humans and the human skeleton using a library such as OpenNI [8, 9, 10]. Moreover, the sensor is capable of measuring the location of human body parts, such as hands and legs. By using these functions, it becomes possible to detect a human's physical actions (e.g., "walking," "sitting," etc.) by determining the positional relation of the respective body parts.

The virtual environment was created with FLASH animation through ActionScript and moves according to input provided in the form of numerical values. Information about the human's location and actions is sent to the PC in control of the animation. Subsequent to which the information is exchanged through socket communication before it is forwarded to the PC controlling the FLASH animation. Finally, depending on the information received, the animation is projected onto the display.

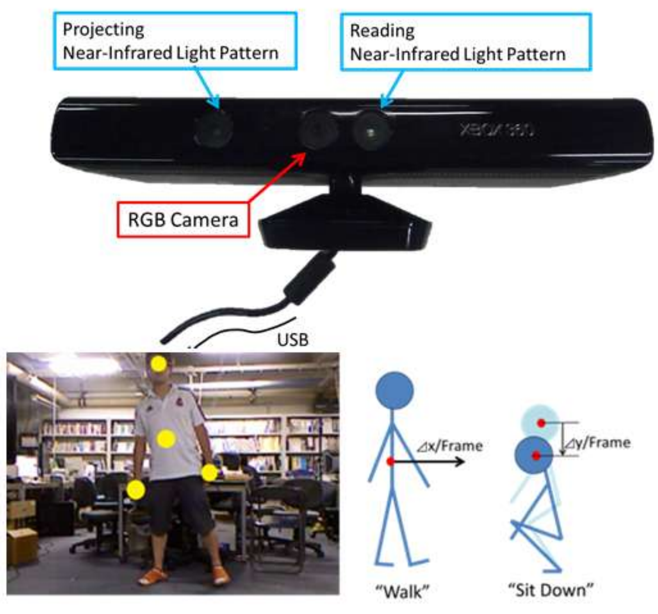

Figure 2. Kinect Sensor

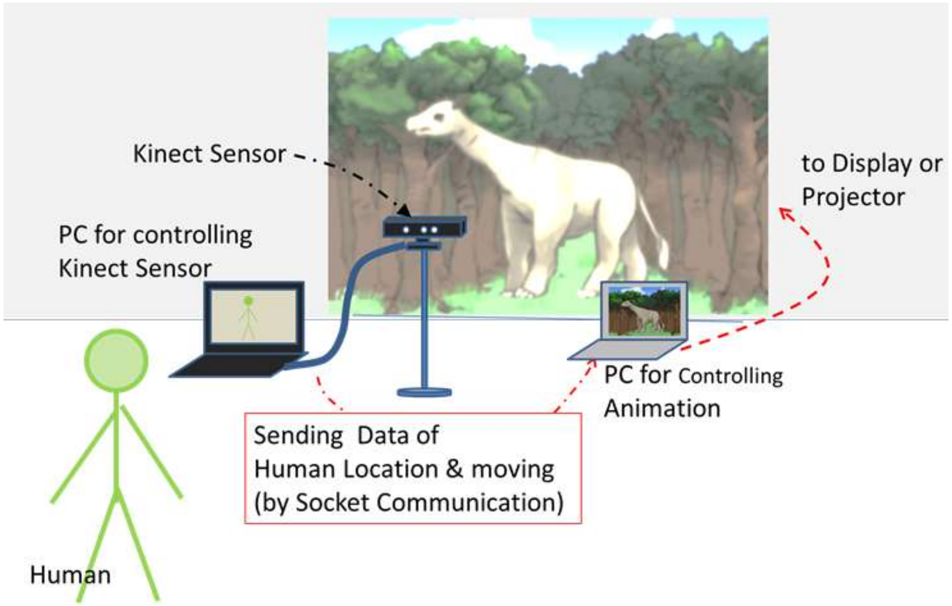

Figure 3. Configuration of the System

III. EVALUATION

a. Evaluation Method

Purpose: We identified the effectiveness of the immersive environmental learning system by comparing situations in which the animation was both unconnected (henceforth, "non-interactive animation") and connected (henceforth, "interactive animation") to participants' body movements, as provided by the immersive environmental learning system. Both types of animation were composed of the same content.

The purpose of the evaluation was to clarify the following three points relating to the immersive environmental learning system. (1) Which approach would best promote participants' immersion into the virtual world, the interactive, or the non-interactive animation? (2) Which approach increased participants' interest in paleontological animals most, the interactive or the non-interactive animation? (3) Which approach most effectively promoted participants' observation of paleontological animals, the interactive or the non-interactive animation?

Tasks: Each task comprised three items. The first was an immersion-related task to ascertain the animation made the participants feel that they had entered the world of paleontological animals, the interactive or the non-interactive animation (henceforth, "immersion task"). The second was an interest-related task to ascertain the animation that was more effective at stimulating learners' desire to learn more about paleontological animals, the interactive, or the non-interactive animation (henceforth, "interest task"). The third was an observation-related task to ascertain which animation allowed careful observation of paleontological animals, the interactive, or the non-interactive animation (henceforth, "observation task"). We asked the participants to select either interactive or non-interactive animation for these three tasks and also requested them to explain the reasons for their selection. These tasks were performed by conducting individual interviews.

Participants: Ten students (aged from 11 to 12 years) in the sixth grade of a Japanese elementary school were recruited to participate in our study.

Procedure: The participants were separated into two groups and shown the interactive animation and the non-interactive animation. The order in which the animations were shown was different depending on the group. This was to control for the order effect. The time required for the interactive and non-interactive animations was about 1 minute, respectively, after which we conducted the interviews to assess the tasks. The time required to interview each person was about 10 min. The evaluations were carried out from February 27 to February 28, 2014.

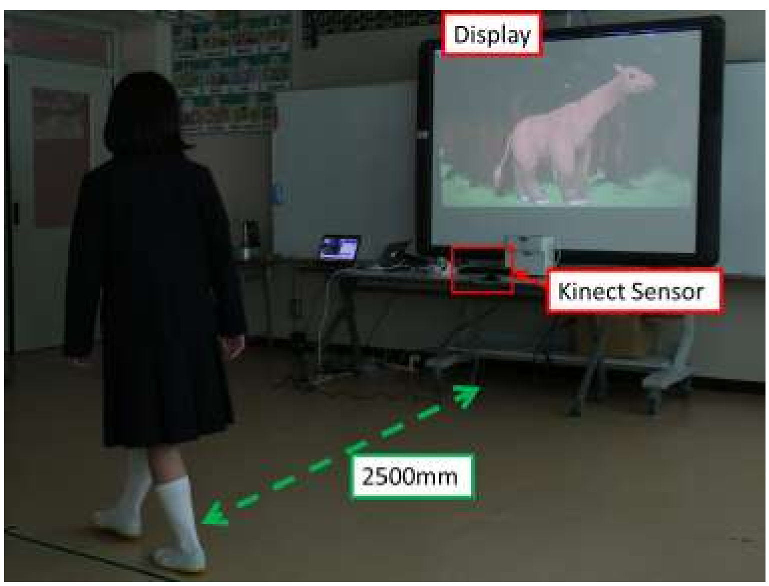

Figure 4. Experimental Environment

Table 1: Responses to the Three Tasks

Task	Number of people who selected interactive animation	Number of people who selected non-interactive animation
Immersion task*	9 people	1 person
Interest task	7 people	3 people
Observation task	4 people	6 people

Note: N=10 for each task; numerical values show the number of participants. * $p < .05$

b. Results

The results did not reveal a difference between the tendencies of the responses of the two groups that could be ascribed to the different order in which the tasks were performed. Thus, we will explain the results by aggregating the responses of the participants in both groups. Table 1 lists participants' responses for the immersion, interest, and observation tasks. First, an examination of the results of the immersion task showed that nine participants selected interactive animation, whereas one participant selected non-interactive animation. We then conducted a Fisher's exact test to test for response bias. The results showed the number of participants who chose interactive animation to be significantly higher than those who chose non-interactive animation ($p < .05$). Table 2 lists representative reasons provided by the participants as to why they selected interactive animation in the immersion task. P2 stated that it enabled them to feel as though they had entered the world in which the paleontological animals lived, because when they moved, the animals also moved in the same direction. In addition, P7 felt as though the paleontological animals were curious about them because the animals would react to their movements and stated that it felt as though they had entered the world of these animals. As noted above, participants described the interaction between their physical movements and the corresponding reactions of the paleontological animals by the raising of hands. On the other hand, the non-interactive animation was only chosen by P4, who pointed out that the benefit of selecting this option was that it allowed them to concentrate on observing the paleontological animals without having to perform any physical movement. P4 also stated that he felt that he was able to enter the world in which the animals existed by focusing on watching the display.

Next, the results of the interest task showed that seven participants selected the interactive, while three the non-interactive animation. A Fisher's exact test, conducted to test for response bias, did not show a significant bias between the responses of the two groups ($p > .10$). Table 3 presents

Table 2: Representative Reasons in Immersion Task

Participant	Selected Animation	Selected Statements
P2	Interactive Animation	The one where I was constantly moving (the interactive animation) felt like I was there in their world, more than the one where I was just standing (non-interactive animation.) It felt like I was somewhere in a forest. It sounds odd to say that I was manipulating it myself, calling it, (the paleontological animal), raising my hand, and walking, but because it walked in the direction I walked and followed me, it felt like we were there together.
P7	Interactive Animation	Because the animals responded to what I was doing, it felt like I was in their world. And because they followed my direction, I thought they were curious about me. I liked it because the paleontological animals' (movements) changed in response to what I was doing.
P4	Non-Interactive Animation	While I was moving my body, I tended to concentrate on my movements. But when I was staring at the movements of the paleontological animals, I was able to concentrate only on watching them. So, I was able to feel like I was in the world in which the animals lived, which included the forest scenery.

Note: P2: Participant2, P7: Participant7, P4: Participant4. "( )" indicates supplementary comments of the author.

the representative reasons for the participants' decisions to select interactive animation to carry out the interest task. P6 felt that the paleontological animals appeared interested in the participants, because their movements and the animals' movements were

connected. As a result, P6 stated that they wanted to examine how the animals ran, and, in addition, that their interest grew in the paleontological animals' distinct features. They would be unable to understand solely by watching the animation about their food. P10 felt a sense of affinity toward the paleontological animals due to the connection between their movements and those of the paleontological animals. As a result, they became increasingly interested in the paleontological animals' names, groups, and ways of living. As stated above, the reasons for the results were confirmed—the participants felt that the paleontological animals showed an interest in them and, in turn, they felt a sense of affinity toward these animals. The statements made by P4 and P9 as to why they chose the non-interactive animation are discussed from now on. P4 selected the non-interactive animation, because it allowed them to concentrate on those aspects of the animal movements in which they were interested without the need to perform any movements themselves. P9 pointed out the disadvantage of having to focus excessively on her physical

Table 3: Representative Reasons in Interest Task

Participant	Selected Animation	Selected Statements
P6	Interactive Animation	(The paleontological animal) Looked at me, showed interest in me, and chased me. This animal, if it is interested in something, will it chase it? How does it run? I thought about various things. They were the same living things as cats or dogs, but the way they moved their feet was different, wasn't it? How does this paleontological animal do it? Also, is it an herbivore, a carnivore? I also ended up thinking that the one I walked with (interactive animation) would not come out (of the display).
P10	Interactive Animation	It (The paleontological animal) moved together with me, observed me, and I had a sense of closeness to it. I thought what does this thing eat? Its name, its group, how it lives. I did not stare at it but I had a sense of closeness to it, so I wanted to know more about it. I think it is the same for humans, we feel like we want to know more about our partners, that's why I wanted to find out about it (the paleontological animal).
P4	Non-Interactive Animation	When I was watching the (non-interactive) animation, I was able to thoroughly focus on the animals' movements. So I wanted to know why they made movements like that. I also wanted to know what they were eating, how strong they were, and how violent they were by nature.
P9	Non-Interactive Animation	I chose this animation because when I had to move my body (with the interactive animation), and I had to concentrate on my own movements. But when I watched the (non-interactive) animation, I knew I concentrated on the animation itself and I was able to pay attention to other details as well as the moving animals. When I was watching the animation, I was able to imagine the type of forests in which they lived, the type of living creatures that they had to fight and the sizes and shapes of the animals.

Note: P6: Participant6, P10: Participant10, P4: Participant4, P9: Participant9. "( )" indicates supplementary comments of the author.

movements during the interactive animation. With the non-interactive animation, it was possible to observe the entire display in a careful manner. Thus, P9 expanded her interest to include the forest that was displayed, in addition to the animals. The aforementioned reasons provide examples of a case in which the participants were intensely interested in features of animals. A case in which the participants were interested in aspects over and above the animals, such as the forest in which the animals lived.

Next, the results of the observation task, for which four participants selected interactive animation and six selected non-interactive animation, are described. Fisher's exact test for response bias did not show a significant bias.

Table 4: Representative Reasons in Observation Task

Participant	Selected Animation	Selected Statements
P6	Interactive Animation	If I had chosen to watch the (non-interactive) animation, I would have watched the entire display distractedly, rather than concentrating on the animals on the display. So I could not have concentrated on the different parts of the animals. When I ran, the animals ran too. So, I was able to see the movements of their feet. When I chased them, I paid attention to the animals rather than the background. When I sat down, the animals stopped and I was able to see them blinking. So, I think that I was able to observe the animals well when I was walking together with the animals (using the interactive animation).
P9	Interactive Animation	(With the interactive animation), the animals followed me, and the movements of the animals on the display matched my movements. Because of this, I felt an affinity toward the animals. So I was able to carefully observe the features of the animals.
P2	Non-Interactive Animation	(With the non-interactive animation), I was able to watch the animals while concentrating only on the animation. So I was able to focus on watching them walking. The way they walked was not the normal way of walking that I usually see. The front feet and back feet were moving almost at the same time. I noticed this because I could concentrate on watching the animation.
P8	Non-Interactive Animation	(Like the interactive animation), when I walked, I was conscious of walking. I preferred the non-interactive animation. I was able to focus solely on observation through the animation. So I was able to see different things, like the background as well as the animals.

Note: P6: Participant6, P9: Participant9, P2: Participant2, P8: Participant8. "( )" indicates supplementary comments of the author.

Between the responses of the two groups ($p > .10$). Table 4 shows the representative reasons why the participants selected to perform the observation task in the way they did. The statements of P6 and P9 were chosen as representative reasons to explain why the participants selected interactive animation. P6 pointed out that, in the case of the non-interactive animation, the focal points for observation were not clear, because he attempted to watch the entire display. However, in the case of the interactive animation, the same participant felt that the focal points for observation were clarified in response to his movements. The example P6 provided was the fact that when he ran, the animals also ran, and when he stopped, the animals stopped moving. Similarly, P9 felt a sense of affinity with the paleontological animals due to the connection between their own movements and the animals' movements,.

The results encouraged them to observe the features of these animals. Collectively, the feedback that was obtained confirmed that the interactive nature of the display facilitated the clarification of focal points for observation and encouraged the observation of the animals due to a feeling of affinity with them. The statements of P2 and P8 are provided as being representative reasons as to why the participants chose the non-interactive animation. P2 pointed out that the non-interactive animation had the benefit of allowing them to focus exclusively on observing the animals without the need to perform any movements themselves. It alsoadded that a drawback of the interactive animation was the fact that he had to concentrate on his movements while participating. As described above for the other two tasks, it was clear that the non-interactive animation allowed the participants to focus on observation, because there was no obligation for them to move their bodies.

IV. DISCUSSION

First, the immersion task will be discussed. We see that the number of participants who chose interactive animation was significantly higher than those who chose non-interactive animation. This result is considered to be a consequence of participants' feeling that they were able to influence the movements of the paleontological animals by raising their hands and that there was a connection between their movements and those of the animals. The perceived affinity and sense of control are therefore considered responsible for promoting participants' immersion into the virtual world. In fact, in the interview part of the survey, P2 stated that they felt that the animals could be manipulated because the animals' movements were connected to their own. In addition, P7 stated that it began to feel as though they had entered the world of the paleontological animals when they responded to participants' raising their hands. From the above, we can conclude that the interactive animation served to promote participants' immersion into the virtual world of the paleontological animals to a larger extent than the non-interactive animation.

Next, the interest task will be discussed. For this task, no significant bias was observed in terms of the number of participants who selected the interactive animation and those who selected the non-interactive animation. From this result, it can be concluded that there was no difference in the extent to which the interactive and non-interactive animations increased participants' interest in the paleontological animals.

Lastly, the observation task will be discussed. As for the interest task, no significant bias was observed in terms of the number of participants who selected the interactive animation versus those who selected the non-interactive version. From this result, it was concluded that there was no difference in the extent to which either the interactive or non-interactive animation encouraged participants' interest to observe the paleontological animals. However, in the case of the interactive animation, some opinions were discovered to the effect that the requirement of participants to move their bodies prevented them from fully concentrating on observing the animals. Future efforts will be directed at addressing the aforementioned problems by improving the immersive environment learning system and by increasing the number of participants to verify the validity of the system.

V. CONCLUSION

Learners, who are learning about past environments, cannot actually observe or experience the environment directly. Thus, it is difficult for them to relate to, understand, and develop an interest in these environments. In an attempt to compensate for this, we focused on the body-experience component of learning by proposing a learning support system to create a more engaging learning experience. In this system, the learner's location and actions ("walk," "sit down," etc.) are measured by Kinect sensors, and the animated virtual environment on the display is controlled according to the results received by the sensors. By moving their own bodies, learners were made to feel as though they had entered the environment owing to the body immersion experience, with the aim of improving their interest and understanding of the learning target. The immersion experience was followed by a survey conducted by using questionnaires. The experimental results confirmed the learning potential of synchronizing an environmental animation with human body actions to provide a sense of immersion and to stimulate interest in a paleontological environment.

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