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Enabling Physical- and Concept-Walk in VRbased Open-ended Historical Learning Space

Aoi MATSUURA[a*], Kazuhisa SETA[b] & Yuki HAYASHI[b]
[a]*College of Sustainable System Sciences, Osaka Prefecture University, Japan*
[b]*Graduate School of Informatics, Osaka Metropolitan University, Japan*
*matsuura@ksm.kis.osakafu-u.ac.jp

Abstract: In history study, it is desirable for students to understand the structural connections among people, events, and historical sites, and to experience the appearance, scale, and location of historical sites, rather than merely memorizing them. On the other hand, it is desirable for students to understand the connections between historical facts and to learn through actual experiences such as visiting actual historical sites. This is difficult to achieve in textbooks because of the limited amount of information that can be presented in textbooks. In this study, we propose a learning support system for exploring historical sites, which aims to achieve both immersion and independence of learners by switching between a pseudo-historical site exploration (Physical Walk) and a related term exploration (Concept Walk). We have developed a system that can follow the interests of various learners and provide a subjective and immersive learning experience by switching between a pseudo-historical site exploration (Physical Walk) and a related term exploration (Concept Walk). In this paper, we overview the system, the technical issues we used to overcome, and the results of an initial evaluation experiment of the system. In addition, we mention a more adaptive support planned to implement which generates questions based on the related terms and ontologies.

Keywords: Learning in an Open-ended Space, Virtual Reality, Physical Walk, Concept Walk

1. Introduction

Proactive learning in which students engage in independent learning while maintaining their interests, and deep learning in which students elaborate their ideas by interrelating knowledge are considered important from the perspective of active learning (MEXT, 2021). Considering support for such learning as applied to history learning, which is the target of this study, it is desirable for learners to learn independently according to their own interests, to expand their interests by immersing themselves in the world of history, and to learn by understanding the relationships among people, events, historical sites, and so on (Sulistyo et al., 2020; Bekele, 2019). To support such learning activities, it is essential to encourage learning that involves a sense of space, and learning that involves structurally linking many persons, events, historical sites, etc., but it is not easy to achieve this in a way that can follow the diverse interests of learners. Because of the limited amount of information available in textbooks, it is difficult to understand the appearance and location of historical sites with a spatial and threedimensional sense. It is also not easy to learn many terms and concepts by structurally relating them through one-dimensional explanations in the text.

In this study, we are developing a learning support system for exploring historical sites in an open-ended learning space, combining the exploration of spatial connections (Physical Walk) to explore historical sites and the exploration of semantic connections (Concept Walk)

to trace related words and phrases, in order to follow learners' interests and create opportunities for deep active learning by expanding their interests.

This paper describes the learning environment provided to learners. From the internal point of view of the system that realizes this environment, we describe the technical challenges to realize the proposed system as an open learning space and the technical breakthrough to overcome them, and report on pilot evaluation experiments to get a feel if our goal is likely to be achieved.

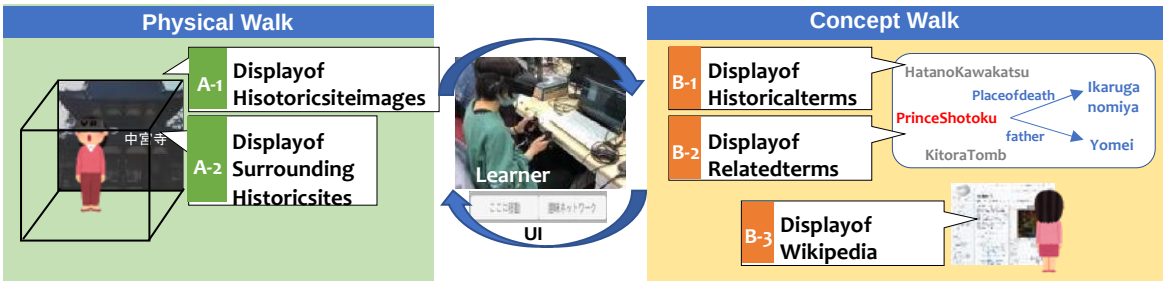

Figure 1. Relationship Between Physical Walk and Concept Walk.

2. Physical Walk and Concept Walk

In order to realize the Physical Walk and Concept Walk, this research utilizes Virtual Reality (VR) technology (Kim & Hall, 2019). By utilizing Virtual Reality (VR) technology, Wikidata Query Service (WDQS)[1], and Google Maps API[2], we will develop an immersive learning support system for exploring historical sites in VR space that enables both Physical Walk and Concept Walk. Figure 1 shows the relationship between Physical Walk and Concept Walk.

Physical Walk: If learners can immerse themselves in a place where they learn history immersively, it is expected to arouse various interests, provoke questions as a learning resource that drives independent learning, and motivate them to explore history. On the other hand, there are not many opportunities to explore actual historical sites. Therefore, we are developing a VR-based support system to realize a pseudo-exploration of historical sites. In this research, we call this "Physical Walk" and realize a mechanism that can recognize the three-dimensional information of historical sites and the positional relationship between groups of historical sites. The goal of this research is to enable learners to observe the scale and atmosphere of historical sites (e.g., Hōryū-ji Temple) and their location in relation to surrounding historical sites (e.g., Chūgū-ji Temple).

Concept Walk: If the system can capture historical sites, people related to them, and historical facts, and visualize and display the connections between them, it will contribute to deep learning by interconnecting knowledge. In this study, we call this activity of exploring related items "Concept Walk." By displaying the paths of related terms representing historical events, people, etc., and allowing the user to move back and forth along the paths, the understanding of semantic connections in multiple directions is facilitated. In addition, by presenting detailed information on the words selected by the learner, we aim to arouse the learner's interest and to promote independent learning driven by this interest.

3. VR-based Support System for Historical Active Learning

We have developed a VR-based historical site exploration and learning support system that combines both Physical Walk and Concept Walk. Figure 2 shows the internal structure and user

[1] Wikidata Query Service: https://query.wikidata.org/

[2] Google Maps API: https://developers.google.com/maps

interface of the developed system. The system uses Wikidata Query Service (WDQS) and Google Street View Static API[1] on Unity. Learners can use the system while wearing an Oculus Rift (Fig. 2(A)).

When the system is launched, the learner selects the region and period of interest on the learning start screen (Fig. 2(B)). Historical terms that match the selected conditions are displayed in the VR space, and the learner can select the term of interest with the controller. The system retrieves the historical terms from WDQS that match the region and period selected by the learner, and places the obtained data in the VR space (Fig. 2(C)). If the learner selects a historical site, he or she can explore and learn in both Physical Walk and Concept Walk modes, and if the learner selects any other terms,

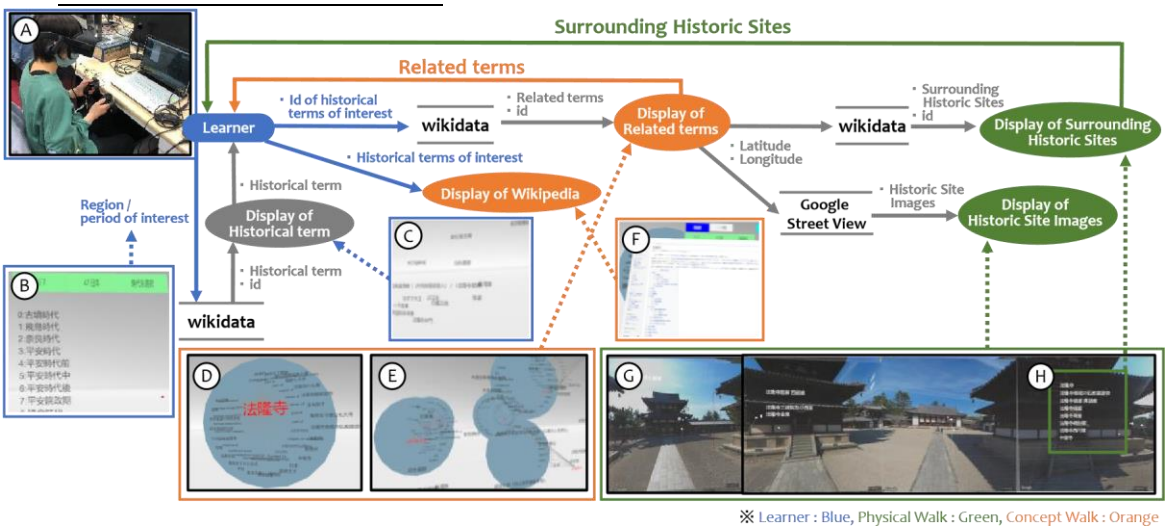

Figure 2. Realizing Physical Walk and Concept Walk.

he or she can explore and learn in Concept Walk mode. Learners can switch between the Physical Walk and Concept Walk on the UI.

⋆ Learning by Physical Walk

The scale and atmosphere of the historic site (e.g., Hōryū-ji Temple) (Fig. 2(G)) and its location in relation to surrounding historic sites (e.g., Chūgū-ji Temple) (Fig. 2(H)) can be observed. At this time, the system will obtain the latitude and longitude information of the site selected by the learner from WDQS, and place images of historical sites obtained from Google Street View Static API in the VR space to dynamically construct a pseudo-space around the historical sites.

Through Physical Walk exploration, the learner can expand their interest in history by observing the scale and atmosphere of the historical site, its location in relation to surrounding historical sites, and geographical information about the surrounding area.

⋆ Learning by Concept Walk

The term selected by the learner from among the historical terms and its related terms are visualized (Fig. 2(D)). The learner can follow the related terms with the controller, and the path can be confirmed by the change in the color of the letters of the terms that the learner has followed (Fig. 2(E)). If the learner selects a term, they can check the Wikipedia page (Fig. 2(F)). This exploration activity is intended to promote understanding of interested terms through understanding. At this time, the system obtains all the properties and values of the terms selected by the learner using WDQS, and visualizes the related words and phrases based on them.

⋆ Learning by going back and forth between Concept Walk and Physical Walk

[1] Google Maps Platform: Street View Static API: https://developers.google.com/maps/documentation/streetview/overview

Learners can conduct exploratory activities combining both Concept Walk and Physical Walk. When exploring Hōryū-ji Temple (Physical Walk), for instance, to understand that the temple was built by Prince Shotoku and that Chūgū-ji Temple is a nun temple that he built for his mother (Concept Walk), and then move on to the temple (Physical Walk) because it is near Hōryū-ji Temple where he is now. At this time, to integrate historical site image data, which does not retain semantic information, and historical terminology (and its semantic relationships), which does not retain spatial information, the system identifies the proper combination using a large-scale knowledge database (Wikidata) as a pivot to integrate Physical Walk and Concept Walk.

4. Pilot Evaluation Study

An evaluation experiment was conducted to confirm the potential of the proposed system in learning to explore historical sites. Five undergraduate and two graduate students who were using the Oculus rift Table 1. *Questionnaire Results*

Questionnaire Items	Average
(i) Did you have a better spatial understanding of the historic sites?	4.1
(ii) Did you understand the relationship between terms while learning?	4.0
(iii) Were you able to proceed with the learning according to your interest?	4.5
(iv) Did you have a greater interest in history?	4.2
(v) Did you connect to deeper learning by exploring historic sites and related terms?	3.8
(vi) Was the system easy to use?	2.5

Figure 3. Adaptive Learning Environment in an Open-ended Space.

for the first time were asked to use the system we developed. The students watched a demonstration video explaining how to use the system for about 3 minutes, and then studied for about 10 minutes using the system. After the study, the students were asked to respond to a five-point questionnaire.

The six questionnaire items were "(i) Did you have a better spatial understanding of the historic sites" from the viewpoint of the learning effect by Physical Walk, "(ii) Did you understand the relationship between terms while learning" from the viewpoint of the learning effect by Concept Walk, "(iii) Were you able to proceed with the learning according to your interest" and "(iv) Did you have a greater interest in history" from the viewpoint of supporting independent learning, and "(v) Did you connect to deeper learning by exploring historic sites and related

terms" from the viewpoint of supporting in-depth learning. From the viewpoint of supporting independent learning, "(vi) Did you proceed with your learning in accordance with your interests?"

Table 1 shows the average scores of the questionnaire results. The average scores for (i) and (ii) were 4.1 and 4.0, respectively. This suggests that the Physical Walk can promote spatial understanding and the Concept Walk can promote understanding of related terms. It is expected to eliminate the difficulty of learning that it is not easy to support learning with a sense of space and learning with many terms structurally related to each other when learning with textbooks. The average scores for (iii) and (iv) were 4.5 and 4.2, respectively, suggesting that the system provided learning opportunities that followed the learners' interests and that the presentation of detailed and relevant information through the exploration of historical sites and related terms motivated the learners to learn history. In fact, positive comments such as "I enjoyed learning as if it were a social studies field trip," and "I felt my knowledge expanding through the expression of the expanding network when I selected a term, and I wanted to expand it further. On the other hand, the average score for (vi) was 2.5. Usability needs to be further improved. The score of 3.8 for item (v) suggests that the user is required to become accustomed to the operation while wearing the Oculus rift.

5. Towards Question Generation Based Support in VR-Based Open Learning Space

One of the main characteristics of the system developed in this research is its generality. The method of implementation presented in this paper allows one to provide learners with an open-ended learning space that is adaptive to their interests without rewriting the program, no matter what the age of the learners in any region.

Figure 3 shows the learning environments provided at Machu Picchu, Peru in the 14th century; Piazza Iran, Iran in the 15th century; Colosseum, Italy in the 1st century; and Angkor Wat, Cambodia in the 12th century.

On the other hand, the information in Concept Walk mode is currently presented as it is in Wikidata. Although the information is stimulating to expand learners' interests and concerns, more active support is desired as a stimulus to induce meaningful learning. In our previous studies, we have developed a mechanism to dynamically generate meaningful questions based on Linked Open Data, Question Generation Ontology and History Domain Ontology for learners learning history in an openended learning space, and have confirmed the quality of these questions and their learning effects (Corentin, Seta & Hayashi, 2016; Corentin, Seta & Hayashi, 2017).

In the learning environment realized in this paper, we would like to realize more active support to deepen learners' learning by making it possible to generate questions that follow learners' learning.

6. Concluding Remarks

We have realized an open learning space combining spatial and semantic information that follows learners' interests via Wikidata and Google Street View, and confirmed its potential to promote independent and deep learning. The Asuka period is taken as an example in this paper, but the proposed system is characterized by its generality and scalability to work in different periods and locations.

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