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Inference of Viewed Exhibits in a Metaverse Museum

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***Abstract*—This paper presents how to infer viewed exhibits in a metaverse museum from a visitor's movement log. This task consists of movement-state detection and viewed-exhibit inference. For the former task, we focus on visitor's fast and slow movement and discuss three differences between our previous methods and new methods: an additional parameter, speed normalization, and key-input accumulation. For the latter task, our new method focuses on the distance and angle between the visitor and each involving exhibit. According to a conducted experiment, the proposed methods could improve the performance (F-measure) by 10.3% and 4.6% for movement-state detection and viewed-exhibit inference, respectively.**

Keywords—recommender system; SVM; Second Life;

I. INTRODUCTION

The demand for metaverses, such as Second Life (SL), is expanding in recent years [1]. A major application in metaverses is that of organizing virtual or digital museums. The purpose of our on-going study is to develop a recommender system for the visitors of such museums that recommends the exhibits they prefer.

This paper focuses on how to infer which exhibits are actually viewed by the visitor from their movement log, including also keyboard input information without doing anything which places a burden on a user such as questionnaires. There are only limited previous studies with the same focus as this work. The higher the accuracy in inferring such viewed exhibits, the better recommending results are achieved [2]. As a targeted metaverse, we use Second Life because there are a number of museums available for research [3], and it is simple enough for beginners to operate their avatar characters We focus on visitor's two types of movement, fast and slow. There are three differences between our previous methods [4] and new methods for state detection. First, we used an additional parameter for this task. Second, we normalized the speed parameter among all visitors. Third, we used the accumulated value for the key input. We also modified our previous method for inferring viewed exhibit [4]. The modified method focuses on the distance and angle between the visitor and each exhibit of interest.

II. METHODS

A. Movement Log

Movement log used in this work is defined as a time series of the *x*-coordinate, *y*-coordinate, and direction of the avatar; the keyboard input for moving forward; and the distance between the avatar and the nearest exhibit (*dist*). Here, the *x*-coordinate and *y*-coordinate of the avatar are represented by the absolute coordinate in the space. The direction of the avatar is represented by the angle of rotation θ from $-\pi$ to π with the positive direction of *x*-axis being zero. The keyboard input (*key*) is represented by the value obtained by a SL script that returns 1 when the forward key is pushed and returns 0 otherwise.

B. Detection of the Movement State

When a visitor is observing an exhibit, it can be said that they rarely stay at the same position for a long time. Following [5], we thus divide the visitor movement into two states *walking* and *hovering*. A walking state is defined as a movement between an exhibit and another exhibit, during which the visitor does not seriously view any exhibits. Hovering is a slower movement, during which the visitor views at least one exhibit and might stay near and turn around them. Because viewing of an exhibit is likely to be done when the avatar is in a hovering state, we first need to detect the movement state in the movement log and then infer a viewed exhibit in each subset of consecutive hovering states.

Detection of the movement state is performed by a support vector machine (SVM) and we use the library named LibSVM, as done in reference [5]. The input features of SVM are the speed and acceleration of the avatar, the aforementioned *key* and *dist.* The avatar's speed and acceleration can be derived from the information on the *x*-coordinate and *y*-coordinate in the movement log.

There are three differences between the proposed detection method and our previous method. The first modification is introduction of *dist* as a new input feature. Second, the speed value is normalized because the avatar speed depends on the environment such as the spec of PC. Third, the accumulated value of *key* is used whose value is reset once the value of 0 appears. By these modifications, we could improve the detection performance of SVM.

C. Inference of Viewed Exhibits

Here, we propose a new method as follows. As mentioned earlier, we only infer a viewed exhibit in a movement subset whose all members are detected as hovering. First, we define the ideal viewing scope and the 100% viewing scope of an

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exhibit as the scope minimizing the least square errors and the scope covering all points the exhibit is observed in the training data, respectively.

For each hovering point in a given hovering-state subset, if the point does not lie in any 100% viewing scopes, we infer that the visitor does not view any exhibit from this point. If the point is in the 100% viewing scope of only one exhibit, we infer that the visitor is viewing it from there. If the point lies in more than two 100% viewing scopes, we decide which exhibit the visitor views as follows:

- Calculate the distance d between the point and ideal viewing scope of each exhibit of interest.
- Calculate angle r between the sight line of the avatar and each exhibit and then calculate R = max {cos r, 0.1}.
- Calculate R/d for each exhibit and infer that the visitor views the exhibit which has the highest value of this ratio at this point.
- Decide the exhibit the visitor views in this hovering subset by majority voting of all member points.

Fig. 1 depicts the above concept where there are two exhibits involved e_1 and e_2 and the hovering-state subset of interest consists of four members (points) shown by small dots.

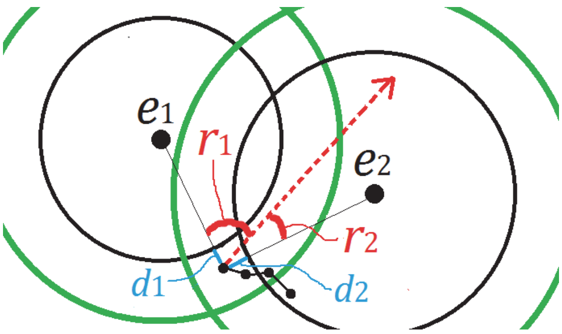

Fig. 1. Concept of infering a viewed exhibit.

III. Experiment

In our experiment, we asked each of 12 subjects (visitors) to roam around a SL museum, which contains 20 exhibits of traditional Japanese clothes, shown in Fig. 2, and view 10 exhibits, out of 20, randomly assigned by us. They were asked not to perform manual operation of the camera in SL. Then, we recorded the movement log of each visitor every 0.5s using a SL script. We also asked each subject to indicate whether or not they view those exhibits, so the information is added into the movement log. For SVM, the Kernel function of SVM was Gaussian. We evaluated both movement-state detection and viewed-exhibit inference by 12-fold cross validation.

Fig. 2. Screen shot of the museum

Table I summarizes the experimental results. In this table, the figure shows the measure of our proposed method and the figure in parenthesis indicates that of our previous method [4]. The proposed methods in this paper outperform our previous methods for both detection and inference.

TABLE I. Experimental Results

	Accuracy	MCC	Recall	Precision	F-measure
Movement State Detection	80.4% (71.6%)	0.514 (0.426)	0.794 (0.715)	0.818 (0.692)	0.806 (0.703)
Viewed Exhibit Inference	83.2% (78.3%)	0.580 (0.547)	0.844 (0.706)	0.732 (0.774)	0.784 (0.738)

IV. Conclusion

According to the experimental results, we improved the result of our previous work. This means our proposed methods are effective to movement-state detection and viewed-exhibits inference. An issue remains that if the distance between two exhibits is close, it becomes harder to infer which exhibit the user views. Accurately inferring of viewed exhibits by the visitor is very important in recommending the exhibits the visitor prefers. Our next objective is to develop a recommender system using the proposed methods in this paper.

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