Evaluation of Mediating Agents that Personalize Museum Exhibitions

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Abstract

Despite having the potential to provide a knowledge sharing environment among experts (e.g. curators) and novices (e.g. museum visitors), traditional museums do not generally function in this way. The biggest problem is the lack of an efficient way for both experts and visitors to represent and exchange their knowledge, interests, and viewpoints, which would allow visitors to examine the exhibitions in a customized manner. Therefore, we have proposed mediating agents between experts and visitors to personalize museum exhibitions based on the needs of the visitor in order to enhance their understanding of the exhibitions. This personalization process can be considered asynchronous collaborative work by curators and visitors through the help of mediating agents. In this paper, we evaluate the mediating agents with a subjective experiment from the visitor's point of view. The results show that the mediating agents are effective in personalizing museum exhibitions.

1. Introduction

Today's computer and network technologies have brought drastic changes to traditional museums in the sense that exhibitions and museum visits are no longer restricted to physical objects and spaces. This is encouraging museums to evolve from being merely spaces to display artifacts to becoming spaces for knowledge sharing between experts, such as curators, and novices such as museum visitors.

The most important requirement for this evolution is bidirectional communication between experts and visitors since the exchange of knowledge and interests is essential to knowledge sharing. Traditional museums have so far lacked this kind of exchange. Meta-Museum [1, 4], which is a new knowledge sharing environment, produces and promotes communications with the help of various agents such as guide agents [2] and mediating agents [3]. It integrates traditional museums in the physical world and virtual museums on computer networks, especially the Internet.

The mediating agents personalize museum exhibitions to match the interests of each visitor by reconstructing the presentation of exhibitions. Such tailored exhibitions can provide visitors with a better understanding of the knowledge presented.

The mediating agents first visualize and show visitors the semantic structure of an exhibition, which is a systematic representation of the expert knowledge of one or several curators. Then, the mediating agents acquire the interests of the visitors and use the information to help restructure the original exhibition, i.e., they produce a new exhibition tailored to each visitor. Thus, the mediating agents can achieve interactive two-way communication by exploiting the knowledge of the curators as well as by conveying the visitors' viewpoints. This personalization process can be considered asynchronous collaborative work by curators and visitors through the help of mediating agents.

In this paper, we evaluate the functions of mediating agents. We conducted subjective experiments to evaluate two aspects of the mediating agents. The first aspect is whether the method used by the mediating agents reflects the visitors' subject appropriately. The second aspect is how the semantic structure can be used for personalization.

The rest of the paper is organized as follows. Section 2 describes the process of personalizing museum exhibitions with mediating agents. Section 3 gives an example of personalized exhibitions with the web page of a permanent exhibition on the Internet. Section 4 describes the classification of object pairs based on the distance between them in two-dimensional space. Section 5 shows an evaluation of the mediating agents from the visitors' point of view. Section 6 concludes the paper.

2. Personalization Process of Exhibitions by Mediating Agents

This section describes how the mediating agents personalize museum exhibitions for each visitor. As described below, these agents create new exhibits adapted to their visitors by integrating the knowledge of the curators with the

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interests of the visitors.

The mediating agents deal with "knowledge" by representing it as 2-dimensional spatial relations among pieces of information (we call them "objects" hereafter) that represent the knowledge and weighted attributes included in the objects. We employ the dual scaling method [6] for spatial structurizing. This method is a multi-variant statistical analysis method that resembles a conventional principal component analysis method. However, it is different in that it arranges not only objects but also their attributes onto an identical space.

The agents obtain two bases of a space by quantitatively grading the object set and the attribute set, i.e., by calculating the shared relations of attributes among the objects, as well as the co-occurring relations of attributes in an object, while considering the weight of each attribute for the object [7]. Then, the agents arrange all of the objects and the attributes onto the space spanned by the two most principal bases. Simply speaking, objects that are arranged closely in the space have similar contents, and attributes arranged between several objects are shared by the objects. In this way, the agents structurize the knowledge as a 2-dimensional space in the following three ways.

2.1 Exhibition Space

First, the agents represent the curators' knowledge as a 2-dimensional space by using the method stated above.

Here, we assume that the curators' knowledge consists of the object set O_c and the attribute set K_c (see Figure 1). An explanatory sentence is given to each exhibition room or artifact on display, which corresponds to an object. Keywords are included in each explanatory sentence, which corresponds to an attribute. Keywords are automatically extracted from the explanations by morphological analysis of the sentences; the weights of the keywords are also automatically calculated by considering their frequency in the entire set of explanation sentences, as well as in a particular explanation [5].

By applying the dual scaling method to O_c and K_c, all of the curators' knowledge is represented as a 2-dimensional spatial structure. Therefore, all of the relations among the explanations and keywords given by the curators are reflected in the spatial structure. Accordingly, we call this space the "exhibition space."

2.2 Visitor's Interest Space

Second, the agents obtain the interests of the visitors and restructurize the exhibition space based on these interests.

The agents let the visitors select several objects in which they have an interest. Here, we assume the selected object set is O_v and the selected objects include attributes that form

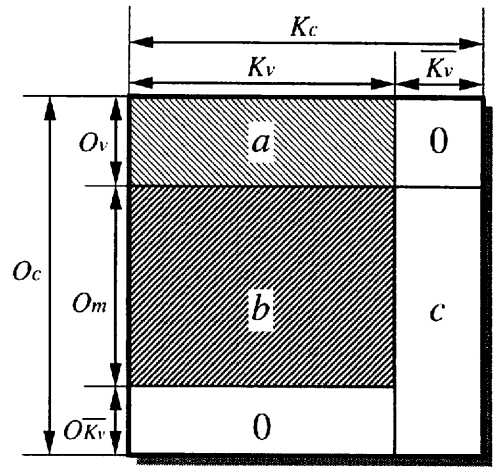

Figure 1. Diagram of relationship between objects and keywords organizing each space

an attribute set K_v (see Figure 1). Hence, no object in O_v includes any keywords in $\overline{K_v}$. Then, the agents calculate the bases of a new space by applying the dual scaling method to O_v and K_v. Consequently, the obtained space is spanned by only the relations from area a in Figure 1. Finally, the agents arrange all of the objects that include keywords in K_v. In other words, the objects of $O_{\overline{K_v}}$, which do not include any keywords in K_v, are discarded.

The base of this space is obtained according to the visitor's interests, and the spatial structure is modified by it. Accordingly, we call this space the "interest space."

2.3 Personalized Space

Third, the agents again restructurize the interest space by using both a part of the original knowledge structure given by the curators and the interests given by the visitors. The agents calculate the bases of a new space by applying the dual scaling method to $O_v \cup O_m$ and K_v. Therefore, the structure of the new space reflects not only the relations from area a but also from area b.

Although the objects in O_m are not selected by the visitors, the objects include keywords in K_v, which are indirectly selected based on the interests of the visitors. Therefore, the objects in O_m can be regarded as objects in which the visitors have an indirect interest. All indirect relations through keywords of K_v are given by the relations in the curators' knowledge. Furthermore, by considering the relations in area b as well as in area a, new co-occurrent relations are expected to exist among keywords of K_v. These relations are also given by the curators. Therefore, in this process the newly obtained space, which we call the "per-

sonalized space," can be regarded as the representation of a fusion of the interests of the visitors and the knowledge of the curators. Such relations derived from the curators' knowledge are possibly overlooked by the visitors. However, they indicate information and viewpoints that are novel to the visitors. This process can be considered as a means of slightly expanding the narrow and shallow knowledge of the visitors with the wider and deeper knowledge of the curators.

Note that this personalized space is not just a simple sub-structure of the exhibition space. The exhibition space includes the relations from area *c* in Figure 1, whose contribution is discarded in the personalized space. This discarding causes not only the simple discarding of relations derived from area *c*, but also allows hidden relations in areas *a+b* to rise to the surface which were previously buried by the effect of the cross-relations between area *a+b* and area *c*. Consequently, the personalized space can possibly show novel relations that can be seen in neither the exhibition space nor the interest space. Such relations may be overlooked by the curators. Therefore, the personalized space is meaningful and informative for not only the visitors but also the curators.

In this way, the mediating agents provide a means of two-way communications, allowing the curators' professional knowledge to be conveyed to the visitor as well as novel viewpoints based on the interests of the visitors to be conveyed to the curators.

3. Example of Personalized Exhibitions

This section provides an example of personalizing exhibitions with mediating agents. We used web pages for a permanent public exhibition, the National Museum of Japanese History[1], as our example exhibition. The museum has five exhibition rooms for permanent exhibition, each with three to six sub-themes. Each web page corresponds to an exhibition room and has descriptions of the sub-themes and artifacts displayed in the room. We regard one explanation for a sub-theme as one object and thus obtained 25 objects.

Figure 2 shows an exhibition space in which the mediating agent visualizes the structure of relevance between the objects and keywords. Note that the mediating agent suppressed the keywords to show the structure in a simple and intuitive manner in the Figures 2, 3, 4. Of course, if required, the mediating agent show the all keywords and objects.

Figure 3 shows an interest space obtained by the mediating agent after a visitor had selected the objects named "Dawn of Japanese Culture," "Aristocratic Culture," and "Popular Culture," indicated by circles. This operation was executed by the visitor clicking the *Select* button in Figure 2 and selecting these three objects. Objects in O_m are also arranged and displayed in the interest space in Figure 3. In contrast, the object "Oki Island" marked by a dotted circle, which is included in the exhibition space, is discarded since it has none of the keywords of the three objects and is considered to be in $O_{\overline{Kv}}$.

When the visitor clicks the *Personalize* button, the mediating agent produces a personalized space merging the visitor's current interest and the curators' knowledge. Figure 4 shows the personalized space resulting from the process. The target objects are 24 objects which remain in the interest space. As can be seen, a structure different from that in the interest space is obtained due to the relevance introduced by O_m.

4. Classification of Object Pairs

The relations between objects arranged in a two-dimensional space can be classified in three ways, namely near, far, and intermediate, based on the distance between the objects. If we choose pairs from among the objects as being either near or far in the exhibition space, the interest space, and the personalized space, there are eight transition patterns, as is listed in Table 1. Closely analyzing the transition pattern of the distance may lead to a criterion for the effectiveness of mediation by the agent for both the curators and the visitor.

We use a normalized distance to judge the distance between a pair of objects. The normalized distance d_{ij} of objects o_i and o_j $(i \neq j)$ is calculated according to the expression

$$d_{ij} = \frac{x_{ij} - \overline{x}}{\sigma},$$

where x_{ij} is the measured distance between o_i and o_j in each space, and $\overline{x}$ and σ are the average and standard deviation of the measured distance among all objects in each space. The relationship of two objects is labeled as "far" when d_{ij} is larger than an upper threshold, while it is "near" when d_{ij} is smaller than a lower threshold. In our experiment, it is far when $d_{ij} > 0.3$ and it is near when $d_{ij} < -0.3$. Example object pairs of each pattern are shown in Table 2.

We can make the role of the mediating agent clearer by categorizing these transition patterns. The categories can be used to color-code and/or change the way the personalized space is displayed in order to illustrate the contribution of the mediating agent to the user more concretely. In addition, the categories can also be used to autonomously customize the display behavior of the mediating agent to meet the user's preference.

[1] http://www.rekihaku.ac.jp/zyoosetu/index.html

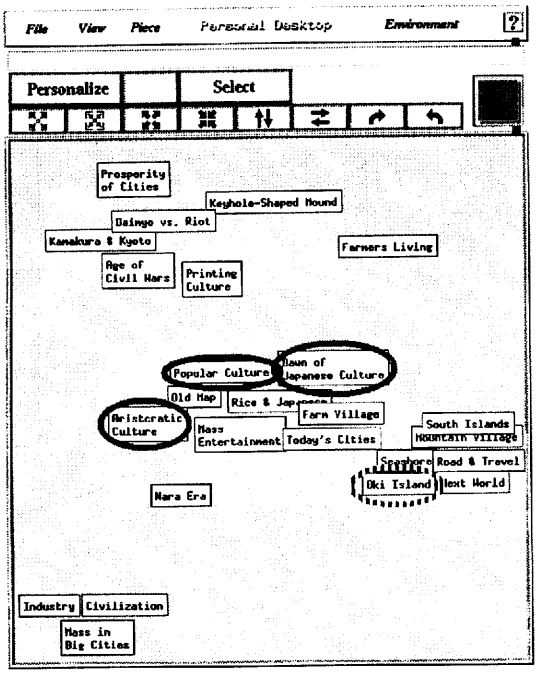

Figure 2. Example of exhibition space

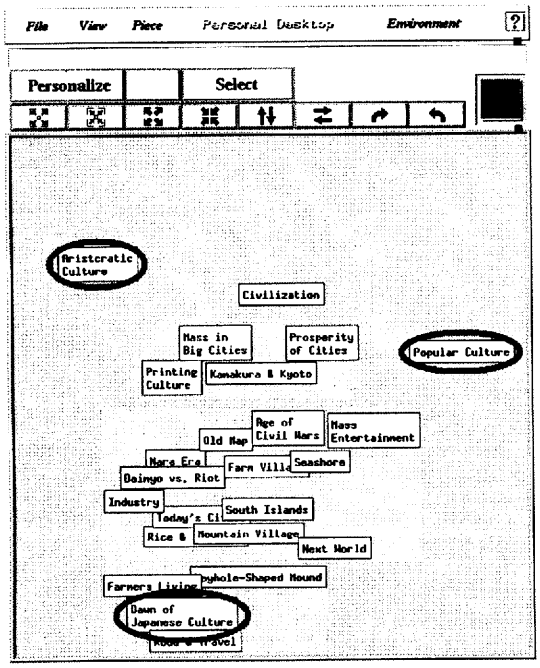

Figure 3. Example of visitor interest space

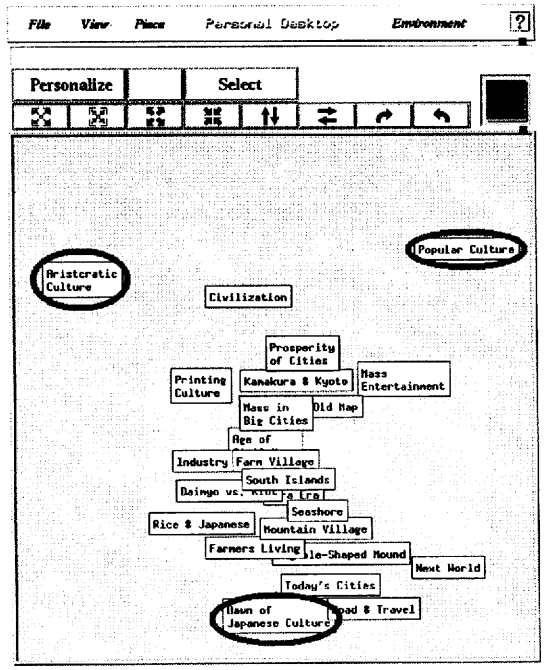

Figure 4. Example of personalized space

Table 1. Patterns of transition of distance

No.	Exhibition Space	Interest Space	Personalized Space
1	near	near	near
2	near	near	far
3	near	far	near
4	near	far	far
5	far	near	near
6	far	near	far
7	far	far	near
8	far	far	far

Table 2. Example object pairs of each pattern

No.	Object Pairs	
1	Dawn of Japanese Culture	Rice & Japanese
2	Rice & Japanese	Next World
3	Road & Travel	Seashore
4	Keyhole-Shaped Mound	Printing Culture
5	Kamakura & Kyoto	Mass in Big Cities
6	Road & Travel	Industry
7	Farmers Living	Mass in Big Cities
8	Road & Travel	Printing Culture

5. Evaluation of Mediating Agents from Visitors' Points of View

We conducted subjective experiments to evaluate two aspects of the mediating agents. The first aspect is whether the distance between two objects in the two-dimensional spaces (i.e., exhibition space, interest space, and personalized space) closely corresponds to the visitor's subjective rating of the relevance between the two objects. The second aspect is whether the classification is effective in customizing the exhibitions. Accordingly, it is the effectiveness for visitors, not for experts that is evaluated.

The subjects were five researchers who are not experts in history. We again used the web pages of the National Museum of Japanese History. Therefore, there were 25 objects considered.

The tasks and procedure of the experiment are as follows:

1. The subjects select arbitrarily numbered objects of interest from among the 25 objects.

   We did not show the subjects the exhibition space where the objects are arranged two-dimensionally but instead 25 separate cards in alphabetical order, each corresponding to one object. Since the arrangement of the objects in the exhibition space might influence the subjects' evaluations of the degree of relevance between two objects, we eliminated this factor. The subjects selected eight objects on average.

2. After making the interest space and the personalized space, we obtained object pairs belonging to one of the eight patterns. We extracted object pairs that belong to patterns no. 1, no. 3, no. 5, and no. 7, where the distance between two objects is near in the personalized space. The numbers of such object pairs are shown in Table 3.

3. Each subject rated the degree of relevance of each object pair obtained from his or her selection. That is, for example, subject 1 rated 108 pairs and subject 2 rated 102 pairs. The rank of 1 degree means "no relevance" and the rank of 5 degrees means "very strongly relevant." Object pairs are randomly shown so that the subjects do not know which object pairs belong to which patterns.

Table 4 shows the average rating of relevance. From this table, it is clear that the degree of relevance of object pairs contained in pattern no. 1, where the object pairs are always "near" in the three spaces, are evaluated highest. In contrast, object pairs contained in pattern no. 7, where the object pairs are "near" only in the personalized space, had the lowest scores. The degree of relevance of object pairs contained in pattern no. 5 is higher than that of object pairs contained in pattern no. 3. This illustrates the fact that the distance of the object pairs in the visitor's interest space in pattern no. 5 is "near," while in pattern no. 3 it is "far." That is, the visitor's viewpoint is more strongly reflected than that of the experts because this experiment is performed from the visitor's viewpoint.

Table 3. Number of object pairs obtained from each subject's selection

	Patterns				
	no. 1	no. 3	no. 5	no. 7	total
Subject 1	81	3	22	2	108
Subject 2	98	2	1	1	102
Subject 3	69	12	23	1	105
Subject 4	66	9	11	16	102
Subject 5	99	2	4	0	105
Total	413	28	61	20	522

Table 4. Subjective rating of relevance between two objects

Patterns	no. 1	no. 3	no. 5	no. 7
Average	2.66	1.96	2.23	1.75

Consequently, regarding the first aspect of our experiment (whether the mediating agents reflect the visitors' subject appropriately), we can confirm the function of the mediating agents. The distance between two objects in the two-dimensional spaces reflects the visitor's subjective rating of the relevance well.

As for the second aspect of our experiment (how semantic structure can be used for personalization), the results suggest that the classification of transition patterns is effective in customizing the exhibitions since the classification corresponds to the visitor's subjective rating, and it is thus expected that the mediating agent can use the patterns to choose object pairs and relate information that is most appropriate to the visitor's requirements.

For example, if the visitor wants to broaden his or her scope of interest, the mediating agent should select objects from pattern no. 3 or no. 7 and arrange them into a personalized exhibition. If the visitor wants to deepen his or her knowledge, the mediating agent should select objects from pattern no. 1.

The evaluation is limited to the four patterns shown in Table 4. We need to evaluate the other four patterns in future work to decisively confirm whether the above conclusions are correct.

6. Conclusions

In this paper, we described the mediating agents for establishing a bidirectional communication path between curators and visitors to produce new museum exhibitions tailored to each visitor and their evaluation by a subjective experiment from the visitor's point of view.

The mediating agents first automatically extract keywords from the explanation set to give a structure to the knowledge. The explanation set is considered to be the curators' knowledge and is given to exhibition rooms and the artifacts displayed. The mediating agents then map the structure onto a two-dimensional space, which is visualized as an exhibition space. The mediating agents then organize the interest space of the visitor by letting the visitor select interesting objects from the exhibition space. Finally, the mediating agents merge the interest space and the exhibition space to create a personalized exhibition space.

We applied this method to the web pages of the National Museum of Japanese History as an example exhibition and showed how the personalization process proceeds. We then described how the mediating agents can use the three spaces for personalization. The distance between two objects in each space was measured to classify the object pairs into eight categories, which are expected to be useful for the mediating agents in selecting and providing objects to compose personalized exhibitions.

A partial evaluation of the mediating agents is also discussed. We conducted a subjective experiment and evaluated two aspects of the mediating agent. The results show that the method used for representing the structure of the exhibitions closely reflects the subjective rating of the relevance between two objects. Furthermore, the results suggest that the classification of transition patterns corresponds to the visitor's evaluation of the relevance of object pairs.

We are considering evaluating the mediating agents from the experts' point of view and are also planning to study a method of creating personalized exhibitions dynamically, i.e., during visits, because interests are always changing.

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