A Graph-Based Model for Experiential Knowledge

Takayuki Hoshino and Rentaro Yoshioka

***Abstract*—Knowledge gained through experiences is useful in enhancing experiences of others and in coping with new situations. However, in order to make use of experiential knowledge, it requires understanding of the situation in which the knowledge was created and adjusting it to circumstances. Empirical knowledge can be flexibly utilized by abstracting experience. A knowledge model for abstracting experiences as a graph structure is proposed. The graph represents an individual experience as a node and the transition between experiences as an edge. The nodes and edges can be assigned different parameters depending on the knowledge elements that affect the experience. An example of using the model for experiential knowledge of visiting a museum is presented and possible analysis of the experience is demonstrated. The data used in this paper is obtained from a pilot study performed at the Matsue History Museum.**

***Index Terms*—Knowledge model, experience visualization, museum exhibit design, active knowledge engineering.**

I. Introduction

Knowledge gained through experiences, i.e. experiential knowledge, is useful in enhancing experiences of others and in coping with new situations. However, in order to make use of experiential knowledge, it requires understanding of the situation in which the knowledge was created and adjusting it to circumstances. This is the difficulty in utilizing experiential knowledge. It is known that people who can flexibly apply knowledge are able to abstract experiences in long-term memory at an appropriate level, so that they can be applied to various situations [1]. Similarly, abstraction is a well-known technique used in computer science to transform knowledge into models that can be widely applied. Hence, it is a natural step to explore possible methods for applying algorithms and transformations used in computation to experiential knowledge. The objective of this research is to make use of experimental knowledge produced by visitors of a museum (hereinafter referred to as museum experience) through a computational model.

A traditional framework for abstracting experiential knowledge is a production system. In this approach, using pattern matching realizes correspondence to various situations [1]. However, it is not applicable to museum experience since it is not necessarily based on rules. A more novel knowledge model for expressing experiential knowledge has been proposed for visits to places [2], and for art-viewing experiences [3], [4]. They abstract the experience in form of knowledge templates and provide a language of symbols for expressing impressions. This research shares the same philosophy as these works and adds to it by focusing on the "sequence" and its effect on the experiences.

The significance of handling museum experiences from the perspective of long-term memory is reported in [5]. The basic idea and the technical domain concerning the abstraction of experience are presented in [6]. It provides possible abstraction methods in general but is not directly applicable to museum experience.

Based on these observations, a graph-based model for museum experience is proposed. In the graph, a node represents a viewing experience of an artifact and an edge represents the cost/value of transitioning from one artifact to the next.

In this paper, a definition of the graph model including associated parameters for each node and edges are explained. The feasibility of the model is demonstrated by transforming visitor data obtained from a pilot study undertaken at an actual museum to the graph model and performing analysis of museum experience.

II. Graph-Based Model

The definition of a graph model including parameter values associated with nodes and edges will be explained below.

The museum experience is modeled as a series of viewing experiences.

The basic components of the graph base model are nodes and edges.

Nodes represent the viewing experience of individual exhibits. The unit of the exhibit to be viewed varies depending on the purpose of the analysis. The unit of viewing experience will be for each exhibit or for each exhibition section. Edge represents a transition to another viewing experience.

When the viewing experience of Museum M was done in the order of "Appreciation of section a", "Appreciation of section b", "Appreciation of section c", "Viewing of section d". It can be expressed as shown in Fig. 1.

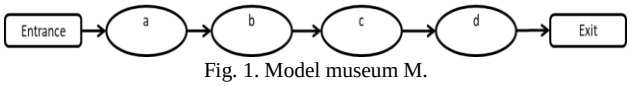

Fig. 1. Model museum M.

Parameters can be associated with nodes and edges.

When appreciating the exhibition materials, the value that visitors can acquire is expressed as "<*value*>" on the node.

The value the visitor can earn depends on the role of the person (museum staff or visitors), and it depends on the intention and purpose, such as how to evaluate the museum experience. Therefore, multiple parameters can be defined. Specific examples are the fun of the exhibition, the degree of expectation for the exhibition, and the preciousness of the exhibits.

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On the edge, the cost necessary for transitioning to another viewing experience is associated, and it is written like "[*cost*]" on the edge. Costs can be defined more than once depending on the intention and purpose of evaluating the museum experience. For example, waiting time in order of viewing, additional observation cost, etc. are conceivable.

Visitors can pass without seeing exhibition materials. In that case, it is assumed that the cost of moving to the passing material is not charged and the value from the passed material is not acquired.

As an example, Fig. 2 shows "Interest" as the value that can be obtained from the exhibit materials, and the waiting time for viewing as the cost of moving.

Fig. 2. Experience at museum M.

When all the exhibition materials a, b, c, d are viewed, the acquired value is 78 and the cost is 7. When passing through the exhibition material b and only a, c, d are viewed, the acquired value is 55 and the cost is 2.

III. Experience at the History Museum

Matsue History Museum is in Matsue City, Shimane Prefecture. Matsue city is a castle town that leaves excavations and townscapes in Matsue Castle and the Edo period. Matsue History Museum has opened exhibitions on the theme of the life and culture of castles, towns and people. In addition to the material exhibition, various display methods such as video, diorama, movable background picture, cutout drawing are used here.

The basic exhibition room is a fee-based permanent exhibition room, with sections established for each of the 11 exhibition themes shown in Table I, and materials are exhibited.

TABLE I: Exhibition Themes

ID	Exhibit section name
A	The beginnings of the castle town of Matsue
B	The Castle Town- now and years ago
C	Matsue's opening
D	People who served Matsue clan
E	Clan government reform and subsequent Matsue clan
F	Industry that supported Matsue
G	The Matsue that YAKUMO loved
H	Coexistence with water
I	People's livelihood in The Castle Town
J	Matsue culture cultivated by FUMAI
K	Underground Remains Restored

A questionnaire survey was conducted on visitors to the history museum to collect actual museum experience data.

The outline of the questionnaire is as follows.

1) Purpose:

Investigate and record the experience of visitors' museums (content of viewing and impressions of exhibits) and use them as knowledge.

2) Target:

Visitors of Matsue History Museum basic exhibition room.

3) Method:

Survey using questionnaire (Questionnaire image is in "Appendix")

4) Main question contents.

- Purpose of visiting
- Exhibition section left in impression
- Exhibition style left in impression
- Overall impression of the exhibit
- Exhibition theme request
- Respondent's own information

5) Investigation period

- 2018/11/26 (Mon) 13: 30 - 17: 00
- 2018/11/27 (Tue) 8: 30 - 17: 00
- 2018/11/28 (Wed) 8: 30 - 12: 00.

TABLE II : Questionnaire Number of Responses

Channels	11/26	11/27	11/28	Total
Number of visitors	27	70	16	113
Questionnaire collected	21	50	11	82
Collection rate	77.8%	71.4%	68.8%	72.7%

As shown in Table II, responses were obtained from 82 people to 113 visitors during the survey period.

65% of respondents were over the age of 60, 96% was the first visitor. Approximately 50% of the visitors are visiting Matsue History Museum as "a part of Matsue sightseeing", not as a destination.

The state of visitors to Matsue History Museum, which was obtained from the questionnaire results, will be introduced below.

Fig. 3 shows the viewing time (the time from entering the exhibition room until exit).

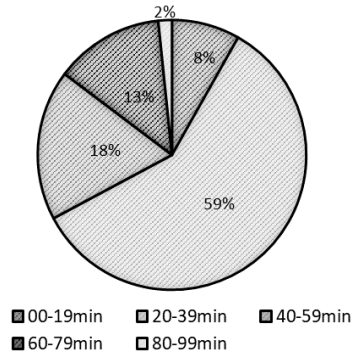


Fig. 3. Viewing time.

The viewing time of 59% visitors was 20 minutes or more and less than 40 minutes. 33% visitors spend more than 40 minutes to viewing, but 8% visitors had extremely short viewing times of less than 20 minutes.

The exhibition section left by the visitor's impression is as shown in Fig. 4. There is an exhibition section that remained in the impression of visitors of less than 40% (31 out of 82 people), while there are exhibition sections where the percentage of visitors remaining in the impression is less than 10% (8 out of 82 people).

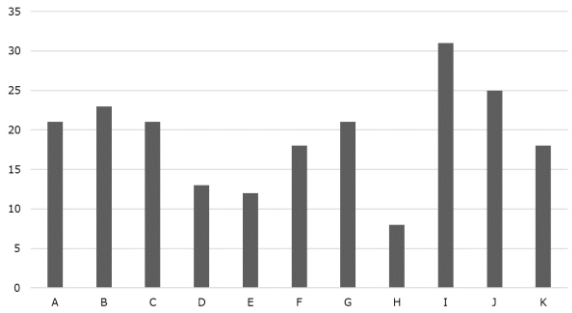


Fig. 4. Exhibition section left in impression.

In each exhibition section, various styles of exhibition are adopted besides showing the materials themselves. As an example, "Supporting the imagination of old scenes using dioramas and images", "Supporting active viewing by interactively manipulating displays" and so on. Fig. 5 shows the style of exhibition left by the impressions of visitors.

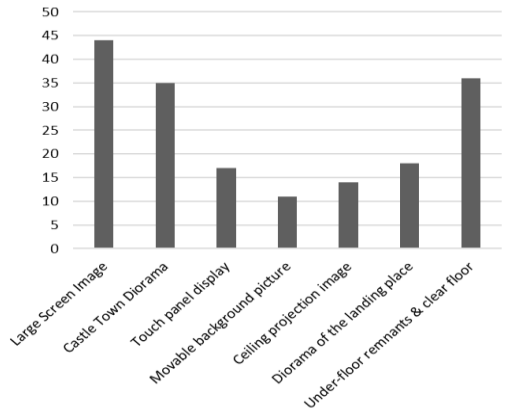


Fig. 5. Exhibition style left in impression.

In each exhibition section, various styles of exhibition are adopted besides showing the materials themselves. As an example, "Supporting the imagination of old scenes using dioramas and images", "Supporting active viewing by interactively manipulating displays" and so on. Fig. 5 shows the style of exhibition left by the impressions of visitors.

In this survey, visitors were asked to rate the impression of the entire exhibition in 8 items. Each item is "easy to understand", "characteristic", "expected satisfaction", "degree of freedom", "easy to see", "interesting", "comfort", "fulfillment degree of exhibition" Items were evaluated in 5 steps from -2 to +2 in 1-point increments. Fig. 6 is a bar chart of the average points of each item.

Although there is no item of remarkably high points, it shows that it gives a good overall impression.

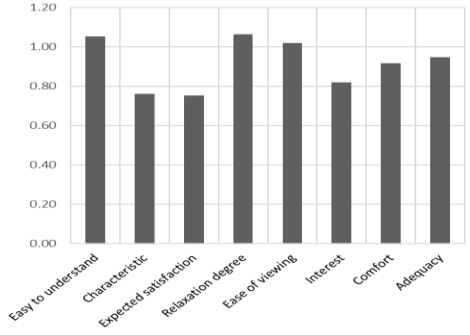


Fig. 6. Impression of the entire exhibition.

Using simple charts simple charts, it is possible to roughly grasp visitors' museum experience. However, in order to use the results of the questionnaire survey as knowledge, it is necessary to knowledge information so that the following questions can be answered.

1) Questions from the museum staff:
"What kind of exhibit are left in the impression of visitors and are satisfied?".
2) Questions from visitors:
"Which exhibits will you be able to view to satisfy your interests and interests?".

IV. Results

Express the museum experience of Matsue History Museum collected by questionnaire survey using graphs.

The image in the actual exhibition room is as shown in Fig. 7. Exhibition sections are arranged along the walls of the exhibition room, and viewing routes are also set

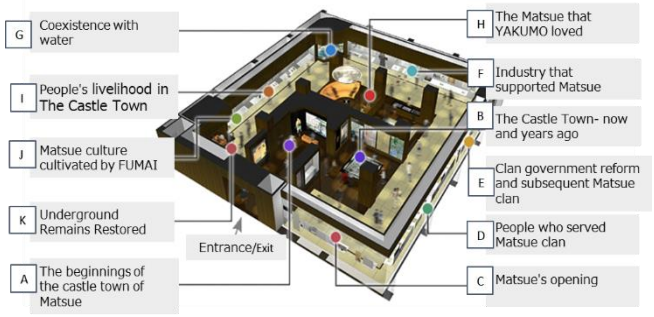


Fig. 7. Image of exhibition room.

The image of this exhibition room is represented graphically as shown in Fig. 8. Each node represents an exhibition section, and each edge represents a route in the exhibition room. The exhibit section name is indicated by the ID shown in Table II. In Matsue History Museum, it is possible to return to the route, so it is represented as an undirected graph.

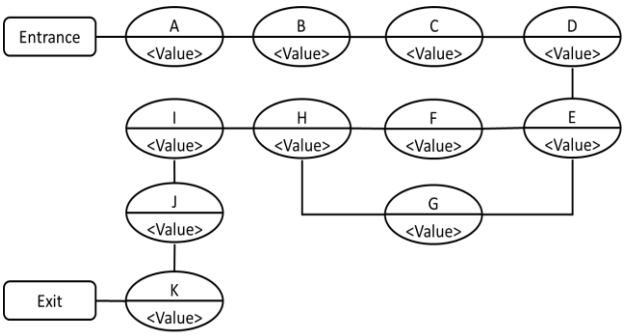


Fig. 8. The graph model of the exhibition room.

In this model, the intention and purpose of the museum experience are expressed by types of values obtained from each node. Regarding the movement of the exhibition section, there are no restrictions, so the edges are not given a cost.

Compare the strength of impressions for each exhibition section. Fig. 9 shows the number of visitors who left the impression in the section. Depending on the number of people, nodes are painted differently. A star mark is added to the node according to the number of people. There are three

in the section remaining in the impression of more than 30 people, two in 20 to 29 people, one in 10 to 19 people, and 0 in less than 10 people.

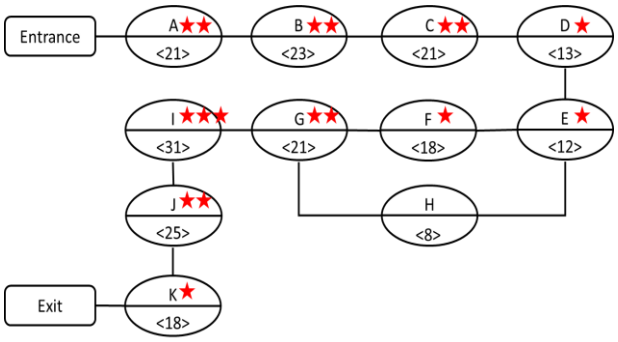


Fig. 9. Compare the impression of exhibition section.

The impression of the exhibition sections near the entrance and the exit is strong, and the impression of the exhibition section located in the middle is weak.

Also, there are two routes between the exhibition sections E and G. It also shows that the impression of the exhibition section H passing through one way is particularly weak.

From this, it turned out that the setting of the exhibits and the route influences the strength of the visitor's impression.

Compare the strength of the impression of the exhibition style in the same way. Each node represents an exhibition place of the exhibition style. The numerical value attached to the node is the number of visitors who left impression of the exhibition style. (Fig. 10)

A star mark is added to the node according to the number of people. Three in the exhibition style left over 40 impressions, two in 20 - 39 people, one in 10 - 19 people.

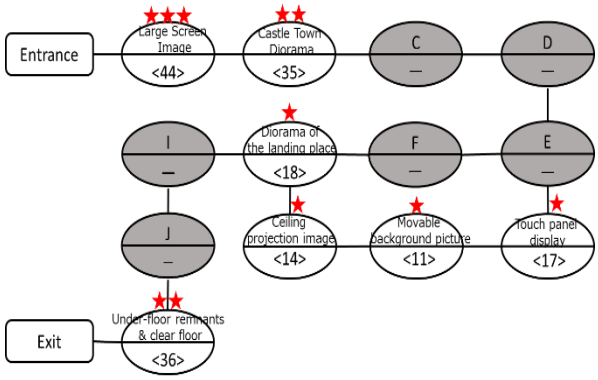


Fig. 10. Compare the strength of the impression of the exhibition style.

Exhibition sections C, D, E, F, I, J are not exhibited in a special form other than exhibition of materials, and three kinds of exhibits are arranged for exhibition section H.

Consider the relationship between the strength of the impression of the exhibition section and the viewing route. The impression near the entrance and exit has a strong impression. The middle part of the route (especially the route where two routes exist) remains in the impression of the exhibition form, but it is weak as the exhibition section.

Another visualization is the relation between the impression of the whole exhibition shown in Fig. 6 and the exhibition section that remained in the impression.

Fig. 11 is a bar graph showing the relationship between the impression evaluation of the entire exhibition and the exhibition section.

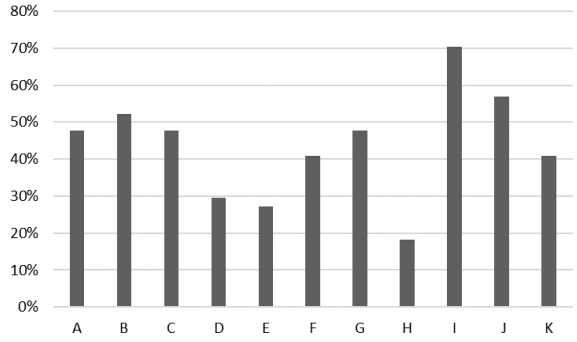


Fig. 11. Impression and the exhibition section.

70 % of those who had positive impression evaluation said that Section I remains in impression. In addition, sections B and J remain in the impression of more than 50% of people.

Express the relation between the impression evaluation of the entire exhibition and the exhibition section left in the impression on the graph. The numerical value of the node is the proportion of those who responded that the impression evaluation was positive and that "the exhibition section was left impressed". (Fig. 12).

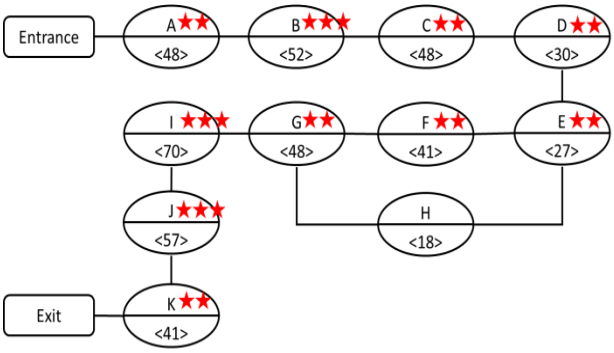


Fig. 12. Impression and the exhibition section (Graph).

A star mark is added to the node according to the proportion. Three in the exhibition style that remained impressive over 50%, two vertical lines in 25% or more and less than 50%, and 0 in less than 25%.

It is understood that the result of the impression evaluation also has the same tendency as before.

V. Discussion

Focusing on the exhibition structure of the museum, by introducing knowledge on the arrangement and route of the exhibition section, it is possible to visualize the exhibition contents of the museum using graphs. Furthermore, by adding the information obtained from the questionnaire and the information held by the museum staff, the museum experience can be shared and used as knowledge.

By visualizing the exhibition section from multiple perspectives, it was possible to show the museum staff differences in the impressions of the visitors due to the arrangement of the exhibits and the setting of the route.

In addition, for the visitors, it was possible to grasp the characteristics of exhibition contents from the impression that the actual viewer felt.

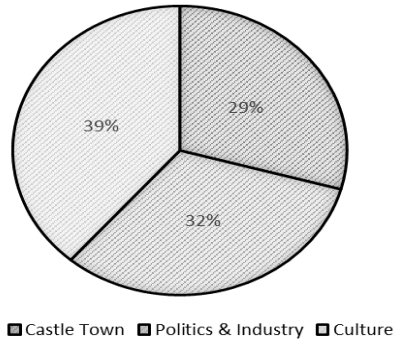


Fig. 13. The theme of visitors' interest.

Expression of the museum experience graphically can be applied not only to visualize the past museum experience but also to the development in the simulation in the exhibition room and the recommendation contents to the visitors.

As mentioned above, most of the visitors are visiting for the first time as part of sightseeing, and the length of stay also varies. Also, as shown in Fig. 13, the theme that is interested is not biased toward a specific theme, and different by visitors.

In such a situation of visitors, it is considered that satisfaction of visitors is improved by presenting an appropriate viewing experience.

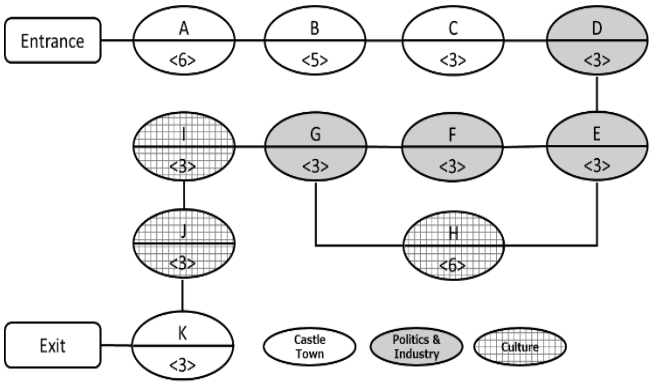


Fig. 14. Model of visitor's experience.

For example, from the museum staff side, recommendation viewing time for each section and exhibition theme of each section are provided as information. In addition, visitors present information on themes of their interests and interests, and the time to divide for viewing. The knowledge is expressed graphically as shown in Fig. 14. Nodes are painted by exhibition theme. The <value> of the node is the recommended appreciation time of each corner.

This problem is defined as an optimization problem of how much the exhibition section that matches the theme of interest or interest is circulated under time constraints.

For example, consider a case where a visitor has 30 minutes of viewing time and is interested in "Castle Town" and "Culture". By watching the exhibition section on the route A-B-C-H-I-J-K, it is possible to appreciate exhibition sections of interest within time.

The museum experience that can be represented at the current stage is relatively simple. However, it is possible to cope with complicated problems by creating algorithms such as the following for complex combinations of visitor's intention and purpose.

1) Algorithm for setting constraint conditions.

2) Algorithm to evaluate the value or benefit obtained when viewing the exhibition section.

3) Algorithm for finding the viewing route to obtain optimum value under constraints.

With doing this, it becomes possible to evaluate and simulate the presentation of a viewing plan to raise the satisfaction level of visitors, the placement of the exhibition materials, and the setting of the route.

In this survey, museum experiences only collect impressions of visitors' overall impressions by questionnaire. In accordance with future data collection and accumulation, it can be expected to promote the development and refinement of algorithms such as extraction of viewing patterns using machine learning.

Table III summarizes the data items and collection methods that are supposed to be collected.

In collecting data, consideration must be given to the impact on the museum experience of visitors. When collecting data by exhibition materials, it is conceivable to collect all the data at once, narrow down to the exhibited materials of interest, and collect data by dividing it into several times.

TABLE III: THE DATA ITEMS AND COLLECTION METHODS

Item	Target		Collection unit			Method	
	Visitor	Museum Staff	Entire	Section	Artifact	Automatic	Questionnaire
Purpose	✓		✓				✓
Interested theme	✓		✓			✓ (In the future)	✓
Viewing time	✓ (Actual)	✓ (Recommended)		✓	✓	✓	
Viewing route				✓	✓	✓	
Impression	✓		✓	✓	✓	✓ (In the future)	✓
Emotion	✓		✓	✓	✓		✓
Evaluation	✓		✓	✓	✓		✓
Exhibition theme		✓	✓				✓
Exhibition room structure		✓	✓				✓
Exhibition theme arrangement		✓	✓				✓

In collecting data, consideration must be given to the impact on the museum experience of visitors. When collecting data by exhibition materials, it is conceivable to collect all the data at once, narrow down to the exhibited materials of interest, and collect data by dividing it into several times.

As for subjective information handling, it is necessary to absorb differences in interpretation by individuals. As in the

approach of active knowledge engineering, it is effective to introduce self-explanatory formats and interfaces using multi-view symbols instead of natural language dependent interfaces in application programs [7]. In addition, it is effective to concurrently conduct acquisition of viewing guide and museum experience data by combining with information providing service that supports visitors' viewing.

Advancing these things, it is expected that everyone can intuitively record their own museum experience without load, visualize it, and use it as knowledge.

VI. Conclusion

A graph-based model for visualizing visitors' museum experience was proposed and its application to visualize data of a historical museum was demonstrated. Different data were mapped to the model to analyze museum layout, exhibit styles, and visitor impressions. As result of the analysis, is was able to provide museum staff with critical information concerning layout of exhibit materials and route setting in the exhibition rooms. Also, it provided insight into improvement of viewing plans according to visitor interests.

Future research may include collecting and integrating knowledge of museum staff and visitor data. By increasing the amount and quality of data, it is expected to promote the development and refinement of algorithms for simulation and optimization of museum experiences, including extraction of viewing patterns using machine learning. Furthermore, the validity of the viewing route obtained as a solution to the optimization problem is verified by an actual visitor.

Appendix

Thank you for visiting us today.
Please cooperate with the questionnaire about exhibition of Matsue Historical Museum.

1. What is the purpose of visiting? (Please add ✔ to applicable items, multiple answers are possible.)

☐Viewing basic exhibits ☐Viewing the exhibition ☐Japanese garden ☐Interest in Museum
☐Sweets and confectionery ☐Use of tea room ☐Use of Museum Shop ☐After Matsue sightseeing
☐Event participation ☐Just a break ☐Use toilet ☐Other( )

2. Please tell me the exhibition corner that remained in the impression. (Please add ✔ to applicable items, multiple answers are possible.)

☐Coexistence with water
☐People's livelihood in The Castle Town
☐Matsue culture cultivated by FUMAI
☐Underground Remains Restored
☐The beginnings of the castle town of Matsue
☐The Matsue that Yokumo loved
☐Industry that supported Matsue
☐The Castle Town-now and years ago
☐Clan government reform and subsequent Matsue clan
☐People who served Matsue clan
☐Matsue's opening
entrance

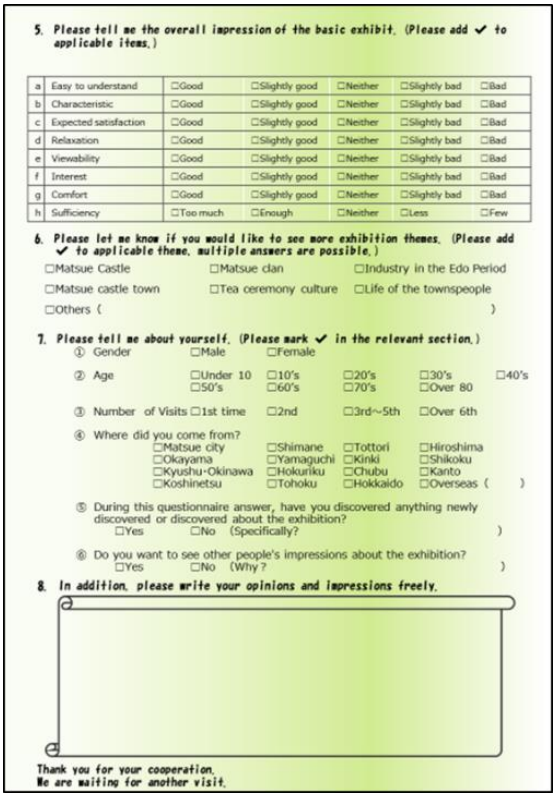
3. Please tell me the exhibition style that remained in the impression. (Please add ✔ to applicable items, multiple answers are possible.)

☐Large Screen Image	☐Town Diorama	☐Touch panel display	☐Movable picture
☐Ceiling projection	☐Harbor diorama	☐Underfloor remnants	☐Other ※Please write in the range to understand such as exhibition name ( )

4. Please let me know if there are exhibits of particular interest. (If you can not write it please also write in the free description column at the end)

Exhibit name (It is fine to understand)	What were you interested in or interested in?

※Also please the back side.



5. Please tell me the overall impression of the basic exhibit. (Please add ✔ to applicable items.)

a	Easy to understand	☐Good	☐Slightly good	☐Neither	☐Slightly bad	☐Bad
b	Characteristic	☐Good	☐Slightly good	☐Neither	☐Slightly bad	☐Bad
c	Expected satisfaction	☐Good	☐Slightly good	☐Neither	☐Slightly bad	☐Bad
d	Relaxation	☐Good	☐Slightly good	☐Neither	☐Slightly bad	☐Bad
e	Viewability	☐Good	☐Slightly good	☐Neither	☐Slightly bad	☐Bad
f	Interest	☐Good	☐Slightly good	☐Neither	☐Slightly bad	☐Bad
g	Comfort	☐Good	☐Slightly good	☐Neither	☐Slightly bad	☐Bad
h	Sufficiency	☐Too much	☐Enough	☐Neither	☐Less	☐Few

6. Please let me know if you would like to see more exhibition themes. (Please add ✔ to applicable theme, multiple answers are possible.)

☐Matsue Castle ☐Matsue clan ☐Industry in the Edo Period
☐Matsue castle town ☐Tea ceremony culture ☐Life of the townspeople
☐Others ( )

7. Please tell me about yourself. (Please mark ✔ in the relevant section.)

① Gender ☐Male ☐Female

② Age ☐Under 10 ☐10's ☐20's ☐30's ☐40's ☐50's ☐60's ☐70's ☐Over 80

③ Number of Visits ☐1st time ☐2nd ☐3rd~5th ☐Over 6th

④ Where did you come from?
☐Matsue city ☐Shimane ☐Tottori ☐Hiroshima
☐Okayama ☐Yamaguchi ☐Kinki ☐Shikoku
☐Kyushu-Okinawa ☐Hokuriku ☐Chubu ☐Kanto
☐Koshinetsu ☐Tohoku ☐Hokkaido ☐Overseas ( )

⑤ During this questionnaire answer, have you discovered anything newly discovered or discovered about the exhibition?
☐Yes ☐No (Specifically?)

⑥ Do you want to see other people's impressions about the exhibition?
☐Yes ☐No (Why?)

8. In addition, please write your opinions and impressions freely.

Thank you for your cooperation.
We are waiting for another visit.

Questionnaire Format

Acknowledgment

We would like to express my gratitude to the Matsue History Museum staff who helped to confirm the validity of the question and to conduct the survey in questionnaire survey of visitors.

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