文化財へのプロジェクションマッピング利用に関する計画論的研究

Application and Methodology study of Projection Mapping Technology in Cultural Heritage Sites

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1. Introduction

(1) Research background

The accelerated advancement of projection mapping (PJM) and interactive technologies has led to the emergence of new interpretative possibilities for the presentation of cultural heritage sites. Digital experiences are gradually becoming an important component of visitors' experiences at cultural heritage sites.

As PJM technology increasingly attracts visitors to museums, heritage pavilions, heritage sites, etc., numerous designers and researchers recognize the value of modern technology for cultural tourism and intellectual experiences, and the concepts of "digital cultural heritage" and "digital cultural tourism" have been widely discussed in professional and academic circles. (Navarrete T, 2013)

Within the area of world heritage studies, one of the critical missions in the international protection of cultural heritage sites is the interpretation of cultural heritage, which is an essential component in the process of heritage conservation (ICOMOS, 2008). The planning designs for many cultural heritage sites separate the visitors from the environment and discourage their willingness to stay longer. Considering this phenomenon, the value of using PJM for transmitting information about cultural heritage sites has been discussed around the world.

However, the methodology of PJM application in cultural heritage sites lacks a fully discussion, and as most of the international cases are organized by companies or individual artists, the implementation of PJM events is too dependent on the subjective aesthetics and experience of the designers (Yun H R, 2013). Also, despite PJM can be used to create visually stunning displays, it is important to ensure that the PJM content is accurate and respectful of the significance of cultural heritage sites, otherwise it may perpetuate stereotypes or misinterpret the history or culture of cultural heritage sites (Kim D, 2015).

(2) Research objective

This study aims to determine the current trends from the perspective of whether the information of cultural heritage is adequately expressed in the PJM implemented in cultural heritage sites, and the perceptions of developers and designers towards PJM in cultural heritage sites. Based on these findings, an "evaluation system of PJM for cultural heritage" was set up to understand whether the features of cultural heritage are being expressed in PJM, and the workflow to achieve the useful data results of the system was also verified in the case study.

(3) Research outlines and methodology

Regarding the research outline of subsequent research, this study will be thoroughly discussed through three stages of research and conclusions in three directions:

1. *The information tendencies demonstrated by PJM events at cultural heritage sites.*
2. *Design and testing of visitors' experience evaluation systems.*
3. *Data analysis and suggestions.*

In the Phase 1, an extensive number of cases from the world will be collected to determine the information tendencies conveyed by heritage PJM. For this purpose, this study proposes an original analysis method called "Timeline Analysis" as the principal analytical method throughout the article, to be a resource and foundation for perspectives, and clarifying the question of "what information designers disseminate through PJM" in the form of data (De Paolis LT, 2022).

The Phase 2 is the process of designing an original evaluation system for visitors' experiences in PJM events at cultural heritage sites, to help relevant designer and developers identify issues and areas for improvement. The evaluation system will be implemented in the form of questionnaires to understand the cultural information that

visitors prioritize when viewing PJM projects and draw conclusions on the "tendency to recall cultural information". Meanwhile, to verify the practicality and scientific validity of the system, a campaign (Tang Cheng, Xiangyang, China), which was the subject of this study, with high relevance of PJM content to the conclusions of the first phase (PJM information tendency), was selected for the trial run of the evaluation system.

In the Phase 3 of this study, the data analysis process mainly employed structural equation modeling (SEM), chi-square tests, Pareto charts, and cross-analysis, to understand variations in visitors' recall and preferences for PJM information as the frequency of visits increases, and further examine the effectiveness of PJM on visitors' cultural experiences. Thus, providing a reference for the developers for improvement (Rowe A, 2014).

Finally, this study will synthesize the beneficial intelligence that can be provided to designer and developers from the evaluation system and identify the ways in which the above intelligence can be consulted for PJM design improvements. The development of the evaluation system and the suggestions for designer and developers derived from the data results will serve as the main contribution of this study.

2. Analysis of information tendency for PJM

(1) Analyzing PJM information tendency

The first stage to identify the cultural information tendencies conveyed by PJM events at heritage sites and investigate the potential underlying causes. The findings obtained from this section can serve not only as a valuable reference for designer and developers aiming to refine their design work, but also as a theoretical basis for the conceptualization and development of "visitors' experience evaluation systems." (Li H, 2021).

(2) Timeline analysis method

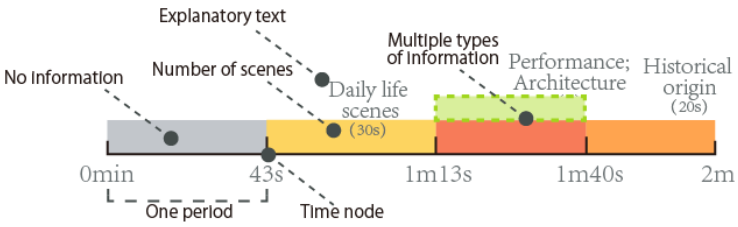

Fig.1 Timeline chart format

This study recognized that most PJM videos in cultural heritage sites have a relatively complete storyline features, i.e., using PJM to create compelling narratives that weave together the historical and cultural aspects of the site, immersing visitors in the stories and events that shaped its history. Therefore, the summarization and analysis of the PJM information can be conceived in the form of a "time/story line". (Li H, 2023)

Timeline analysis method is devoted to segment the PJM video content into distinct temporal intervals, allowing for a comprehensive analysis and documentation of the number of scene units and information trends exhibited during each period (Fig.1).

(3) Result of information tendency

The author distinguishes PJM projects into "large-scale PJM" and "medium/small-scale PJM" based on carrier size and, compares and integrates information tendencies for both types of PJM using timeline analysis charts, deriving conclusions on PJM "information tendency."

After completing a detailed analysis of 33 cases and data summaries, the conclusions of PJM's "information tendency" can be synthesized as: the features of large-scale PJM include its excellence in presenting historical flow concepts, such as stories of historical development and war histories. The features of medium/small-scale PJM include its versatile ability to express many types of information with wide applicability. Compared with large-scale PJM, the information expressed in medium/small-scale PJM has a tendency toward showing more "ornament and art" information (Fig.2).

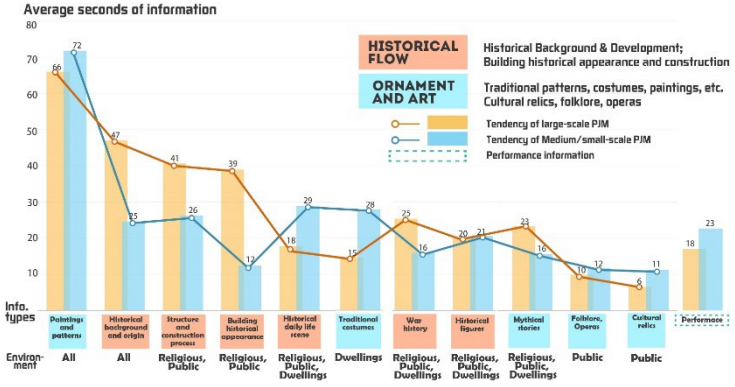

Fig.2 Information tendency data

Meanwhile, to determine the relationship between PJM vehicles and PJM content, the author proceed with an in-

depth discussion regarding three aspects of the information composition of large-scale PJM, the three-dimensional and functional attributes of the vehicles, and the interior and exterior technical features.

The author first categorizes the vehicles into three types of "Religious buildings/Dwellings of authority/Public living facilities" based on the criterion of the "functionality of the vehicle in history", and further distinguish the vehicle's three-dimensional structures into "Horizontal walls/ Vertical and tower/ Aisa roofs/ Water, bridge". Combine with the information tendency result, the religious and faith-related buildings (5 of 33 cases, temples, monasteries, churches, etc.), are more inclined to display the building structure and historical appearance, and scenes of people engaging in religious worship.

Different from the religious faith buildings, the PJM events of the dwellings of authority display a completely opposite information tendency (16 of 33 cases). Regardless of citadels or palaces, the dwellings of authority not only represent the specific historical origins and development of a country, as well as to a certain extent reflecting the development of architectural techniques and the process of building renovation and restoration in various eras.

Compared to the two types of vehicles mentioned above, the information conveyed by PJM events in the "public facilities" category was more evenly distributed, with both "Historical flow" and "Ornament and art" information widely included (12 of 33 cases). Meanwhile, the historical flow information is not displayed as frequently as "Dwellings of authority," which tend to display the lifestyle of historical figures more than the historical background and development. In summary, the historical function and characteristics of buildings indeed influence the information tendency of PJM to a certain degree, especially among large-scale PJM vehicles.

3. Evaluation system design

(1) Interview survey of designer and developers

The author argues that the demonstration of PJM information does not equate to "cultural information receiving by visitors effectively". Therefore, to understand the potential influence of PJM on the visitors' cultural experience and complete the design of evaluating system for visitors' experience, seven designers who are currently engaged in digital media design careers and three developers of digital media technology-related companies were interviewed for this study. After understanding the questions currently encountered in their work, the following directions were formulated as a reference for the system design:

1. *The designers and developers are gradually diverting the attention to visitors' experience surveys but lack a methodical and scientific methodology.*
2. *"Overall experience of PJM," "Impressive cultural knowledge," "Negative comments," and "Post event publicity" are the sorts of visitor feedback that designers/developers are most concerned about.*
3. *The necessity for "historical rigor" also inevitably limits the creativity and efficiency of the designer while creating historically relevant PJM content.*
4. *It was necessary for designers and developers to have a thorough awareness of the actual effects of PJM on the visitors' experiences, particularly the condition of knowledge experience.*
5. *Designers are more concerned with the understanding and propensity of visitors to recall the cultural content in PJM, while developers are more concerned with the cultural experience and touring comfort of visitors through PJM events.*

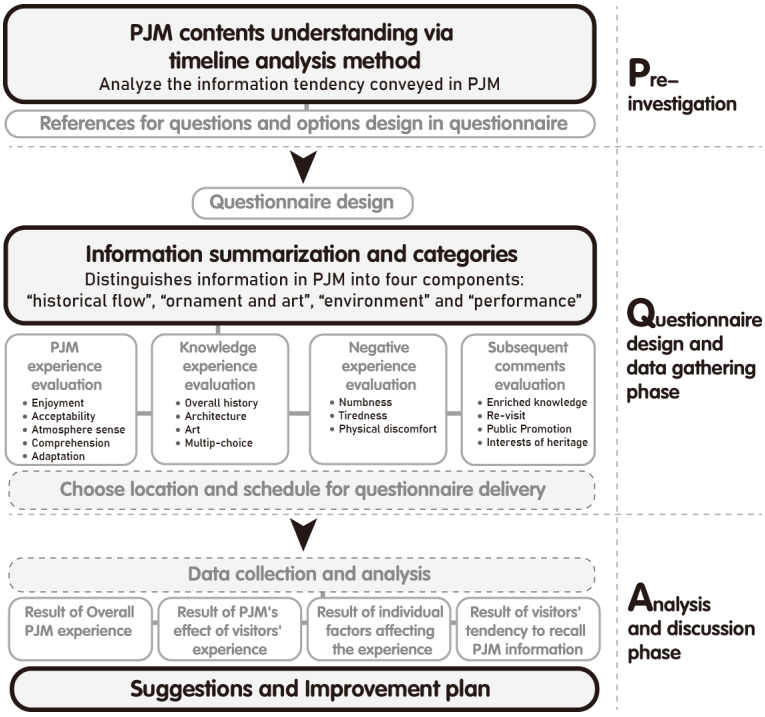

Fig.3 Framework and procedures of the evaluation system

(2) Framework of evaluation system

The information demands that designers and developers expect from the evaluation system can be divided into two directions. First is concerning "overall experience of PJM / knowledge experience / negative experience / willingness on recommendation after event." This direction corresponds to the most common and central demands of the designers and developers interviewed. The next is concerning "PJM contents understanding of current PJM content / evaluation of the effectiveness of PJM on the visitors' experience / visitors' tendency to recall PJM information." This direction relates to information, which was not directly mentioned by the interviewees, but considered important to discuss in-depth to better capture the direction of improving PJM content (Fig.3).

The evaluation system has a tripartite structure, with a "pre-investigation phase," a "questionnaire design and data gathering phase," and an "analysis and discussion phase," also referred to as "Phase P," "Phase Q," and "Phase A" (Fig. 2). Each phase includes a central work task (marked in bold black squares), the completion of which directly influences the designer's reflection on the existing questions as well as the applicability and rationality of the questionnaire design.

"Phase P" refers to the pre-investigation phase. During this phase, the investigators were required to conduct an inspection of each site and building where the projection was to be applied. Simultaneously, the investigator was required to conduct a PJM content understanding to review the precise information conveyed by the PJM via timeline analysis method.

"Phase Q" refers to the formative investigation phase. In this phase, the investigator first needed to categorize the cultural information revealed in the PJM into four categories, "historical flow," "ornament and art," "environment," and "performance," and to incorporate information such as question options into the "knowledge experience evaluation" section. The next task in Phase Q was to design the questionnaire according to the results and summarization of interview survey. This study categorized the common problems into four categories:

1. *PJM experience (enjoyment / acceptability / sense of atmosphere / comprehension / adaptation)*
2. *Knowledge experience (history/ architecture /art/ multi-choice)*
3. *Negative experience (numbness / tiredness /physical discomfort)*
4. *Subsequent comments (enriched knowledge / intention to revisit / public promotion)*

4. Visitors' experience evaluation

(1) A trial run of the system in China Tangcheng

To test the feasibility of the evaluation system, the author conducted a trial run of the system in a study of a digital media campaign in the Tangcheng national scenic area, Xiangyang City, Hubei Province, China, from 1 October to 7 October 2021, of which they were co-investigators. Meanwhile, prior to the official investigation, we first disaggregated and analyzed the three main PJM events in Tangcheng through a timeline analysis. The results of the information tendency derived from the timeline analysis can be used as an important reference in questionnaire design and later data analysis.

A total of 25 questions were contained in the entire questionnaire, which were spread out into two phases for distribution. The Phase 1 questionnaire was distributed at the Tangcheng heritage site with 1,672 responses gathered, for a total of 1,101 valid responses; The Phase 2 questionnaire contained 6 questions and 362 responses, for a total of 237 valid.

(2) Determine the PJM' effects on visitor' experience

With a view to determine the effectiveness of the Tang Cheng PJM applications in enhancing the visitors' experience, this study adopts the structural equation model (SEM) approach to ascertain the effectiveness of PJM applications in Tang Cheng pertaining to several aspects of the visitors' experience (Fig.4).

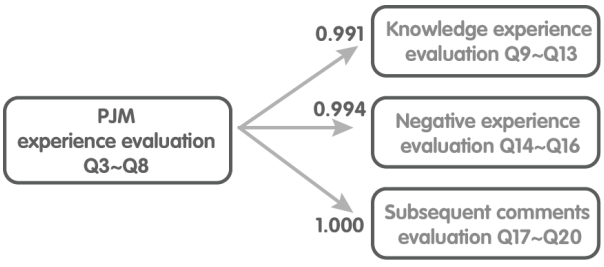

Fig.4 Path diagram of SEM

The data results indicate a significant correlation and influence between visitors' evaluations of their PJM experiences and other types of experiences. Accordingly, the findings can be interpreted to signify the substantial

influence on visitors' knowledge experiences, negative experiences, and subsequent comments through the integration of PJM.

(3) Visitors' tendency to recall PJM information

Next, a cross-tabulation analysis and Pareto diagram were used to analyze the visitors' tendency to recall PJM information. Since the questions of "knowledge experience" were developed in a multiple-choice format, this study classified the cultural information presented in the three PJM events into four categories: historical flow/ornament and art/environment/performance as a reference for the Phase 2 questionnaire. The definition of four types of information for Tangcheng is: "Historical flow" refers to historical background and development regarding the establishment of the Tang dynasty and significant war history; "Ornament and art" encompasses Tang dynasty texts, patterns, and portraits; "Environment" includes physical vehicles such as walls, bridges, and pagodas. "Performance" comprises sword dances, court dances, and the entirety of costume components.

To acquire the result of visitors' tendency to recall PJM information, this study conducted Phase 2 questionnaire that showcased the results in terms of "cumulative percentage" and "influence of trip frequency on recall". Consequently, the results of "visitors' tendency to recall PJM information" in Tang Cheng are divided in two parts, for building-surface PJM is: historical flow > performance > ornament and art = environment; for in-water PJM and on-bridge PJM is: ornament and art = performance ≥ historical flow >environment. However, the relationship between visitors' perceptions of PJM content and the structure of PJM content can still be understood by incorporating the results of the timeline analysis. Based on the comparative analysis, the author summarized three important PJM content features that would influence visitors' perceptions:

1. *Visitors' tendency to recall PJM information is not entirely based on the duration that displayed, but rather on the attributes of the information (historical flow information is recalled more frequently with short duration).*
2. *Information displayed during the first half period of the PJM program is more rememberable by visitors.*
3. *Visitors will also occasionally interpret "historical flow" information related to historical context from "ornament and art" and "performance" information, i.e., subjective associations with PJM information.*

(4) Contribution of the evaluation system

Subsequently, through such a set of evaluation system and analysis process, the authors summarized the specific types of results will designer and developers acquired in the following:

1. *Information tendency of PJM.*
2. *Comprehensive evaluation of visitors' experience.*
3. *PJM' effects on visitors' experience.*
4. *Correlation of individual factors with phenomenon.*
5. *Visitors' tendency to recall PJM information.*

5. Conclusion

This study is dedicated to developing an evaluation system for PJM technologies in heritage sites, for promote the development and cultural disclosure of contemporary cultural heritage sites, in the expectation that it will help relevant designer and developers to interpret the contribution of modern visual technologies to the cultural dissemination of heritage sites through scientific research methods and surveying approaches and provide valuable methodologies and suggestions for technical applications and design concepts. The conclusions of this study can be summarized as "one system, two tendency, and five suggestions".

Regarding the "one system", this study formulated an evaluation system that assesses the visitors' experience of PJM event at cultural heritage sites. Distinguishing from the conventional method and logic of visitors' experience investigation, the evaluation system advocates PJM developers to carry out PJM content understanding through timeline analysis before the investigation start. This step is helping the practitioner to form a hypothesis theory that serves as a scientific rationale for subsequent questionnaire design. With reference to the results of the "information tendency," the system also advocates classifying culture information into four types (Historical flow/Ornament and art/Environment/Performance), with the goal of attaining in-depth comprehension of visitors' tendency to recall PJM information and offering innovative scientific references for the creation and

improvement of PJM content.

Regarding the “two tendencies”, the results refer to the “PJM’s tendency to convey information” and the “visitors’ tendency to recall PJM information”. “PJM’s tendency to convey information” explicated that the information from large-scale PJM is inclined to “historical flow” and small/medium-scale PJM is inclined to “ornament and art”. Meanwhile, the study about “relationship of vehicle features and PJM information” also indicated that the current PJM in heritage sites does not well utilize the advantage of vehicle features.

Despite that “visitors’ tendency to recall PJM information” is not a common conclusion, this study also identified a significant prioritization of “Historical flow” information on visitors’ recall, even in a PJM program that focuses on “Ornament and art” and “performance,” the visitors can still associate “Historical flow” with the historical context. Both conclusions demonstrate the contribution of PJM to heritage sites from the perspective of both the “information transmitter” and the “information receiver”. Based on the results of the “two tendencies,” this study is intended to provide five suggestions for designer and developers:

1. *To increase productivity and quality, it is suggested that choose a longer historical time horizon and concentrate on the Historical flow historical context when planning the presentation of “Historical flow” information about historical context and development. This will help us avoid spending too much time researching and learning about insignificant and contentious historical events.*
2. *The “Ornament and art” information can be mixed in with the “Historical flow” information to ensure that visitors can enjoy the costumes, patterns, and other decorative elements without disrupting the overall logic and integrity of the PJM historical story.*
3. *When planning a PJM program in the form of “PJM combined with stage performance”, the length of the program should be controlled, as excessively long stage performance content will lead to boredom and weaken the cultural experience.*
4. *Designers ought to avoid utilizing heritage vehicle (building or landscape) to project an “artistic animation” that is no different from a regular screen, and more concerned with the three factors regarding the PJM vehicle's historical function, external structure, and surrounding environment to determine the PJM's design. Meanwhile, designers should consider optimize the interactive feature of PJM to enable visitors to connect with the heritage site environment and take PJM as a medium to integrate into the cultural environment of the site, rather than treating the heritage vehicle as a screen that outputs cultural information in a unidirectional mode.*
5. *It is suggested that designers should utilizing timeline analysis at the planning phase to comprehend the information trend of the PJM plan in a “time-split” style, to foresee options for questionnaire design.*

In the future study, the author would like to set up the topic to discuss the impact of interactive PJM on visitors’ experience, which will provide more ideas for designers to improve their design strategies.

References

1) Navarrete T. Digital cultural heritage. Handbook on the economics of cultural heritage. Edward Elgar Publishing, 2013.

2) ICOMOS. The ICOMOS charter for the interpretation and presentation of cultural heritage sites. 2008.

3) Yun H R, Kim D W, Ishii T. A study of digital media art utilizing the contents of the architecture cultural property. International Journal of Asia Digital Art and Design Association 17(2): 77-84. 2013.

4) Kim D. Projection mapping contents development of architectural heritage. Advanced Science and Technology Letters 113: 90-95. 2015.

5) De Paolis LT, Liaci S, Sumerano G, De Luca V. A Video Mapping Performance as an Innovative Tool to Bring to Life and Narrate a Pictorial Cycle. Information 13(3):122. 2022

6) Rowe A. Designing for engagement in mixed reality experiences that combine projection mapping and camera-based interaction. Digital creativity 25(2): 155-168. 2014

7) Li H, Ito H. Comparative analysis of information tendency and application features for projection mapping technologies at cultural heritage sites. Herit Sci 9, 126 .2021.

8) Li H, Ito H. Visitor’s experience evaluation of applied projection mapping technology at cultural heritage and tourism sites: the case of China Tangcheng. Herit Sci 11, 52. 2023.