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RESEARCH ARTICLE

Optimizing Projection Mapping in Cultural Tourism through Ryan's Interactive Narrative Framework

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ABSTRACT

This paper investigates how Marie-Laure Ryan's interactive narrative framework is used to optimize projection mapping technology in cultural tourism. Through an in-depth examination of four interaction modes, internal-exploratory, internal-ontological, external-exploratory, and external-ontological, this study evaluates the contribution this framework can make toward strengthening the coherence of narratives and deepening visitor engagement in projection mapping-based exhibitions. Four case studies of the cultural heritage sites are used to demonstrate how integrating Ryan's framework, with its benefits and limitations, contributes to the development of a more effective and memorable cultural tourism experience through the enhancement of visitor interaction and educational value.

Contribution/Originality: This study contributes to the existing literature by applying Ryan's interactive narrative framework to optimize projection mapping in cultural tourism, enhancing narrative coherence, visitor interaction, and educational value through four case studies of cultural heritage sites.

1. Introduction

According to Azuma (1997), augmented reality refers to the integration of digital content into the real world. While projection mapping is considered a form of augmented reality because it overlays digital elements such as animation or visual effects on the surface of the real world (Barber et al., 2017), it also represents an emerging form of spatial augmented reality where visual effects have the potential to be presented in novel and exciting ways. These sophisticated methods have enhanced the density of the special effects within cultural exhibitions by projecting static and dynamic images onto various structures that help visitors delve more deeply into the content presented (Li & Ito, 2023). Projection mapping can effectively integrate the virtual with the physical by projecting computer-generated images onto architectural surfaces and creating optical illusions that make virtual scenes appear very realistic (Chatzigrigoriou & Koutsabasis, 2022). Unlike

traditional augmented reality, projection mapping requires no personal devices, allowing immersive augmented experiences without glasses or other equipment (Iwai, 2017). With the development of projection mapping technology, its applications have expanded from traditional canvas surfaces to buildings, cars, and even live performers (Chatzigrigoriou & Koutsabasis, 2022). Yet much of its current application remains focused on visual spectacle, with less emphasis on conveying the cultural and historical meanings embedded in the structures, even in various cultural heritage settings where projection mapping is applied primarily for visual effects rather than reinforcing the building's cultural identity (Mikolajewska, 2023). Existing studies highlight the need for a systematic framework to assess projection mapping's effectiveness in enhancing visitor engagement and cultural appreciation (Beck & Jung, 2019; Li & Ito, 2023). This research responds to these calls by exploring how Ryan's (2006) interactive narrative framework can enhance projection mapping's design and application, aiming to deepen visitor engagement and reinforce cultural narratives within these immersive exhibits.

1.1. Problem Statement

Within cultural tourism, the utilization of projection mapping (PM) technology has developed as a powerful tool to make the experience of visitors more attractive and interactive with their surroundings. However, most applications of PM focus on creating spectacular visual experiences rather than communicating the historical and cultural values of heritage sites. Chrysanthi et al. (2021) identified that while digital storytelling is one of the widely applied interpretative tools in cultural heritage sites, there are challenges in developing interactive narratives. The interactive paradox refers to how the unpredictability of user movement and choice can be integrated into a pre-defined narrative structure that holds coherence in the story told. As a design focuses more on the interaction of the user, the coherence in the narrative structure is harder to achieve. Digital storytelling, therefore, needs further research to move away from simple narrative structures into more meaningful and complex ones. Ryan's (2006) framework differentiates four strategies of interactivity in interactive narratives, respectively, built based on two binary pairs, namely, internal/external and exploratory/ontological (Ryan, 2006, p. 107). This structure has provided a scientific approach to the analysis and enhancement of interactive experiences.

1.2. Research Questions and Objectives

This study aims to explore how can Ryan's (2006) interactive narrative framework be used to optimize the application of projection mapping in cultural tourism by analyzing internal-exploratory, internal-ontological, external-exploratory, and external-ontological interactions. To answer this question, the research objective is to apply Ryan's (2006) interactive narrative framework within cultural heritage contexts to design more immersive, educational, and culturally relevant visitor experiences.

Hence, this study aims to explore the potential of projection mapping (PM) technology in cultural tourism, with a focus on historical sites and museums. This research seeks to fill a gap in understanding how to optimize projection mapping, focusing on enhancing its educational and participative aspects within cultural heritage contexts. It also examines how projection mapping can be integrated with Ryan's (2006) narrative framework for optimal narrative design. Thus, the objective of this research is to create visitor experiences with deeper educational value and cultural relevance by analyzing the pros and cons of the four interaction modes.

2. Literature Review

As an innovative tool, projection mapping (PM) has been increasingly applied to different fields, with particular emphasis on the entertainment and cultural heritage sectors to enhance interaction through interactive or immersive experiences. Barbiani et al. (2018) pointed out that video projection mapping technology is usually used for entertainment, creating creative and artistic content by projecting animation onto real objects to provide audiences with an entertainment experience. This application not only transforms traditional static performances into dynamic art forms but also provides artists with an innovative platform to showcase visual content and attract broader audiences. Elashmawy (2020) emphasized that projection mapping technology can transform arbitrary surfaces, such as buildings or 3D models, into huge video screens and display animated images through virtual programs, creating interactive visual theatrical performances. This technique therefore combined digital visual and physical settings into an immersive interactive experience that enhanced aesthetic value and connected the audience more with the historical context of the performance.

Beyond entertainment, recent studies have explored how projection mapping finds considerable applications in museums and the conservation of cultural heritage. Building on these immersive possibilities, Rodrigues, Campos, and Cabral (2020) developed an interactive device called "StoryWall," which uses PM technology integrated with a touch board. The device uses conductive ink and a touchpad to create interactive sensors on the cardboard. When visitors touch the interactive surface, the system will trigger digital content, such as videos, to light up the walls and create an immersive narrative story experience. The creative approach will not only entertain visitors but also increase visitor engagement and the educational effectiveness of a museum and show the potential of PM in cultural communication.

King, Stark, and Cooke (2016) emphasized that "*the rise of new digital technologies brings a different dimension to this discussion, offering the potential to enhance active two-way engagement with heritage and facilitate access*" (p. 78). This suggests that digital technologies can allow people to participate more actively in cultural heritage and have easier access to relevant information. According to Georgescu Paquin (2020), King et al. (2016) noted that projection mapping has the potential to establish a 'cultural value of digital involvement' with heritage (p. 193). Georgescu Paquin (2020) pointed out that PM technology can enhance the monumentality of cultural heritage by adding layers of digital media. Projection mapping is not only a symbolic way to disseminate heritage information in the built environment, it also enables the narrative of heritage to transcend the physical space of the building through interactive collective experience, giving it a deeper meaning. As a spatial augmented reality tool, PM not only enriches the display form of museum exhibits but also creates varied media content through virtual reconstruction and interactive display. In the exhibition " The First Emperor China's Terracotta Army " at the Moesgaard Museum, visitors use PM in collaboration with the Center for Advanced Visualization and Interaction (CAVI) to illustrate that the Terracotta warriors in the tomb of the First Emperor of Qin were originally colored. Visitors can choose colors similar to those originally used and project their choice onto the replica, which is then integrated into a digital army display (Georgescu Paquin, 2020). With this interaction, visitors could engage more in a historical perspective, thereby making the various artifacts on view more understandable and meaningful.

2.1. Identified Gaps in Literature

Although PM has already found a remarkable scope of application in the entertainment field and in the conservation of cultural heritage, its optimization in educational contexts and a long-term assessment of its impact remain underexplored. Mikolajewska (2023) mentioned that "most of the video mapping performances carried out on Cultural Heritage still present a weak link between visual contents and the identity of the architecture involved in the projection" (p. 19), with much of the visual content lacking a connection to the uniqueness and cultural value of the building itself. Mikolajewska (2023) suggested that this technology should ideally disseminate scientific and cultural content without compromising the integrity of cultural heritage by prioritizing spectacle over substance. In a related line of research, Nikolakopoulou et al. (2022) put special attention on the possible use of PM for delivering intangible cultural heritage through interactive storytelling and marshaling a variety of multisensory experiences for visitors. However, indicated that there were some limitations and challenges found regarding projection mapping technology in practical applications, such as the complexity of the user interface. Much more empirical research is needed with regard to assessing the long-term effects of such installations on visitor learning and engagement. This literature gap underlines the need for further research to establish how PM can be systematically integrated into museum practice in order to make positive contributions toward the improvement of educational outcomes and cultural appreciation.

2.2. Theoretical Framework: Interactive Narrative Framework

Ryan (2006) "*distinguishes four strategic forms of interactivity based on two binary pairs: internal/external and exploratory/ontological.*" (p.107). Internal interactions occur when the user experiences the virtual world as a character, while external interactions involve the user viewing the virtual world from the outside. Exploratory interactions allow the user to explore without changing the state of the virtual world, while ontological interactions involve the user's decisions impacting the virtual world. By cross-classifying these two binary pairs, four combinations can be obtained. Each combination has different genre characteristics, favors a particular type of structure, and offers different narrative possibilities. Ryan (2006) defined four specific types of interactions: internal-exploratory, internal-ontological, external-exploratory, and external-ontological interactivity.

Internal-exploratory interactivity places the user in a virtual character or perspective in a virtual world, but the user's actions have no impact on the development of the virtual world or the fate of the character. In internal-ontological interactivity, the user becomes a role in the virtual world, and his behaviour determines the fate of the role, thus affecting the direction of the virtual world. External-exploratory interactivity: As an observer outside the virtual world, the user can choose different paths to explore the virtual world without influencing the events in the virtual world. External-ontological interactivity: The user plays the role of a virtual world and can influence the development of the virtual world (Ryan, 2006).

Ryan's (2006) theoretical framework is often applied to games or text narratives. This paper will innovatively explore the application of her framework to projection mapping techniques in cultural tourism, providing valuable insights for optimizing their educational and cultural applications by analyzing interactive narrative frameworks that use projection mapping techniques in cultural tourism projects worldwide.

2.3. Literature Summary

Existing literature suggested that projection mapping (PM) significantly enhanced the visual appeal and immersive experience of cultural exhibitions. PM has evolved from entertainment to preserving and interpreting cultural heritage, providing innovative ways to engage visitors and deepen their understanding of historical contexts. Applying these types of interactions may help improve the design of projection maps in cultural tourism projects, thereby increasing visitor engagement and leading to more immersive experiences and greater educational value.

3. Methodology

This research investigates projection mapping in cultural heritage tourism. In this respect, the study analyzes relevant literature and case studies using qualitative research methods by means of textual analysis. As a legitimate method of research, textual analysis allows the investigation of intricateness within a digital narrative setting in cultural heritage contexts and helps in gaining insight into how such narrative elements raise visitor interaction and learning experiences.

The secondary data on which the textual analysis is based will be clearly detailed in terms of its source and selection criteria. This will be followed by the procedure for data analysis, specifying how the texts collected will be interpreted and comprehended. Finally, a review of the suitability of Ryan's (2006) theoretical framework to assess any application of projection mapping in tourism to cultural heritage will be undertaken with a view to ensuring rigor and credibility in this research. For this reason, it is intended for the research to provide insightful guidelines to optimize the design of projection mapping in cultural heritage tourism projects.

3.1. Case Selection

This research involves four selected cultural heritage sites or museums with projection mapping technology. The selection criteria were chosen to provide a rich foundation in which PM enhances educational and immersive experiences. The first criterion is that each site should have a significant historical background to support PM applications, such as storytelling, reenactments, or interactive displays, allowing for comparisons of different approaches.

The second one is that the selected sites should be documented in the literature to ensure sufficient detail for in-depth analysis. This criterion will provide a foundation for supporting research through sufficient evidence and comprehensive assessments. Also, these cultural heritage sites must be open to the public to ensure that everybody can easily access them. Public accessibility ensures the relevance of research findings and their applicability to other similar public heritage sites, enhancing the practical value of research findings.

The third criterion is that every site's PM content should directly relate to its historical events, context, and architectural features. Relevance makes deployment involving PM technology both engaging, knowledgeable, and educative. Finally, the media in each case must be relatively complete online in either video or picture. Such media availability will

make thorough visual analysis possible, hence a comprehensive presentation of the research results.
These criteria will ensure that the selected cases provide a solid basis for exploring how PM might best enhance educational and immersive experiences within cultural heritage sites.

3.2. Data Collection

Data will be collected from academic journals, conference papers, books, research papers, and case studies. These literature sources will give a detailed explanation of the application of PM in historic sites and museums context, discuss innovative uses, and provide insight into PM technology. Following this shall be a systematic analysis of the data collected to identify patterns, themes, and insights about using PM to promote cultural tourism. The challenges and opportunities of integrating PM into cultural heritage settings will also be analyzed through four frameworks internal-exploratory, internal-ontological, external-exploratory, and external-ontological interactions.

3.3. Data Analysis

Data analysis will use the interactive narrative framework proposed by Ryan (2006) to identify key types of interactions occurring in these selected texts. This study will investigate how interaction types (internal, external, ontological, exploratory) influence visitor engagement and educational outcomes. The findings will be put into comparison across internal-exploratory, internal-ontological, external-exploratory, and external-ontological interaction types in order to find similarities and differences in PM. This approach aims to provide insight into best practices in PM integration within the context of cultural tourism to ensure the improvement of visitor experiences and the appreciation of culture.

4. Finding and Discussion

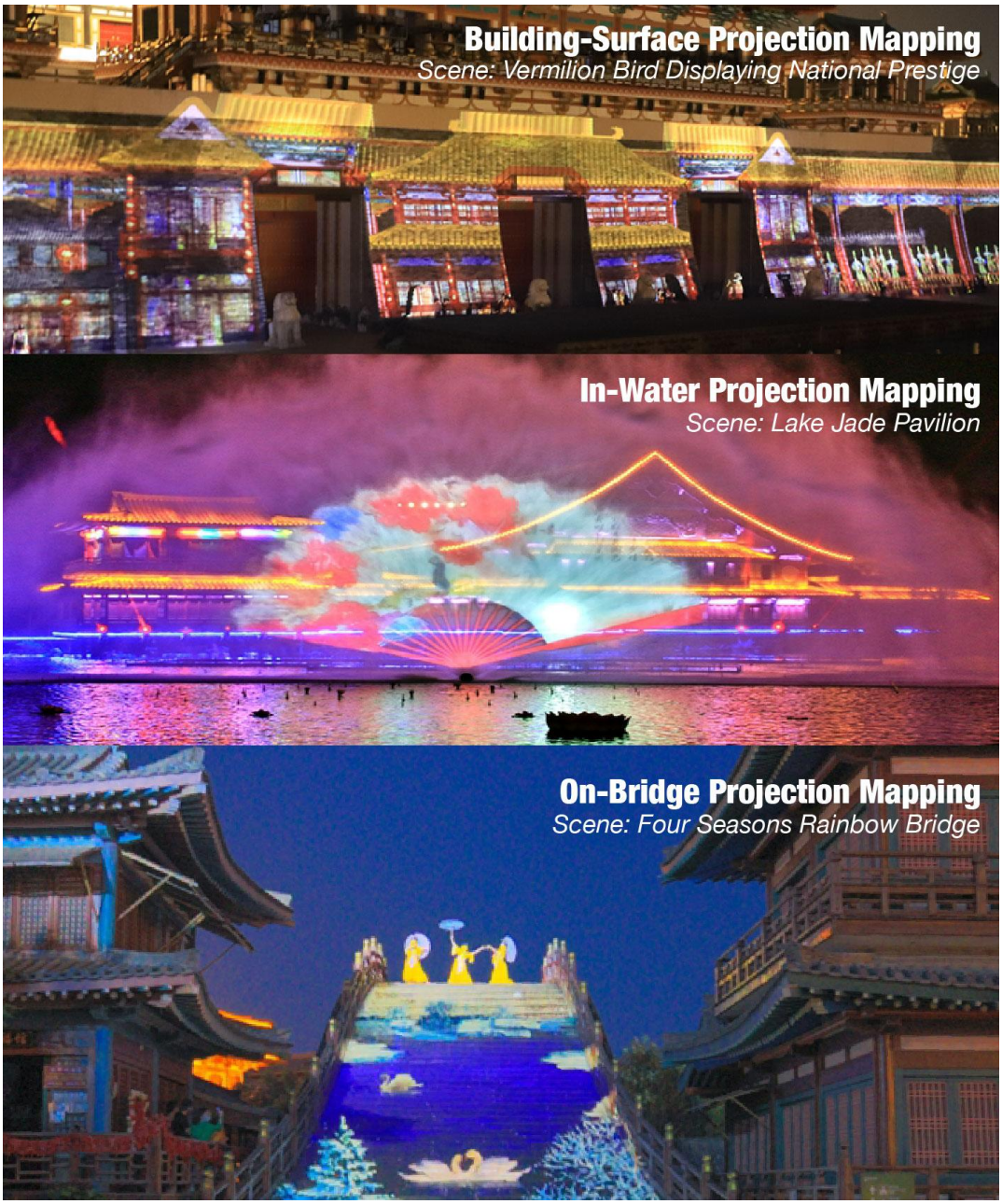
Projection mapping technology in cultural tourism enhances visitor interaction with various interaction types. Ryan's (2006) framework for interactive narrative allows for an analysis of such interaction types, categorizing them into four types: internal-exploratory, internal-ontological, external-exploratory, and external-ontological. Each one reflects a specific approach to engaging a visitor. In this regard, four case studies are going to be analyzed in this research paper to show such interaction types in practical applications. These cases demonstrate how projection mapping in cultural tourism can enhance cultural appreciation.

4.1. Internal-Exploratory Interaction: Tangcheng, Xiangyang, China

Located in the Hubei Province of China, Tangcheng is a famous 4A class tourist destination with more than 3.7 million square meters in area. It is also renowned for cultural tourism and as a popular film shooting location. This site includes a variety of projectable objects, such as buildings, towers, walls, courtyards, bridges, and water-based projection platforms. Tangcheng faithfully recreates the style, scale, materials, and spatial layout of Tang Dynasty architecture, making it an ideal comprehensive reference for studying the application of projection mapping on multiple objects.

Li and Ito (2023) outlined three main projection mapping activities in Tangcheng: building-surface projection mapping, in-water projection mapping, and on-bridge projection mapping (see Figure 1). The architectural surface projection mapping shows the macro-level information of historical development and architectural structure. Conversely, water holographic projection mapping conveys information at the micro-level, such as traditional paintings, artworks, mythological stories, and patterns. Bridge projection mapping combines dance performance with projection mapping to display ethnic costumes, dances, and Tang Dynasty poetry scenes.

Figure 1: Three types of projection mapping in Tangcheng.



Source: Tangcheng Official Website (n.d.)

The projection mapping activities in Tangcheng allow visitors to immerse themselves in historical narratives without changing the storyline. Offering a first-person perspective, these activities enhance visitors' connection to historical and cultural context, thus increasing their engagement. This interactive approach aligns with the principles of

internal-exploratory interaction. By experiencing the historical scenes of Tangcheng as part of the story, visitors' emotional involvement and interest in the cultural heritage presented significantly increases (Li & Ito, 2023). Compared to passive observation, this immersive experience helps retain historical knowledge, allowing visitors to explore historical narratives from a first-person viewpoint and gain a deeper understanding of Tang Dynasty culture and architecture. Besides, the realistic reproduction of the environment of the Tang Dynasty allows visitors to appreciate the aesthetic and architectural achievements of the period and provide a greater appreciation for cultural heritage.

However, Li and Ito (2023) noted that although projection mapping is good at showcasing the traditional costumes, music, and dances of different generations, it has insufficient historical backgrounds and narrative depths. This may result in most visitors acquiring aesthetic knowledge rather than a deeper historical understanding. The authors indicated that the current method of projection mapping needs to be more about cultural content and historical significance rather than just decoration. With this, it is suggested that there should be more elaborative historical narratives or contextual information in projection mapping activities. The improvements may change the type of experience for visitors from pure visual enjoyment to cognitive enrichment and emotional involvement, fully realizing the function of internal exploratory interaction.

In summarize, these projection mapping activities in Tangcheng, especially those involving internal exploratory interactions, are able to increase visitor participatory engagement and learning experience considerably. Because it immerses visitors in historical and cultural narratives, creating rich, engaging, and instructive experiences. Further development regarding the depth of historical content and narrative is recommended to ensure that effectiveness is realized to its full potential and, consequently, their contribution to the visitor experience.

4.2. Internal-Ontological Interaction: Wu Kingdom Helv Relics Museum, Wuxi, China

Located in Wuxi, China, the Wu Kingdom Helv Relics Museum is another good example of how modern projection mapping technology can change historical exhibits into interactive and captivating displays. Advanced technological techniques are used in this museum, highlighting the rich cultural legacy of the Wu Kingdom, to bring ancient stories to life: an approach that resonates with Ryan's (2006) concept of internal-ontological interaction. While other practices only use projection mapping directly onto historical buildings, this museum features a dedicated multimedia theater which transports the visitor to a 15-minute epic that takes them back to the era of King Helv to witness his rise to power, military campaigns, and crucial moments (Kraftwerk Living Technologies, 2014). One of the unique features of the museum would be the "Time Machine" installation, comprising 22 high-resolution projectors coupled with edge-blending technology that seamless visual displays across the theatre. This immersive environment is further enhanced by interactive sensors, infrared lighting, and tracking cameras, which allow visitors to engage with the content on a deeper level, making the experience more personal and impactful. The installation also incorporates a sophisticated multi-channel audio system, featuring 30 strategically positioned sound sources that produce an extraordinary acoustic atmosphere, enhancing the emotional impact of the exhibit (Tamschick Media+Space, 2014). According to Spallazzo and Ceconello (2021), "*projections transform both walls and floor into interactive areas for visitors... the walls are*

transformed into the scenography of an evolving story, while the floor becomes a place where visitors can interact with digital objects, animals, and natural elements" (p. 159). Through the timelines of the narrative scenes and the complete plot design, combined with the infrared motion capture system, the audience can trigger dynamic images in the plot as they walk, such as the ripples on the ground in the rain scene (see Figure 2).

Figure 2: The audience interacts with ripples on the ground in the rain scene.

Source: Tamschick Media+Space (2014)

This way of making the audience a narrative character ensures that they are not only passive observers but also active participants. The full immersion interactive experience allows the audience to interact freely through the combination of visual, auditory, and other senses, expands the scope of visual content through the mirror wall, enhances the visual impact, and brings a strong sense of immersion and rich emotional experience.

This interactive and immersive design helps visitors better understand historical events and their significance. According to iF Design (2015), the unique visual style combines movie-like martial arts scenes with painterly animation, reinforcing the linear narrative and enhancing the sense of time travel, as if visitors were witnessing the rise of the Wu Kingdom during the Spring and Autumn Period.

Kryvuts (2023) mentioned that the museum uses advanced projection mapping and VR technology to bring the history of the Kingdom of Wu to life, allowing visitors to experience the historical narrative in an immersive and interactive way. This approach enhances the visitor's understanding of the content and makes the learning experience more inclusive by accommodating different learning styles and abilities. Although Wu Kingdom Helv Relics Museum uses light shadow interaction and panoramic projection mapping, which enables visitors to become characters in the story, these interactions do not affect the outcome of historical events. History itself is an objective fact, so these interactions are designed more to deepen visitors' understanding and memory of history rather than to allow them to change the course of the story. Unlike Ryan's (2006) internal-ontological interaction theory, this design places more emphasis on the immutable nature of historical events. This paper, hence, targets using such interaction to enhance the education experience and make visitors retain historical knowledge more deeply. Given

this, the theory of Ryan (2006) may not be fully applicable since it is more oriented toward how actions within virtual narration by a character drive the story forward rather than on communicating and teaching facts about history.

4.3. External-Exploratory Interaction: Old Town of Zuoying, Taiwan, China

The old town in Taiwan is one of the well-preserved cultural heritages, and several digital technologies have been put into service to develop its visitor experience. It is one of the earliest stone fortifications built during the Qing Dynasty. Zuoying Old Town integrates the use of projection mapping, augmented reality, virtual reality, and dynamic model displays as methods for visitors to experience the rich historical and cultural legacies interactively (Liu, 2020). Its dynamic model display uses digital animation and projection mapping to show the town's architectural transformations across different historical periods. This model employs 50 vertical motion components to capture the changes in the town's structure and help visitors understand its historical development more effectively (Liu & Lin, 2021). See Figure 3 for an illustration.

Figure 3. Illustration of the architectural transformations of the Zuoying old town

Source: Regeneration of Historic Sites (2018)

Moreover, AR and VR technologies even enrich external-exploratory interaction. For instance, within the activity of the "Old City Treasure Hunt," with the help of an augmented reality device, visitors are enabled to detect digital information in the exhibition space. Additional historical information on important artifacts and events is revealed when visitors collect virtual currency. Such an interactive scavenger hunt type of activity links the exhibition together, encouraging visitors to actively explore the perspective of history.

Projection mapping works effectively in showing the historical and cultural development of Zuoying, but it might be limited in the application when deeper and more personalized interaction occurs. In this regard, AR and VR can increase the interactive and immersive experience for visitors in approaching historical content in a more dynamic manner. Such an integration of projection mapping with AR and VR will increasingly enhance the visual effects of educational experiences and emotional connection with the visitors.

In short, digital display technologies at Zuoying, especially those grounded in Ryan's (2006) framework of external exploratory interaction, have significantly enhanced the level of visitor engagement along with the learning outcomes. Since digital technology has become more widespread in the cultural heritage sector recently, Liu (2020) noticed that most visitors have had limited prior experience with digital display technologies, with many encountering AR and VR for the first time and struggling with unfamiliarity. Projection mapping, therefore, remains more accessible to visitors with limited experience and will continue playing an important role in museums and historical sites. However, this could be furthered to maximize the effectiveness of such an exhibition by incorporating projection mapping with AR and VR technologies to provide a richer historical narrative and deeper interactive experience.

4.4. External-Ontological Interaction: The Mastic Museum, Chios Island, Greece

The Mastiha Museum, located on the island of Chios in Greece, is dedicated to preserving and showcasing the cultural heritage surrounding "mastiha," which has been recognized as an important cultural asset by UNESCO's Representative List of the Intangible Cultural Heritage of Humanity. The museum utilizes interactive storytelling combined with projection mapping to integrate virtual content onto physical artifacts, thereby conveying the historical and cultural significance of mastiha cultivation. This approach enables visitors to engage with both the physical and digital aspects of the exhibit. A key feature of the museum is its interactive projection mapping system, which presents a 3D-printed scale model of a historic settlement. By interacting with this tactile and dynamic installation, visitors activate video projections that narrate key historical events and seasonal cultivation activities (Nikolakopoulou et al., 2022).

Projection mapping technology in this Mastiha Museum enacts the concept of external ontological interaction, allowing visitors to select and customize the sequence of exhibit content, enabling them to experience and learn from the exhibition at pace with their own interests and needs. This interaction allows visitors to actively participate in the presentation of historical and cultural content, with their choices influencing how the story unfolds. For example, once visitors select different artifacts, it can trigger projections related to different historical periods, such as Genoese or Ottoman rule, as well as the architectural and societal transformations of those times. Moreover, The installation embeds projections presenting the mastiha cultivation procedure, including seasonal villagers' activities and the tools they used (Nikolakopoulou et al., 2022). See Figure 4 for an illustration of visitor interactions with the projection mapping installation.

In this respect, the concept of external ontological interaction is particularly important. This installation deepens visitor engagement and enhances their ability to actively choose during the cultural heritage visiting experience. Visitors become active participants in shaping the narrative rather than passive observers, leading to a more immersive and personalized experience. This approach further increases the educational value of the museum visit, as participants are more likely to retain information and develop a deeper appreciation for the cultural and historical background of mastiha cultivation.

To sum up, projection mapping in the Mastiha Museum strengthens the engagement and educational outcomes of visitors through external-ontological interaction. By giving visitors choices and thereby changing the narrative of the installation, it becomes dynamic, interactive, and closely connected with the culture of mastiha cultivation.

Figure 4: Field study screenshots from the Chios Mastic Museum, showing interactions with the installation: a group of friends (left) and students with their teacher (right).

Source: Nikolakopoulou et al. (2022)

4.5. Summary of Findings

This chapter examines how projection mapping technology is used and affects people in four historical sites. In Tangcheng, the internal-exploratory interaction through projection mapping enhances emotional involvement and cultural understanding through vivid historical narratives. In the Wu Kingdom Helv Relics Museum, sensors combined with projection mapping enable visitors to step inside the narrative to witness the legendary history of Wu, though they cannot alter its course. In Zuoying Old Town, the external-exploratory interaction with projection mapping and moving models adds vibrant digital displays to intuitive interpretations, enhancing visitor participation and historical perception. Finally, at the Mastiha Museum on the Greek island of Chios, external-ontological interaction through interactive projection mapping allows visitors to make choices that shape displayed content, deepening engagement and emotional connection. External-exploratory interaction primarily relies on visual devices, positioning visitors as observers outside the virtual world. This approach may limit some visitors' engagement depth, as it offers less direct physical or emotional connection. Embedding additional interaction types could further enhance the learning experience. For example, internal exploratory interactions place visitors in a virtual role, letting them witness historical scenes unfold and thereby deepening their understanding of history. In external-ontological interactions, visitors can make decisions to develop the storyline, selecting and positioning artifacts to trigger relevant content and personalize their experience. Internal ontological interactions similarly enhance engagement, allowing visitors to choose storylines while maintaining the overall narrative.

5. Conclusion

Projection mapping increases the level of immersion for visitors by creating visually captivating environments that are enriched with narrative and sound elements, making it a great storytelling tool. In Tangcheng, internal-exploratory interactions enable the visitors to be a part of the historical narrative, which deepens their emotional involvement and helps them understand the culture. Ryan's (2006) framework of interactive narratives can be applied to optimize projection mapping through internal-exploratory, internal-ontological, external-exploratory, and external-ontological interactions. Further, in creating digital exhibits based on Ryan's (2006) theory, most interaction modes can blend together in one exhibit to create more interactive and

effective designs that will increase visitor participation in improving learning processes. For instance, the internal-ontological interactions at Wu Kingdom Helv Relics Museum enable visitors to become performers of the story, as subjects of the Wu Kingdom, observe essentially the historical process, enhance personalization, and be more active. Similarly, in Zuoying Old Town, a mix of moving models, projection mapping, AR, and VR integrates dynamic digital presentations into the exhibits, which increases visitor participation and their interpretation of historical events in context

Projection mapping also increased the education and knowledge retention of visitors to cultural heritage sites. For example, projection mapping at the Zuoying Old Town removes the operational challenges that come with more technologically advanced integrations such as AR and VR, making it more accessible and user-friendly for visitors of all technological skill levels. Internal-exploratory interaction allows the visitor to become part of the historical scene and builds emotional and historical understanding, while external-ontological interaction enables the visitor to have some influence on the unfolding narrative, increasing the level of engagement and personalization of the experience. This multi-layered approach ensures a comprehensive and immersive learning experience, enriching cultural tourism.

In conclusion, when combined with multiple interactive narrative frameworks, projection mapping technology can significantly enhance visitor engagement, educational outcomes, and overall immersive experiences while maintaining content quality and artistic expression. Future research can continue to explore integrating related technologies, such as 3D projection and holographic projection, to further enhance cultural heritage displays.

Ethics Approval and Consent to Participate

This study did not involve human participants, and therefore, ethical approval and informed consent were not required.

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Conflict of Interest

The authors reported no conflicts of interest for this work and declare that there is no potential conflict of interest with respect to the research, authorship, or publication of this article.

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