Digital Museum and Mosque Architecture: A Survey on Cultural Heritage Preservation and Emotional Design

Abstract

This survey paper explores the integration of digital technologies in the documentation, preservation, and presentation of mosque architecture, emphasizing the emotional and experiential aspects of design. It examines how digital museums and heritage preservation strategies incorporate scene theory and cross-cultural perspectives to enhance understanding and appreciation. The paper is structured to provide a comprehensive overview, beginning with key definitions and background on mosque architecture's cultural significance. It discusses digital heritage preservation's role in maintaining architectural integrity and addresses challenges like technological limitations and ethical considerations. Emotional design principles are analyzed for their impact on audience engagement, highlighting how architectural elements evoke specific responses. Scene theory is employed to interpret mosque architecture's functional and symbolic dimensions, while cross-cultural perspectives are integrated to enrich architectural appreciation. Case studies of digital museum projects illustrate innovative methodologies and outcomes, demonstrating the potential of technologies like 3D modeling and VR in enhancing visitor experiences. The survey underscores the transformative role of digital technologies in cultural dissemination, promoting educational equity and public appreciation. It concludes by advocating for the integration of digital technologies, emotional design, and cross-cultural perspectives in preserving mosque architecture, highlighting the need for collaboration and standardization in heritage practices to ensure cultural heritage remains vibrant and accessible.

1 Introduction

1.1 Structure of the Survey

This survey offers a thorough examination of digital museum practices and mosque architecture, emphasizing cultural heritage preservation and emotional design. It begins with an introduction that contextualizes the role of digital technologies in preserving and presenting mosque architecture. Section 2 provides essential background and definitions, clarifying key concepts such as digital museums, mosque architecture, and emotional design. Section 3 focuses on digital heritage preservation, discussing the impact of digital technologies while addressing associated challenges and innovations. Section 4 analyzes emotional design principles within mosque architecture and their effects on audience engagement. Section 5 investigates scene theory and cross-cultural perspectives, highlighting their significance in enhancing the appreciation of mosque architecture. Section 6 showcases case studies of successful digital museum projects, offering practical insights into methodologies and outcomes. The survey concludes with a reflection on key findings, emphasizing the importance of integrating digital technologies and cross-cultural perspectives in preserving mosque architecture. This structured approach aims to address gaps in the literature, aligning with the motivations and

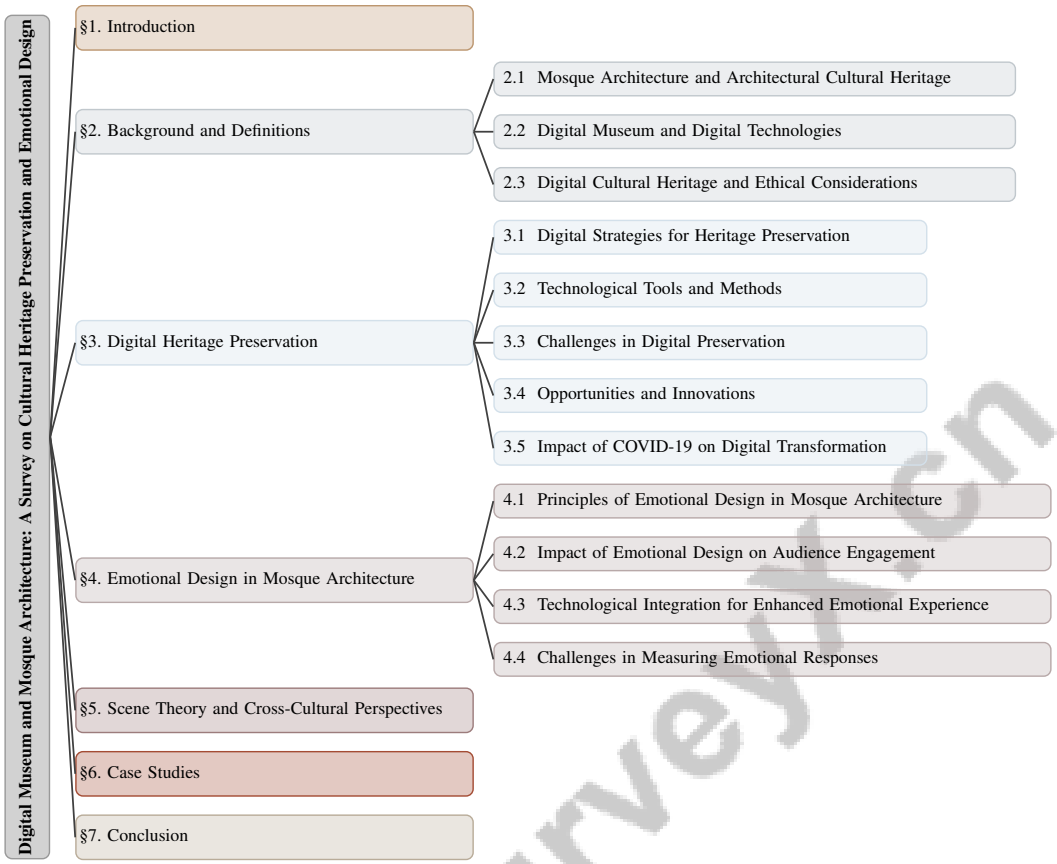

Figure 1: chapter structure

experiences of arts management graduates as highlighted in prior research [1].The following sections are organized as shown in Figure 1.

2 Background and Definitions

2.1 Mosque Architecture and Architectural Cultural Heritage

Mosque architecture is a cornerstone of cultural heritage, reflecting the religious, social, and artistic values of Islamic societies across different historical periods. Beyond their function as places of worship, mosques convey cultural and historical narratives significant to their communities. For instance, the medieval mosques in Nora, Ethiopia, demonstrate a blend of local traditions and Islamic influences, showcasing cultural exchanges [2]. This interaction exemplifies how mosque architecture embodies cultural interactions and historical evolution.

Architectural elements, such as those in the Shah Mosque in Isfahan, illustrate broader cultural narratives through the use of mathematical concepts like the golden ratio, achieving both aesthetic beauty and spiritual symbolism [3]. This precision not only signifies artistic mastery but also reflects a divine order through geometric harmony.

Preserving the cultural significance of mosque architecture requires a nuanced understanding of its meanings, especially regarding worship rituals. Innovative assessment methods are essential to uphold the spiritual and cultural dimensions, as highlighted by Salura [4]. This need is pressing in light of modern challenges, including the decline of traditional architectural symbols and Sufi influences in contemporary designs within post-colonial contexts [5].

The evolution of mosque architecture from the Seljuk to the Ottoman and Republic periods reveals a rich tapestry of stylistic and cultural transformations [6]. Each era contributes distinct aesthetic and functional elements to the architectural heritage of mosques today. This diversity poses challenges,

particularly as differing perceptions between architects and non-architects may lead to misunderstandings of architectural aesthetics [6].

Preservation efforts must consider the material and structural integrity of these historical structures. Techniques like multispectral imaging are used to assess and preserve cultural heritage elements by analyzing materials and pathologies [7]. Such technological interventions are crucial in maintaining architectural heritage for future generations, ensuring mosques remain cultural and spiritual beacons. The underutilization of Building Information Modeling (BIM) in heritage contexts highlights the need for effective methodologies to enhance preservation efforts [8].

2.2 Digital Museum and Digital Technologies

Digital museums utilize digital technologies to create immersive experiences that transform the preservation and presentation of cultural artifacts, particularly mosque architecture [9]. These technologies enable documentation and management of cultural heritage in ways that traditional methods cannot. Incorporating virtual reality (VR), augmented reality (AR), and mobile technologies enhances interactivity, offering innovative avenues for audiences to engage with cultural heritage.

The integration of digital technologies in heritage conservation is evident in regions like Jordan, where digital solutions are prioritized due to their relevance in the contemporary technological landscape [10]. This underscores the transformative potential of digital tools in preserving architectural heritage while maintaining historical integrity [11].

Digital cultural strategies not only enhance visitor interactivity but also create new revenue streams for museums, a crucial aspect in the evolving landscape of cultural heritage preservation [12]. The application of 3D digital technologies, AR, and VR plays a vital role in this transformation, offering dynamic methods to convey cultural narratives [13]. These technologies are especially important in enhancing visitor experiences and providing economic support for museums during challenges like the COVID-19 pandemic [14].

The efficacy of VR technology in cultural heritage conservation is illustrated by projects like the Myin-pya-gu temple, showcasing the potential of these technologies to preserve and present architectural heritage effectively [15]. Comprehensive studies exploring the relationship between mosque architectural designs and the ritual needs of Islamic activities further emphasize the role of digital technologies in addressing cultural and religious dimensions [16].

Digital museums and technologies represent a paradigm shift in cultural heritage preservation, offering innovative solutions that expand the reach and depth of cultural experiences. These advancements ensure cultural heritage remains accessible and engaging for diverse audiences. By employing methods such as 3D modeling, augmented reality, and immersive virtual environments, these innovations foster a deeper understanding and appreciation of architectural and cultural narratives, bridging historical significance with contemporary relevance [13, 17, 18, 19].

2.3 Digital Cultural Heritage and Ethical Considerations

The preservation of digital cultural heritage involves numerous ethical considerations, particularly concerning the roles of archives, libraries, and museums in safeguarding cultural narratives [20]. A significant challenge is the potential bias in selecting and interpreting cultural heritage, which can distort historical and cultural representations. This issue is exacerbated by funding influences on digitization decisions, often creating tension between privacy needs and the desire for broad accessibility [20]. Additionally, limited private funding and community engagement in cultural heritage preservation restrict resources for comprehensive and inclusive digitization efforts [21].

The ethical implications are especially pronounced regarding the digitization of Indigenous knowledge. Given the historical use of archives as colonial tools, sensitivity and respect are crucial to avoid perpetuating historical injustices [22]. Furthermore, the classification and management of digital cultural heritage in informal digital environments complicate ethical considerations, often lacking clear criteria and standards [23].

Rapid technological advancements and obsolescence pose significant threats to the preservation of digital cultural heritage, as the ephemeral nature of digital materials can lead to their loss [18]. The environmental impacts of digital preservation practices, particularly the reliance on information and

communication technology (ICT), raise ethical concerns due to their contribution to climate change [24]. This highlights the need for sustainable practices in digital heritage preservation.

The integration of emerging technologies, such as AI, in digitization efforts presents additional challenges due to inconsistencies between human values and AI development programs, potentially leading to negative perceptions and resistance to digital cultural heritage [25]. Such ambivalence can impede the effective utilization of digital technologies in the protection and interpretation of cultural heritage sites, as heritage site managers often lack clear objectives and understanding of the benefits of digitalization [26].

Developing a robust ethical framework is essential for guiding digital cultural heritage preservation. A comprehensive framework should prioritize the responsible and inclusive integration of technological advancements, ensuring that ethical considerations and environmental impacts are thoroughly addressed. This involves critically examining the motivations behind current practices and shifting the paradigm of appraisal, permanence, and availability of digital content, as emphasized in recent literature. By explicitly incorporating environmental sustainability into digital preservation strategies, we can mitigate the adverse effects of information and communication technology, which pose significant threats to preservation organizations themselves [24, 20].

In recent years, the field of digital heritage preservation has evolved significantly, driven by the need to adapt to contemporary challenges and opportunities. This evolution is particularly evident in the hierarchical structure that encompasses various strategies and technological tools employed in the preservation process. Figure 2 illustrates this structure, highlighting not only key strategies but also the challenges and opportunities that have emerged, particularly in the context of the COVID-19 pandemic and its impact on digital transformation. Each category within the figure is meticulously broken down into specific advancements, frameworks, and future directions, thereby emphasizing the integration of innovative technologies and methodologies that are crucial for the effective preservation of cultural heritage. This comprehensive overview serves to underscore the dynamic interplay between technology and heritage conservation, illustrating the necessity for ongoing adaptation and innovation in the field.

3 Digital Heritage Preservation

3.1 Digital Strategies for Heritage Preservation

Digital strategies are pivotal for the preservation of cultural assets, addressing modern challenges by enhancing documentation, management, and presentation of cultural narratives [27]. These strategies ensure heritage sites remain accessible and relevant, guided by frameworks that integrate architectural form with cultural meanings [4]. The use of digital technology for co-creation marks a significant advancement over traditional methods [21]. Virtual Reality Technology for Cultural Heritage Preservation (VR-CHP) exemplifies this by creating immersive environments that enhance cultural artifact presentation [9]. Digital twins—categorized into content-centric, communication-centric, and collaboration-centric types—further enrich visitor experiences and operational efficiency in museums [28].

As illustrated in Figure 3, the hierarchical categorization of digital strategies for heritage preservation encompasses various elements such as technological interventions, digital co-creation methods, and approaches for documentation and engagement. These strategies collectively enhance the preservation, accessibility, and presentation of cultural heritage. Advanced methodologies, such as deep learning, automate architectural heritage image classification, streamlining documentation [29]. Aligning 3D models with 2D images enhances digital representation accuracy, contributing to more informative heritage documentation [30]. Trillo's taxonomy categorizes digital technologies based on their application in heritage conservation, emphasizing tailored solutions [10]. This includes VR, AR, mobile applications, and GIS, focusing on documentation, user engagement, and education [31]. The digitization of intangible cultural heritage (ICH) has also progressed, enhancing public access and engagement [32].

Mendoza's survey categorizes methods into technological interventions (70

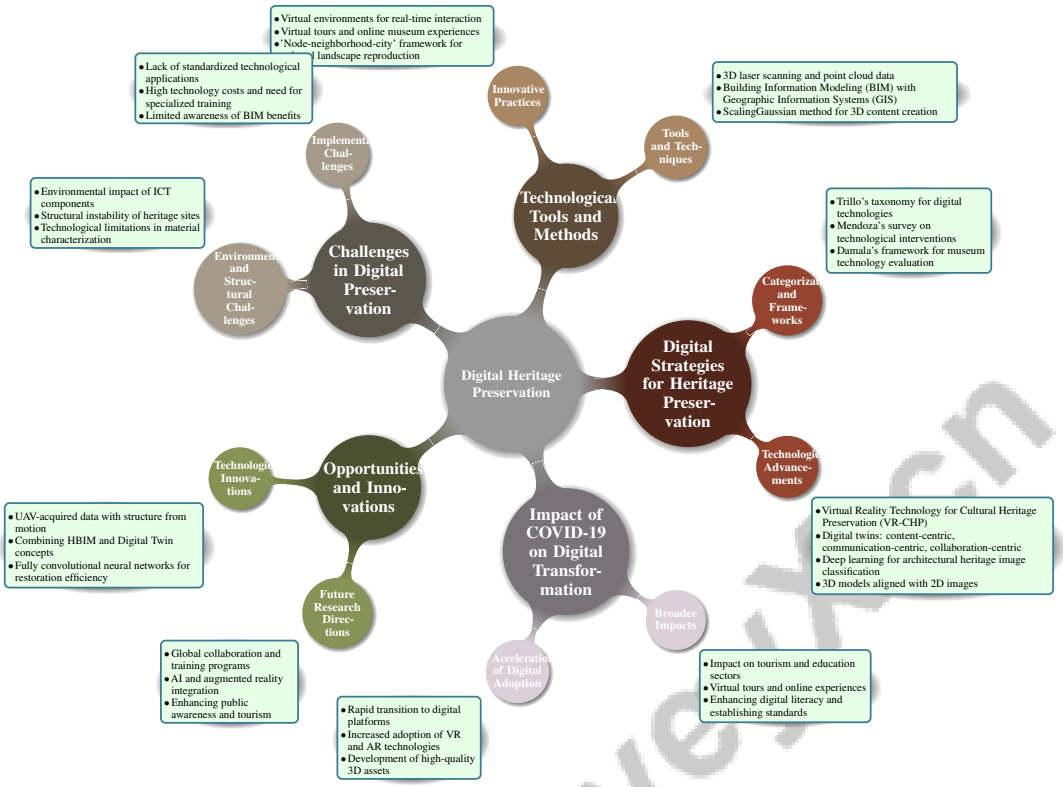

Figure 2: This figure illustrates the hierarchical structure of digital heritage preservation, highlighting key strategies, technological tools, challenges, opportunities, and the impact of COVID-19 on digital transformation. Each category is further broken down into specific advancements, frameworks, and future directions, emphasizing the integration of innovative technologies and methodologies in cultural heritage preservation.

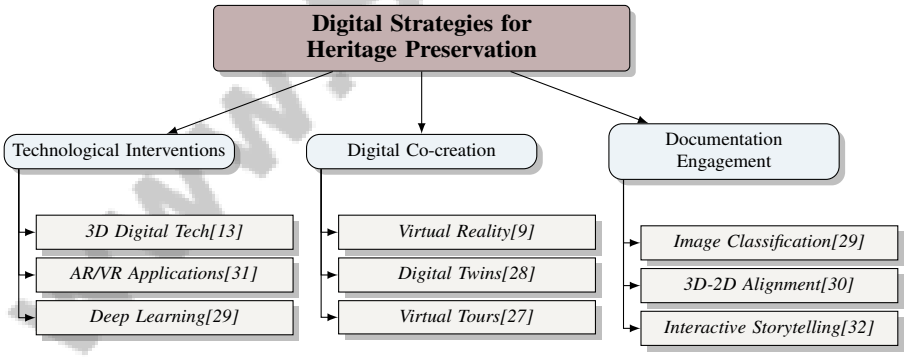

Figure 3: This figure illustrates the hierarchical categorization of digital strategies for heritage preservation, highlighting technological interventions, digital co-creation methods, and approaches for documentation and engagement. These strategies collectively enhance the preservation, accessibility, and presentation of cultural heritage.

3.2 Technological Tools and Methods

Technological tools in digital heritage preservation are essential for effective documentation, management, and presentation. These tools encompass digital acquisition, enrichment, content management, and long-term preservation, evaluated for technological advancement and effectiveness [19]. Notable advancements include 3D laser scanning technology and point cloud data, which enhance digital databases for cultural heritage sites [33]. The integration of Building Information Modeling (BIM) with Geographic Information Systems (GIS) supports accurate digital representations crucial for

Method Name	Technological Integration	Digital Representation	Automation and Efficiency
3D-DIM[33]	3D Laser Scanning	Accurate Digital Representations	Automated Processes
SG[34]	3D Diffusion Models	3D Content Creation	Automated Processes
IMF[35]	Game Engine Technology	Virtual Environment	Automating The Integration
VT[27]	-	Virtual Tour	-
UIPA[30]	Depth Map Generation	3D Woodblock Models	Unified Image Processing
DLIC[29]	Deep Learning Techniques	Digital Documentation Efforts	Automate The Classification
UAV-P[36]	Uav-acquired Data	3D Models	Automated And Manual
HBIM-DT[37]	Real-time Monitoring	Dynamic Model	Automated Processes

Table 1: Summary of technological methods and their applications in digital heritage preservation, highlighting the integration of various technologies such as 3D laser scanning, diffusion models, and deep learning. The table compares different methods based on technological integration, digital representation capabilities, and automation efficiency.

preservation and education [38]. The ScalingGaussian method improves 3D content creation by using 3D and 2D diffusion models to generate high-quality assets from single-view images [34].

Virtual environments enable real-time interaction with historical data and models, enhancing user engagement and providing dynamic platforms for cultural narrative exploration [35]. Virtual tours expand cultural heritage reach by offering accessible online museum experiences [27]. Current digital practices are categorized into technology types like virtual tours and cataloging, illustrating the breadth of available tools for innovative cultural heritage preservation [39]. The 'node-neighborhood-city' framework provides a structured approach to cultural landscape reproduction at multiple scales, emphasizing theoretical models in digital preservation [40].

Advanced methodologies like unified image processing algorithms integrate depth map generation, normalization, and alignment of 3D models with 2D images, achieving precise registration and enhancing digital representation accuracy [30]. Deep learning techniques automate architectural heritage image classification, improving accuracy and efficiency [29]. UAVs capturing aerial imagery combined with photogrammetry create detailed 3D models of heritage buildings, offering comprehensive views [36]. Multispectral imaging, using active and passive sensors, enhances cultural heritage assessment by providing detailed material and structural information [7]. Combining HBIM data management with real-time monitoring through Digital Twin technology enhances decision-making in heritage conservation [37]. Table 1 presents an overview of various technological methods employed in digital heritage preservation, illustrating their integration, digital representation, and automation efficiency.

3.3 Challenges in Digital Preservation

Digital preservation faces challenges that hinder effective cultural heritage safeguarding. A lack of standardized technological applications across cultural heritage types requires interdisciplinary collaboration for effective implementation [13]. Encoding qualitative data into HBIM models and ensuring software interoperability complicates preservation efforts [37]. High technology costs and the need for specialized training among practitioners create barriers to widespread digital preservation method adoption [11].

Traditional conservation approaches often limit preservation scope, necessitating a shift towards integrated methodologies [41]. Inadequate awareness of BIM benefits in heritage conservation and limited digital tool usage highlight the need for increased global collaboration among researchers and institutions [8]. Environmental considerations pose challenges, with limited understanding of ICT components' life-cycle impacts in digital preservation [24]. This emphasizes the need for sustainable practices that minimize digital preservation's ecological footprint.

Archaeological site degradation and limited historical records complicate architectural remains interpretation, as seen in medieval mosques of Nora, Ethiopia [2]. Structural instability of heritage sites and potential damage from increased visitor access threaten fragile artifacts and structures [15]. Technological limitations, such as difficulty in accurately characterizing materials and integrating data from various sensors, present challenges in digital documentation [7]. Ink bleeding through paper complicates text extraction and document restoration, illustrating difficulties in preserving textual heritage [42].

Comprehensive guidelines promoting robust and sustainable practices are essential to address these challenges. Enhancing public awareness of digital technologies' environmental impacts and encouraging a paradigm shift among cultural heritage professionals towards sustainability in digital content appraisal, permanence, and accessibility is crucial [17, 24, 43, 19, 20]. This ensures cultural heritage's continued relevance and accessibility in the digital age, fostering a deeper appreciation of shared heritage.

3.4 Opportunities and Innovations

Digital heritage preservation is experiencing opportunities and innovations driven by advanced technologies and sustainable practices. Integrating UAV-acquired data with structure from motion software produces high-resolution 3D models and spatial analyses that surpass traditional methods in efficiency and accuracy [36]. This approach enhances heritage site documentation and promotes greater cultural heritage awareness and appreciation [10]. Developing sustainable digital preservation frameworks is critical, with future research encouraged to explore alternative technologies and foster collaborations prioritizing environmental impacts [24]. Such frameworks ensure digital archives remain accessible and adaptable amidst evolving technological landscapes. Combining HBIM and Digital Twin concepts represents a significant innovation, creating dynamic models that incorporate real-time data to evaluate conservation interventions' impacts on heritage significance [37].

Innovative approaches include using fully convolutional neural networks to automate and enhance restoration efficiency, replacing manual parameter tuning in Gaussian mixture modeling [42]. The MUSETECH model serves as a versatile tool for evaluating museum technology, highlighting the need for a multi-faceted approach to assessing and integrating digital tools in cultural heritage settings [44]. VR technologies play a pivotal role in improving user awareness of cultural heritage and conservation importance, serving as valuable tools in heritage research [15]. Integrating VR technology for interactive 3D modeling enhances user engagement and accuracy in cultural heritage preservation. Additionally, exploring new sensor technologies and improving data processing algorithms are vital for enhancing analysis accuracy in digital heritage preservation [7].

Future research should focus on enhancing global collaboration, developing training programs for stakeholders, and investigating AI and augmented reality integration in heritage applications [8]. These efforts will stimulate tourism and enhance public awareness of cultural heritage, ensuring cultural narratives remain vibrant and accessible to a global audience [11].

3.5 Impact of COVID-19 on Digital Transformation

The COVID-19 pandemic catalyzed rapid digital transformation in cultural heritage preservation, emphasizing digital technologies' vital role in maintaining public access to cultural resources during unprecedented times [45]. The closure of cultural institutions worldwide necessitated a swift transition to digital platforms, particularly for small and medium-sized museums adapting to this new paradigm [14]. This transition signifies a fundamental change in cultural heritage access and appreciation, highlighting digital heritage's resilience and flexibility as a medium.

The pandemic accelerated technologies like VR and AR adoption in cultural heritage digitization, providing innovative alternatives to traditional preservation methods [32]. Frameworks like ScalingGaussian illustrate these advancements, offering methods to create high-quality 3D assets with enhanced geometric and textural fidelity, significantly improving digital representations' accuracy and immersive quality [14]. These technologies have become essential for creating engaging experiences that allow audiences to explore cultural narratives remotely, extending cultural heritage's reach beyond geographical constraints.

Moreover, the pandemic underscored the necessity for strategies addressing existing digital implementation limitations and exploring emerging trends in digital engagement within museums [45]. This includes advancing shape recognition algorithms, automating modeling processes, and developing universal H-BIM libraries to facilitate interdisciplinary collaboration. Enhancing digital literacy among users and establishing clear standards for digital cultural heritage are crucial steps for effective and inclusive use of digital technologies in heritage preservation [32].

The transformation extends beyond preservation, impacting tourism and education sectors, where the pandemic necessitated new interaction and communication modalities [14]. Virtual tours and

online museum experiences have become integral to engaging audiences, providing educational opportunities, and sustaining tourism activities in a digital format. This digital pivot mitigates physical restrictions' impact while fostering a broader understanding and appreciation of cultural heritage across diverse audiences.

4 Emotional Design in Mosque Architecture

Exploring the relationship between emotional design and mosque architecture involves understanding foundational principles that inform architectural decisions, enhancing users' emotional and spiritual experiences. The following subsection highlights key principles, demonstrating how they resonate with cultural and spiritual narratives.

4.1 Principles of Emotional Design in Mosque Architecture

Emotional design in mosque architecture aims to evoke aesthetic and emotional responses, enriching the spiritual and sensory experience. The golden ratio is a fundamental principle, contributing to beauty and harmony, symbolizing divine order through geometric precision [3]. Zhou et al. emphasize a systematic approach involving affective-cognitive needs analysis, ensuring spaces resonate emotionally [46]. Tools like the Aesthetic Emotions Scale (A ESTHEMOS) provide insights into the emotional impact of design elements [47].

Interpreting architectural forms through meaning classification offers insights into enhancing worship experiences [4]. This method ensures emotional design aligns with cultural and spiritual narratives. The synthesis of Sufism with local practices, exemplified by the Melaka Tengkera Mosque, creates a distinct architectural identity resonating with cultural and spiritual values [5]. The historical evolution of mosque facades reveals perceptual characteristics influencing emotional responses, highlighting the need for designs catering to diverse emotional and cultural expectations [6].

Digital technologies present opportunities to democratize knowledge and enhance emotional experiences but pose challenges related to authenticity and representation [48]. Addressing these challenges allows emotional design in mosque architecture to create spaces fulfilling functional and spiritual needs while engaging users profoundly.

As illustrated in Figure 4, this figure highlights the principles and influences in the emotional design of mosque architecture, emphasizing key design principles, cultural integration, and the impact of technology. Emotional design principles in mosque architecture illustrate how built environments influence spiritual experiences. Visual representations, such as floor plans and cultural frameworks, highlight the integration of geometric shapes, spatial orientation, and cultural elements. These examples demonstrate how emotional design principles evoke peace, community, and spiritual connection, transforming mosques into profound architectural experiences [3, 40, 4].

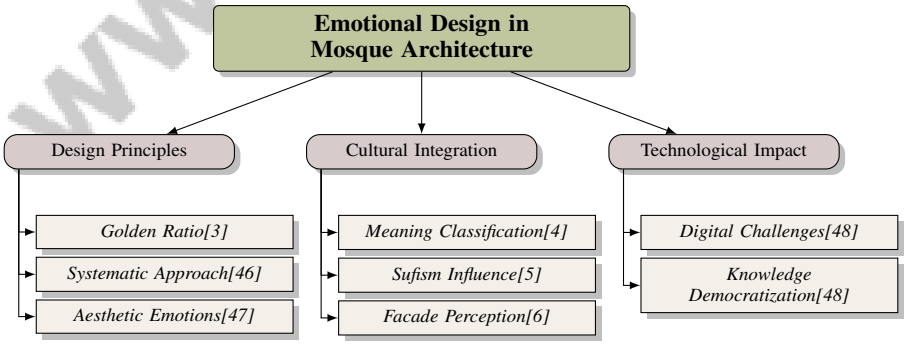

Figure 4: This figure illustrates the principles and influences in the emotional design of mosque architecture, highlighting key design principles, cultural integration, and the impact of technology.

4.2 Impact of Emotional Design on Audience Engagement

Emotional design enhances audience engagement in mosque architecture by evoking specific emotional responses, fostering deeper connections between architecture and users. The Aesthetic Emo-

tions Scale (A ESTHEMOS) captures emotional responses to aesthetic stimuli, providing insights into design elements' influence on engagement [47]. Emotional design transforms user experience, enriching worship experiences and appreciation of cultural narratives [46].

Sufi principles in mosque design exemplify emotional design's role in creating spaces resonating with spiritual values and cultural identity [5]. Perceptions of architectural aesthetics vary, with architects and non-architects interpreting mosque facades differently [6]. Emotional design strategies must cater to diverse audience expectations, ensuring engagement on emotional and intellectual levels.

Incorporating emotional design principles fosters environments meeting worshippers' functional and spiritual needs, enhancing emotional connections and engagement. This approach transforms mosques into cultural landmarks resonating with the community [3, 4, 46, 6, 16].

4.3 Technological Integration for Enhanced Emotional Experience

Digital technologies enhance emotional experiences in mosque architecture, transforming user interaction with sacred spaces. Technologies like Building Information Modeling (BIM) and Augmented Virtual Reality (AVR) create immersive environments, enhancing engagement with architectural narratives [49]. Digital tools revolutionize museum learning, making it interactive and accessible, mirroring shifts in mosque architecture [50]. Virtual tours and interactive displays foster deeper appreciation and understanding of mosque architecture.

Evaluating digital representations in museums provides insights into visitor engagement and educational outcomes, applicable to mosque architecture [48]. A novel framework for integrating digital and physical experiences emphasizes inclusive, participatory models [45]. This framework ensures digital technologies create culturally and spiritually inclusive spaces, enhancing emotional resonance.

A strong digital presence and engaging social media activities enhance visitor loyalty, encouraging sustained engagement with mosques' architectural narratives [14]. Leveraging digital technologies creates emotionally rich environments resonating with diverse audiences, ensuring sacred spaces remain vibrant and relevant.

4.4 Challenges in Measuring Emotional Responses

Measuring emotional responses in architectural design is challenging due to the complexity and subjectivity of human emotions. The Aesthetic Emotions Scale (A ESTHEMOS), though valuable, may not capture every emotional response, highlighting the difficulty in developing comprehensive tools [47]. Reconstruction of architectural sites faces criticism for perceived inauthenticity, influencing emotional responses [51]. Balancing historical accuracy with emotional resonance is crucial, as emotional impact is shaped by narratives and experiences.

Studies encounter limitations in measuring emotions in naturalistic settings, as traditional methodologies may not capture the complexity of emotions [46]. Professional development gaps in digital skills hinder effective use of technologies to enhance emotional engagement in architecture [39]. Without adequate training, digital tools' potential to measure and enhance emotional responses may remain underutilized.

5 Scene Theory and Cross-Cultural Perspectives

5.1 Application of Scene Theory in Mosque Architecture

Scene theory provides a valuable framework for understanding the interplay between architectural expression and functional significance in mosque architecture. By examining how physical spaces accommodate activities, the theory reveals how architectural elements fulfill religious and cultural roles while enhancing aesthetic appeal [4]. This approach emphasizes the importance of spatial arrangement in shaping worship experiences and conveying cultural meanings. Key elements such as the orientation towards Mecca, prayer hall design, and structural features like domes and minarets express religious identity and facilitate Islamic rituals [4, 5, 6, 40, 16]. Understanding these elements through scene theory helps scholars and architects grasp their functional roles within the mosque's cultural and religious context.

Digital technologies, as highlighted by Trillo, underscore the need for standardized protocols to responsibly document and analyze mosque architecture, preserving its cultural heritage [10]. Future research should enhance scene theory's application by developing methodologies that capture the interactions between architectural spaces and their cultural functions, deepening the understanding of how mosque designs reflect local values and historical contexts [4, 5, 6, 40, 16].

5.2 Integrating Cross-Cultural Perspectives

Integrating cross-cultural perspectives is crucial for appreciating and preserving architectural heritage, emphasizing the need to acknowledge diverse cultural narratives and styles. This approach fosters an understanding of architecture's cultural significance and historical context, enhancing the recognition of varied styles and heritage's role in shaping identity [47, 17]. Cultural heritage sites, such as medieval mosques in Nora, Ethiopia, illustrate the blend of local traditions and Islamic elements, highlighting the dynamic nature of cultural exchange [2]. Cross-cultural perspectives ensure preservation efforts respect the cultural narratives embedded within structures, aligning with their spiritual significance [4].

Moreover, digital heritage preservation, through technologies like virtual and augmented reality, enhances educational potential by creating immersive experiences that convey architectural heritage's cultural significance to diverse audiences. These platforms can transform museums and libraries into sustainable entities safeguarding intangible cultural heritage while addressing financial challenges [17, 12, 32].

As depicted in Figure 5, the integration of cross-cultural perspectives in architectural heritage is illustrated through the significance of cultural heritage sites, the role of digital preservation technologies, and the importance of preservation efforts that respect cultural narratives and spiritual significance. This figure encapsulates the multifaceted nature of architectural heritage, reinforcing the argument for a holistic approach to preservation.

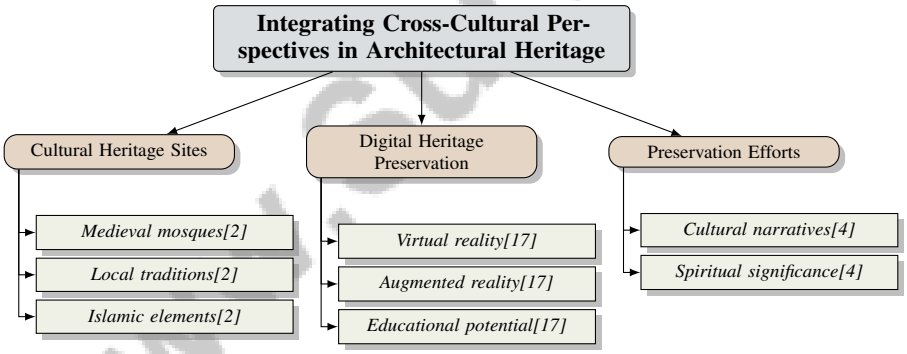

Figure 5: This figure illustrates the integration of cross-cultural perspectives in architectural heritage, highlighting the significance of cultural heritage sites, the role of digital preservation technologies, and the importance of preservation efforts respecting cultural narratives and spiritual significance.

5.3 Cross-Cultural Perspectives and Emotional Design

Cross-cultural perspectives enrich emotional design in architecture by integrating diverse narratives, aesthetic values, and emotional responses. This approach enhances the aesthetic appeal of spaces while addressing the affective and cognitive needs of varied user groups, fostering a more inclusive environment [17, 3, 46, 6, 47]. The Aesthetic Emotions Scale (A ESTHEMOS) helps assess how cultural contexts shape emotional responses, ensuring that emotional design elements resonate meaningfully across cultures [47].

Despite its potential, gaps remain in integrating emotional design principles across cultural contexts [46]. Addressing these gaps requires incorporating cross-cultural perspectives into design processes, ensuring strategies are informed by cultural narratives and values. This leads to more inclusive designs that reflect a range of human experiences, fostering a sense of belonging and connection among users [47, 17, 46, 6].

5.4 Architectural Diversity and Local Traditions

Architectural diversity and local traditions are pivotal in shaping cross-cultural architecture, particularly in mosque design. The Melaka Tengkera Mosque exemplifies how local traditions and spiritual ideologies, such as Sufism, create a unique architectural identity resonating with cultural values [5]. This integration underscores the need to balance spiritual and material aspects, ensuring designs reflect communities' cultural narratives and religious practices.

While mosque facade perceptions are influenced by cultural and religious contexts, further research is needed to understand how these factors shape aesthetics [6]. By examining these influences, architects can appreciate how architectural elements convey cultural meanings. Incorporating local traditions not only preserves heritage but also enriches the architectural landscape with diverse expressions, facilitating cross-cultural understanding and appreciation [18, 17]. Embracing diversity and traditions allows mosque design to bridge cultures, fostering dialogue and mutual appreciation.

Local traditions and architectural diversity are essential for creating culturally significant and aesthetically engaging spaces. By acknowledging diverse cultural, historical, and spiritual elements in mosque architecture, architects can honor community values while enhancing the global architectural narrative, ensuring sacred spaces resonate with shared heritage complexities and evolving needs [11, 4, 16].

6 Case Studies

6.1 Case Studies and Applications

Case studies in digital museum projects focusing on mosque architecture and cultural heritage reveal critical insights into methodologies, challenges, and outcomes of digital heritage preservation. Digital display technologies significantly enhance visitor experiences by fostering exploration and engagement, as demonstrated in institutions like the Pitt Rivers Museum and the American Museum of Natural History, where digital and physical collections are integrated to enrich visitor experiences [52, 48]. A comparative survey highlights that while video games can increase interest, they may not significantly impact female attendance, contrasting with their effect on male attendance, underscoring the need for gender-sensitive approaches in digital technology applications within cultural heritage contexts [53].

Digital reconstructions, such as those of 'Piazza IV Novembre' in Perugia and 'Republic Square' in Foligno, demonstrate the effectiveness of digital technologies in revitalizing historical spaces, preserving architectural integrity, and enhancing public engagement with historical narratives [54]. A comparative analysis of medieval mosques in Nora, Ethiopia, illustrates both similarities and distinctions in construction techniques and styles compared to other regional Islamic structures, emphasizing the significance of local traditions in cultural heritage preservation [2]. A survey involving 100 participants (50 architects and 50 non-architects) assessing the facade features of 16 mosques using a semantic differential scale reveals diverse perceptions of architectural aesthetics, highlighting the need for designs that resonate with a broad spectrum of emotional and cultural expectations [6].

The contrasting case studies of the Sang Cipta Rasa Mosque in Cirebon and the Salman Mosque in Bandung illustrate the diverse applications of digital technologies in preserving both traditional and contemporary mosque architectures, addressing unique preservation needs [16]. Surveys indicate that 3D digital technologies are most prevalent, followed by AR/VR applications, in cultural heritage preservation, playing a crucial role in enhancing documentation, management, and presentation of architectural heritage for future generations [13].

6.2 Case Studies of Emotional Design in Mosque Architecture

Emotional design in mosque architecture aims to create spaces that resonate with users on sensory and spiritual levels, enhancing worship experiences and fostering connections with cultural and religious narratives. The Shah Mosque in Isfahan exemplifies this approach, using the golden ratio to achieve aesthetic harmony and reflect spiritual ideals through geometric precision, enhancing both visual appeal and spiritual ambiance [3]. The Melaka Tengkera Mosque integrates local traditions and Sufi principles, creating a distinct identity that fosters a unique emotional experience and a sense

of belonging [5]. Comparative studies of mosque facades reveal varying perceptions of architectural aesthetics, emphasizing the need for designs that cater to diverse emotional and cultural expectations [6].

Integrating digital technologies in mosque architecture offers significant potential to enrich emotional and spiritual experiences by crafting immersive environments that foster meaningful interactions. This approach enhances both the aesthetic and functional aspects of sacred spaces, aligning with contemporary cultural heritage preservation methods and transforming individual engagement with mosque architecture [4, 55, 11, 52, 6]. By leveraging digital tools, architects can create spaces that fulfill functional and spiritual needs while engaging users on profound emotional levels, enriching their overall experience and appreciation of architecture.

6.3 Innovative Educational and Engagement Practices

Innovative educational and engagement practices in digital museums have revolutionized audience interaction with cultural heritage, offering new avenues for learning and exploration. Digital technologies facilitate immersive experiences that engage tech-savvy visitors, enhancing their understanding of cultural narratives. Social media plays a pivotal role in this outreach, enabling museums to maintain dynamic connections with visitors and foster community around cultural heritage [14]. Digital museums utilize VR and AR technologies to create interactive environments, allowing users to experience historical sites and artifacts in novel ways, transforming traditional museum visits into dynamic educational journeys that foster deeper understanding and retention [44, 14, 50, 56].

Moreover, digital museums serve as collaborative learning platforms, enabling users to interact with diverse cultural content and engage in meaningful discussions. This engagement deepens the understanding of cultural heritage, as digital tools facilitate modernized learning experiences that transcend traditional museum visits. By leveraging social media and digital communication channels, these platforms encourage broader community involvement in cultural heritage management, enhancing public participation and promoting sustainable urban development [17, 43, 50, 28, 26]. This collaborative approach is further enriched by digital platforms that allow for sharing insights and discoveries, fostering a deeper understanding of cultural contexts and historical connections.

Future research should focus on excavating additional sites and exploring connections between architectural traditions of different regions, such as the mosques in Nora and other Islamic structures, to enrich the educational content offered by digital museums [2]. By broadening the scope of digital museum content and incorporating diverse cultural narratives, these institutions can continue to play a vital role in education and audience engagement, ensuring that cultural heritage remains accessible and relevant in the digital age.

7 Conclusion

Digital technologies have profoundly influenced the preservation and presentation of mosque architecture, serving as pivotal tools in cultural dissemination and highlighting the architectural distinctiveness of these sacred sites. The employment of 3D-GIS data and immersive technologies markedly enhances interactivity and visibility, thereby enriching visitor engagement and educational outcomes. This digital integration not only democratizes access to cultural resources but also acts as a catalyst for public appreciation and education.

Emotional design principles, such as the golden ratio, play a crucial role in augmenting both aesthetic and spiritual experiences within architectural spaces. By systematically integrating affective and cognitive elements, spaces are crafted that resonate profoundly with users, fostering meaningful architectural expressions in religious contexts. This is exemplified by the contrasting influences observed in the SCR Mosque and the Salman Mosque, where local traditions and modernist ideologies uniquely shape their emotional and functional characteristics.

Cross-cultural perspectives significantly enrich the architectural domain, fostering a comprehensive understanding and appreciation of diverse cultural narratives. These perspectives are vital for ensuring that the reproduction of cultural landscapes contributes to cultural dissemination and the broader cultural industry. The need for enhanced collaboration and standardization, especially in the application of Building Information Modeling (BIM) in heritage contexts, underscores the necessity for a more unified approach to digital heritage preservation.

The integration of digital technologies into cultural heritage practices is imperative, alongside the development of new competencies to manage these transformations effectively. Successful digital practices identified in this survey highlight the importance of ongoing training and adaptation as museums and cultural institutions navigate the evolving digital landscape. Despite improvements in awareness and capabilities for managing digital heritage, significant challenges remain, requiring continuous strategy adaptation.

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