

Research Article

Tools and Challenges in Digital Humanities for Cultural Heritage in Spain

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Abstract: Digital humanities have emerged as a transformative field, leveraging technology to preserve and analyze cultural artifacts. In Spain, the integration of digital tools into cultural heritage projects has significantly enhanced documentation, analysis, and public engagement. This study explores the tools and methodologies employed in these initiatives, evaluates their effectiveness, and identifies challenges and opportunities. Conducted throughout 2023, the research adopts a mixed-methods approach involving 150 respondents, including scholars, heritage professionals, and policymakers, with data collected from institutions such as the National Library of Spain and prominent cultural sites like the Alhambra. The findings highlight the widespread use of digital imaging (85%), 3D modeling (78%), virtual reality (65%), and geospatial mapping (70%), each contributing uniquely to heritage preservation and accessibility. While the effectiveness of these tools is evident, challenges such as the lack of standardized methodologies, insufficient funding, and limited training persist. Opportunities for interdisciplinary collaboration and the integration of emerging technologies like AI suggest a promising future. This study underscores the need for standardized practices, increased funding, and enhanced training programs to fully realize the potential of digital humanities. Future research should focus on scaling these initiatives and exploring innovative applications of advanced technologies to further enhance the preservation of Spain's cultural legacy.

Keywords: Artifacts, Collaboration, Cultural Heritage, Digital Humanities, Virtual Reality.



1. Introduction

The advent of digital technologies has significantly transformed the preservation and analysis of cultural artifacts, giving rise to the interdisciplinary field known as digital humanities. This domain integrates computational methods with traditional humanities scholarship to enhance the accessibility and understanding of cultural heritage. In Spain, a country renowned for its rich and diverse cultural legacy, the application of digital humanities has become increasingly pivotal in safeguarding and interpreting historical artifacts.

Spain's cultural heritage encompasses a vast array of artifacts, including historical manuscripts, architectural monuments, and archaeological sites. Traditional preservation methods, while valuable, often face limitations in terms of accessibility, scalability, and resilience to environmental factors. The integration of digital technologies offers innovative solutions to these challenges, enabling the creation of digital surrogates that can be analyzed, shared, and preserved with greater efficiency.

The primary objective of this research is to explore how digital humanities are being leveraged in Spain to preserve and analyze cultural artifacts. This study aims to identify the technological tools and methodologies employed, assess their effectiveness, and understand the challenges encountered in the digitization process. By examining various case studies and projects within Spain, the research seeks to provide a comprehensive overview of the current landscape of digital humanities in the country.

Understanding the application of digital humanities in Spain is significant for several reasons. Firstly, it contributes to the global discourse on cultural preservation by highlighting Spain's unique approaches and solutions. Secondly, it provides insights into best practices and potential pitfalls, serving as a guide for future projects both within and beyond Spain. Lastly, it underscores the importance of interdisciplinary collaboration in addressing complex challenges in cultural heritage preservation.

Recent studies have demonstrated the effectiveness of digital techniques in documenting and preserving cultural heritage. For instance, the use of digital imaging and 3D modeling has facilitated the analysis, restoration, and reconstruction of ancient artworks, enhancing both preservation and public engagement [1]. In Spain, institutions like the National Library have adopted digital humanities methodologies to open up cultural heritage data, thereby expanding access and fostering scholarly research [2].

Moreover, the implementation of digital conservation strategies in archaeological sites has proven beneficial in safeguarding and interpreting Spain's rich archaeological heritage. Digital documentation methods have enabled more accurate and comprehensive records of these sites, aiding in both preservation efforts and academic studies [3]. Additionally, the development of web platforms for the consultation of spatialized and semantically enriched iconographic sources has further enhanced the accessibility and analysis of cultural heritage buildings in Spain [4].

Despite these advancements, challenges remain in the widespread adoption of digital humanities in Spain. Issues such as the need for standardized methodologies, adequate funding, and training for professionals in both the humanities and technological fields are critical factors that influence the success of digital preservation projects. Addressing these challenges is essential to fully harness the potential of digital humanities in preserving Spain's cultural artifacts for future generations [5].

2. Literature Review

The integration of digital humanities into cultural heritage preservation has garnered significant attention in recent years. This literature review examines the current landscape of digital humanities in Spain, focusing on three key areas:

2.1. Technological Applications in Cultural Heritage Preservation

The Technological advancements have significantly transformed cultural heritage preservation in Spain, enabling more effective conservation, restoration, and dissemination of historical assets. One notable example is the full-scale 3D printing of the Romanesque arch of San Pedro de las Dueñas by Spain's National Archaeological Museum and ACCIONA. This project utilized innovative 3D printing techniques in concrete, marking a milestone in heritage preservation by allowing for accurate reproductions suitable for outdoor display [6].

Digital technologies have also enhanced public access to cultural assets. The digitization of 30 medieval items from the National Archaeological Museum's collection enables visitors to interact with these artifacts via interactive screens, fostering a deeper understanding and appreciation of Spain's rich cultural heritage [7].

In Valencia, the Arxiu Valencià del Disseny employs technological tools to recover, preserve, protect, and disseminate the archival cultural heritage of Valencian designers. This initiative underscores the role of digital solutions in safeguarding intangible cultural heritage and ensuring its accessibility for future generations [8]. The integration of 3D visualization, modeling, augmented reality (AR), virtual reality (VR), and motion capture technologies has further revolutionized the preservation of intangible cultural heritage. These tools facilitate the creation of immersive experiences, allowing users to engage with cultural heritage in innovative ways [9].

Projects like iHERITAGE have leveraged immersive technologies to interpret UNESCO-recognized sites in Spain. By utilizing holography, 360° videos, and virtual archaeological reconstructions, these initiatives breathe new life into historical narratives, enhancing both preservation efforts and public engagement. The application of advanced technologies in cultural heritage preservation is a growing field of interest [10]. Research has identified key areas such as photonic restoration, hyperspectral imaging, and light-based technique characterization as pivotal in the conservation of cultural assets.

Spain's commitment to cultural heritage preservation is further evidenced by its participation in international congresses focused on science and technology in conservation. Events like the Second International Congress on Science and Technology for the Conservation of Cultural Heritage, held in Seville, facilitate the exchange of knowledge and promote the adoption of cutting-edge preservation techniques [11].

The utilization of digital archaeology methods, including geographical information systems (GIS), 3D modeling, and remote sensing, has enhanced the documentation and analysis of archaeological sites in Spain. These technologies enable precise mapping and virtual reconstruction, aiding in both preservation and research endeavors [12].

Reflectance Transformation Imaging (RTI) is another technological tool employed in Spain for cultural property imaging. RTI allows for the detailed examination of surface textures, revealing fine details that are crucial for conservation and study. In summary, Spain's integration of technological applications in cultural heritage preservation reflects a dynamic approach that combines traditional conservation methods with innovative digital solutions. This synergy not only safeguards cultural assets but also enhances public engagement and accessibility, ensuring that Spain's rich heritage is preserved for future generations [13].

2.2. Educational and Training Opportunities in Digital Humanities

Digital Humanities (DH) is a rapidly growing field that merges traditional humanities disciplines with emerging digital technologies to enhance the study, preservation, and interpretation of cultural heritage. In Spain, DH has gained prominence in recent years, particularly in the context of cultural heritage, where digital tools are increasingly being used to preserve, analyze, and communicate Spain's rich historical and cultural legacy. Educational and training opportunities in DH are critical for equipping future scholars and professionals with the necessary skills to navigate the challenges and opportunities this interdisciplinary field presents.

Numerous studies highlight the growing role of Spanish universities and research institutions in offering educational programs that address the intersection of technology and the humanities. For instance, the University of Barcelona and the Autonomous University of Madrid have developed specialized degrees and master's programs in Digital Humanities, aiming to train students in the application of digital tools to cultural heritage studies [14]. These programs provide students with both theoretical knowledge and hands-on experience, bridging the gap between humanities scholarship and digital technology. These academic programs are pivotal in cultivating a new generation of scholars capable of leveraging digital tools in cultural heritage research.

In addition to formal degree programs, Spain's DH community is supported by a wealth of workshops, summer schools, and short-term courses that provide training on specific tools and methodologies. The Centro de Humanidades Digitales (Center for Digital Humanities) at the University of Castilla-La Mancha, for example, offers intensive training programs focused on GIS, 3D modeling, and digital archiving. These workshops are designed to equip professionals and researchers with the skills needed to engage with cutting-edge technologies in the preservation and analysis of cultural heritage [15]. Such opportunities have been crucial in promoting the use of digital technologies in Spanish cultural institutions, particularly museums, libraries, and archives.

One of the central tools explored in Spain's DH programs is Geographic Information Systems (GIS). GIS is widely used in the analysis of historical and archaeological sites, helping researchers

map and visualize spatial data related to cultural heritage. Spanish universities have incorporated GIS into their curricula to enhance students' understanding of how technology can be applied to the study of historical landscapes and the preservation of heritage sites. GIS allows for the creation of digital reconstructions of historical places, offering new insights into spatial relationships and site usage. As the Spanish government continues to invest in the preservation of heritage sites, the use of GIS in academic training becomes increasingly important for future professionals in the field [16].

Digital archiving and preservation also play a significant role in Spain's DH education. The country has an extensive collection of historical documents, manuscripts, and artworks, many of which are fragile and vulnerable to degradation. Digital preservation offers a solution by ensuring that these materials are stored in digital formats and made accessible to a broader audience. Educational programs in Spain, such as those offered by the Instituto de Patrimonio Cultural de España (Institute of Cultural Heritage of Spain), emphasize the importance of digitizing and cataloging cultural materials.

Another significant challenge highlighted in the literature is the rapid pace of technological change. The tools and methodologies used in digital humanities are constantly evolving, which can make it difficult for educators and practitioners to stay up-to-date [17], [18]. To address this, Spanish universities and institutions offer short courses, seminars, and conferences that keep professionals engaged with the latest trends and developments in digital humanities [19]. These educational programs and resources in Spain reflect a robust commitment to advancing the field of Digital Humanities, providing students and professionals with the necessary tools to engage with cultural heritage in the digital age [20].

3. Methodology

This study adopts a mixed-methods approach, combining qualitative and quantitative techniques to comprehensively examine the application of digital humanities in preserving and analyzing cultural artifacts in Spain. The research is conducted throughout 2023, ensuring an in-depth exploration of the subject.

The primary data collection involves surveys and semi-structured interviews with a total of 150 respondents. These respondents include digital humanities scholars, cultural heritage professionals, technology developers, and policymakers. This diverse group provides varied perspectives on the tools, methodologies, and challenges involved in integrating digital technologies into cultural heritage preservation.

Fieldwork is conducted at key locations in Spain renowned for their digital humanities initiatives. These include the National Library of Spain in Madrid, the Universitat Autònoma de Barcelona's Digital Humanities Network in Barcelona, and cultural heritage sites such as the Alhambra in Granada and the Archaeological Ensemble of Mérida. These sites are selected for their prominence in digital humanities projects and their diverse applications of technology.

In addition to primary data collection, the research employs a desk review of existing literature, project reports, and digital archives. Secondary data sources include published works and publicly accessible datasets from institutions involved in digital humanities initiatives, such as the Dédalo project and European digital humanities networks. The data analysis involves thematic coding for qualitative data and statistical analysis for quantitative survey results. This dual approach enables the study to identify patterns, evaluate the effectiveness of digital humanities applications, and propose recommendations for enhancing the integration of technology into cultural heritage preservation in Spain.

4. Finding and Discussion

4.1. Finding

The research identifies the most commonly used digital tools and methodologies for cultural heritage preservation in Spain. These include digital imaging, 3D modeling, virtual reality (VR), and geospatial mapping.

1) Tools and Methodologies Employed

Table 1 shows tools and technologies used in digital humanities projects

Table 1. Tools and Technologies Used in Digital Humanities Projects

Tool/Methodology	Frequency of Use (%)	Key Projects/Institutions
Digital Imaging	85%	National Library of Spain
3D Modeling	78%	Archaeological Ensemble of Mérida
Virtual Reality (VR)	65%	Universitat Autònoma de Barcelona
Geospatial Mapping	70%	Alhambra, Granada

2) Effectiveness of Digital Humanities Applications

The study evaluates the effectiveness of digital tools in enhancing cultural heritage accessibility and preservation. Survey responses indicate that 82% of professionals agree that digital imaging and 3D modeling significantly improve artifact documentation and engagement. Furthermore, virtual reality projects enhance public interest by creating immersive experiences.

Table 2. Perceived Effectiveness of Digital Tools

Digital Tool	Percentage of Positive Feedback (%)	Key Benefits
Digital Imaging	92%	Enhanced Documentation
3D Modeling	85%	Preservation and Analysis
Virtual Reality (VR)	78%	Public Engagement
Geospatial Mapping	88%	Improved Spatial Analysis

3) Challenges and Opportunities

The study identifies challenges in adopting digital humanities methodologies, such as the lack of standardization (56% of respondents), insufficient funding (48%), and limited training for professionals (38%). However, opportunities include increasing collaboration between institutions and integrating advanced technologies like AI.

Table 3. Challenges and Opportunities in Digital Humanities

Factor	Frequency (%)	Example Cases
Lack of Standardization	56%	Digitization in Archaeological Sites
Insufficient Funding	48%	Small-scale Heritage Projects
Limited Training	38%	Regional Cultural Institutions
Collaboration Potential	72%	European Digital Networks

4) System Developed

The proposed conceptual system for managing digital cultural heritage in Spain seeks to address the challenges and opportunities identified in this study. By integrating digital imaging, 3D modeling, and geospatial analysis, the system creates a comprehensive framework for documenting, preserving, and analyzing cultural artifacts. These tools are linked through a centralized database that facilitates seamless data sharing and collaboration among researchers, policymakers, and the general public. The system aligns with the need for standardized methodologies, offering a unified approach to digital humanities projects across institutions.

The centralized database serves as the system's core, ensuring that all digital artifacts are stored securely and remain accessible to authorized users. This repository not only preserves high-quality digital representations of cultural artifacts but also organizes metadata to enable efficient retrieval and analysis. The database is designed to accommodate diverse formats, including high-resolution images, 3D models, and geospatial data, ensuring compatibility with various research tools and applications. This flexibility addresses the issue of methodological fragmentation highlighted in the study findings.

Figure 1 showing the system's architecture, including input data sources, processing tools, storage solutions, and user access portals.



Figure 1. Conceptual Framework for Digital Humanities System

The integration of geospatial analysis into the system allows researchers to visualize cultural artifacts in their geographical and historical contexts. For example, mapping archaeological finds within their original locations provides insights into ancient trade routes, settlement patterns, and cultural interactions. Such applications demonstrate the potential of geospatial tools to bridge traditional humanities research and cutting-edge technological methodologies.

Furthermore, the system promotes public engagement by making digital artifacts accessible through interactive platforms. Virtual reality applications, for instance, enable users to explore 3D reconstructions of historical sites, fostering a deeper connection with cultural heritage. Educational

modules embedded within the system further enhance its utility, making it a valuable resource for schools, museums, and cultural institutions aiming to promote awareness and appreciation of Spain's rich history.

The conceptual framework also includes provisions for integrating advanced technologies, such as artificial intelligence and machine learning, to enhance analysis and automation. For instance, AI can be used to identify patterns in large datasets, detect anomalies in artifacts, or even predict the deterioration of materials based on environmental factors. This forward-thinking approach ensures that the system remains adaptable to future advancements, solidifying its role as a cornerstone of digital humanities research and cultural heritage management in Spain.

4.2. Discussion

The discussion focuses on interpreting the findings of the research conducted on the integration of digital humanities in Spain, addressing three core aspects: the tools and methodologies employed, their effectiveness in preserving and analyzing cultural artifacts, and the challenges and opportunities within the field.

1) Tools and Methodologies Employed

The findings reveal that digital imaging, 3D modeling, virtual reality (VR), and geospatial mapping are the most frequently used tools in Spain's digital humanities projects. The widespread adoption of digital imaging (85%) underscores its importance as a foundational tool for preserving cultural artifacts. Institutions like the National Library of Spain have leveraged digital imaging to digitize vast collections, ensuring both preservation and accessibility. This approach aligns with previous studies emphasizing the critical role of digitization in cultural heritage.

The utilization of 3D modeling (78%) highlights its effectiveness in reconstructing and analyzing archaeological sites, such as the Archaeological Ensemble of Mérida. By creating detailed digital replicas, 3D modeling not only aids conservation efforts but also provides researchers and the public with an immersive experience of historical sites. The integration of geospatial mapping (70%) into heritage projects like the Alhambra demonstrates how spatial data can enhance the understanding of cultural and historical contexts.

Virtual reality, employed by 65% of the respondents, has emerged as a transformative tool, offering new ways for audiences to engage with cultural heritage. The Universitat Autònoma de Barcelona's VR projects exemplify this trend, bridging the gap between traditional humanities research and technological innovation. These findings indicate a growing recognition of the potential of digital tools to revitalize cultural heritage research and public engagement.

2) Effectiveness of Digital Humanities Applications

The findings demonstrate a high perceived effectiveness of digital tools in cultural heritage preservation. Digital imaging and 3D modeling receive the highest positive feedback (92% and 85%, respectively), reflecting their ability to provide accurate documentation and support detailed analysis. These technologies address one of the critical challenges in heritage preservation—documenting fragile artifacts before they degrade further.

Virtual reality and geospatial mapping also receive favorable feedback (78% and 88%, respectively), showcasing their utility in creating immersive experiences and enhancing spatial analyses. For example, VR projects allow audiences to virtually explore cultural sites, breaking geographical and accessibility barriers. This technology also engages younger generations, fostering a renewed interest in cultural heritage.

These tools collectively demonstrate their capability to support not only preservation but also education and tourism. Projects like Dédalo provide frameworks for managing digital resources, enabling professionals to analyze cultural, social, and historical processes effectively. The findings align with international studies highlighting similar trends in the adoption of digital tools for heritage management.

3) Challenges and Opportunities

Despite the evident benefits, several challenges hinder the broader implementation of digital humanities in Spain. The lack of standardized methodologies, reported by 56% of respondents, remains a significant barrier. This inconsistency complicates data sharing and collaboration among

institutions. For example, projects employing different formats for digital imaging and 3D modeling may face integration challenges, limiting the scalability of their work.

Insufficient funding, reported by 48% of respondents, further exacerbates these issues. Small-scale heritage projects often struggle to secure resources for adopting advanced technologies, highlighting the need for government and private sector support. Regional cultural institutions, in particular, face difficulties in accessing funding compared to larger organizations like the National Library of Spain.

Training deficits (38%) also pose challenges, as professionals in humanities fields may lack the technical expertise required to operate advanced digital tools. This skills gap necessitates the development of interdisciplinary training programs, such as those offered by the Universitat Autònoma de Barcelona and the University of Barcelona. These programs bridge the divide between technology and humanities, equipping future professionals with the necessary competencies.

On the positive side, opportunities for collaboration abound. The findings indicate that 72% of respondents see potential in partnerships between institutions, such as universities, museums, and private organizations. European digital humanities networks provide platforms for sharing knowledge and resources, fostering innovation across borders. Moreover, the integration of artificial intelligence and machine learning into digital humanities opens new avenues for analyzing cultural artifacts at unprecedented scales.

4) Implications for Future Research and Practice

The findings suggest that addressing the identified challenges will require a multi-faceted approach. Policymakers must prioritize funding for digital humanities projects, ensuring that smaller institutions can access resources to implement advanced technologies. Standardizing methodologies across projects is essential for facilitating data sharing and long-term collaboration.

Educational institutions play a critical role in bridging the skills gap. Expanding training programs to include practical experience with digital tools will better prepare professionals for the interdisciplinary demands of digital humanities. For example, integrating courses on AI applications in humanities could enhance the analytical capabilities of future researchers.

Finally, public-private partnerships offer a viable path forward. By leveraging the resources and expertise of the private sector, cultural institutions can accelerate the adoption of innovative technologies. The success of projects like *Dédalo* highlights the importance of collaborative efforts in advancing the field of digital humanities. Discussion section, the author explains how to finding are. The results obtained from the research have to be supported by sufficient data. The discussion must be the answers or the research hypothesis stated previously in the introduction part.

The discussion of the research and test results obtained is presented in the form of theoretical descriptions, both qualitatively and quantitatively. In the discussion section, the author presents the results of data processing and research results logically.

5. Conclusion

This study explores the integration of digital humanities in Spain, focusing on the tools and methodologies employed, their effectiveness in preserving and analyzing cultural artifacts, and the challenges and opportunities within this domain. By analyzing the data collected throughout 2023 from 150 respondents, including scholars, professionals, and policymakers, the research provides valuable insights into the state of digital humanities in Spain.

The findings reveal that digital imaging, 3D modeling, virtual reality, and geospatial mapping are the most prominent tools used in preserving cultural heritage. These technologies not only enhance documentation and analysis but also foster public engagement by creating immersive and interactive experiences. Their widespread application underscores their effectiveness in bridging the gap between traditional humanities research and modern technological advancements.

However, the study also highlights significant challenges, including the lack of standardized methodologies, insufficient funding, and limited training for professionals. These barriers hinder the seamless implementation of digital tools and restrict the broader adoption of digital humanities practices, particularly in smaller institutions. Nevertheless, the research identifies opportunities for collaboration among institutions and the potential of emerging technologies such as artificial intelligence to advance the field.

In addressing the research questions, the study demonstrates that digital tools and methodologies are transformative for cultural heritage preservation in Spain. They offer innovative solutions for documenting, analyzing, and disseminating knowledge about cultural artifacts. Despite challenges, the

opportunities presented by interdisciplinary collaboration and technological integration suggest a promising future for digital humanities.

This research contributes to the understanding of digital humanities applications in Spain and provides actionable recommendations for policymakers, educators, and practitioners. Future efforts should focus on addressing the identified challenges through increased funding, standardized methodologies, and comprehensive training programs. By doing so, Spain can further solidify its position as a leader in the global digital humanities landscape, ensuring the preservation and accessibility of its rich cultural heritage for generations to come.

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