Research on Innovative Design of Digital Culture under the Integration of Culture and Technology: Knowledge Graph Analysis Based on Citespace

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Abstract. In the face of China's rich cultural resources, this paper aims to use Citespace tool to measure and analyze the field of cultural heritage digitization under the background of cultural science and technology integration. It focuses on the digital protection of material and cultural heritage, the digital protection of Intangible Cultural Heritage, and the development of digital culture under the integration of culture and technology on the basis of the remarkable achievements in digital reconstruction technology, cultural big data storage and digital innovation tool platform. Also the design participation goal in the development of digital culture is deeply discussed, such as using immersive technology to enhance the accessibility of digital culture, carrying out cooperation to promote the reuse of digital culture, and mobilizing public participation to promote the reflection of digital culture. In order to have a clearer understanding of the specific areas in which design participates in Digital Cultural Innovation, this paper conducts further research to process and make use of the existing cultural data from the angles of designing and applying digital technology, to improve the user-oriented cultural experience, and promote the development of cultural ecology of digital culture by using bibliometric method. It improves the user-oriented cultural experience, and balances the dual-track innovation development of digital culture between industry and public through multi-dimensional cultural value assessment, thus further promoting the innovation of digital culture and providing new space and pattern for Chinese culture going out.

Keywords: Digitization; Cultural innovation design; Citespace; Knowledge graph

1. Introduction

China's long-standing historical and cultural resources are an important foundation for carrying out cultural construction and building a cultural power. At the end of the 20th century, the Forbidden City and the Dunhuang Research Institute opened the precedent of digital protection of cultural heritage in China. In the early 21st century, the country launched the "Cultural Resource Sharing Project (2002)". Over the following decade, from the government to various institutions, they were adapting to technological changes and continuously exploring the potential of technology to support cultural construction. Until 2012, the "Cultural Digitalization Construction Project" was officially launched, promoting the development of cultural resources Comprehensive digitization of cultural production and

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dissemination. At this point, cultural digitization has basically achieved the supply of public services that benefit the people, but there are still problems of mismatch between services and public cultural needs, and low public participation. Faced with the goal of improving quality and efficiency, during the 13th Five Year Plan period, the "Guiding Opinions on Promoting the Deep Integration of Culture and Technology" and the "Opinions of the Ministry of Culture and Tourism on Promoting the High Quality Development of the Digital Culture Industry" were successively issued, requiring the full release of the support potential of technology for culture, stimulating the support of technology for the entire chain of cultural creation, production, dissemination, and consumption, and improving the quality and connotation of the digital culture industry, This means achieving a breakthrough in digital culture from public services to industrial development, and stimulating the consumption potential of digital culture. In 2022, the General Office of the Central Committee of the Communist Party of China and the General Office of the State Council issued the "Opinions on Promoting the Implementation of the National Cultural Digitalization Strategy", which further clarified the eight key tasks of cultural digitization and promoted the transformation of cultural stock resources into production factors.

To sum up, on the one hand, cultural digitalization has not only transformed culture into digital form, but also the expression of "digital cultural resources", "digital cultural products and services" and "digital cultural industry" indicates that the overall "digital cultural ecology" around cultural production, circulation and consumption is gradually taking shape; On the other hand, in order to enhance the transformation and application efficiency of digital culture, "innovation" has become a key word, targeting the goals of "creating digital cultural consumption scenarios" and "innovating cultural expression methods". Innovation is not only reflected in the deep excavation of digital cultural resources by digital intelligence technology, but also in the re creation of culture in digital form. In the process of cultural digitization, "digital cultural innovation" has gradually become the focus and has been included in the "National Medium - and Long Term Science and Technology Development Plan (2021-2035)" as a key task for the development of cultural technology and modern service industry. The innovation of digital culture follows the logic of content as the king, focusing on the excellent traditional Chinese culture and advanced socialist culture. Among various cultural contents, cultural heritage (including material and intangible cultural heritage) is often the primary target of digital cultural innovation due to its importance in cultural value and the urgency of protection. In practice, a number of joint innovation actions focusing on cultural heritage have emerged among universities, enterprises, and cultural institutions, such as the "Exploration Plan" promoted by multiple institutions such as the China Cultural Relics Protection Technology Association, Tencent, Tsinghua University, and Renmin University of China, and the "Cultural Big Data Artificial Intelligence Innovation Competition" initiated by Qicheng Research Institute. Therefore, sorting out the development context, research status, and future key goals of digital culture innovation represented by cultural heritage can better guide collaborative innovation and design participation in this field.

2. From Edge to Center: Design Participation in Digital Cultural Ecology

The digitization of cultural heritage emerged in the 1990s, and countries in Europe and America have successively utilized digital technology to carry out digital storage, recording, and virtual display of cultural resources. According to the definition of UNESCO, "digital heritage is composed of computer-based materials, which have lasting value and should be preserved for future generations. Digital cultural heritage comes from different communities, industries, departments, and regions, and the enduring value of different heritage varies. Therefore, digital protection should be carried out for cultural heritage with high enduring value, and digital data should be ensured to be continuously accessible. In 2003, under the constantly emerging wave of digital heritage, UNESCO adopted the "Charter for the Protection of Digital Heritage" at the 32nd session of UNESCO, advocating for global attention and importance to the protection of digital cultural heritage; In 2005, the European Commission issued the Faru Convention, which serves as a framework convention on the value of social and cultural heritage. The Faru Convention clarifies that heritage itself is not a priority, but rather the significance and purpose bestowed upon it by people, as well as the value they represent, and advocates for contracting parties to "develop the use of digital technology"; In 2017, the European Commission released the "21st Century European Cultural Heritage Strategy", which put forward requirements for the role of technology in heritage protection, including secure and authentic storage of data, restoration and enhancement of heritage, accessibility of heritage data, and digital collaboration platforms. It can be seen that from the initial broad advocacy to the continuously refined requirements, people's understanding of digital heritage is constantly improving.

In order to have a more objective understanding of this development process, this article adopts a bibliometric research method. Using the Web of Science (WoS) database as the data source and Professor Chen Chaomei's Citespace tool, a visual knowledge graph analysis was conducted on global papers in this field to explore global research progress. In order to understand the overall picture of digital protection of cultural heritage, in the first stage of literature measurement, this article selected the "cultural heritage" that includes both tangible and intangible cultural heritage. When using the WoS database for retrieval, the keywords were selected as "digital preservation cultural heritage" and "digital cultural heritage", the literature types were selected as articles and reviews, and the language was "English". A total of 1467 related literature were obtained. Through literature screening and deduplication in Citespace, 1100 literature were ultimately obtained. In the second stage, this article focuses on bibliometric analysis of the digital protection of intangible cultural heritage. By searching for "digital intangible cultural heritage" in the WoS database, 64 articles were obtained. By performing keyword co-occurrence graphs, timeline graphs, time zone graph graphs, and strongest emergent keywords operations on these two batches of data, we can summarize the development trends, recent emerging fields, and potential future hotspots in this field.

2.1. Digital Protection of Material Cultural Heritage

The keyword co-occurrence graph visualizes the clustering of paper keywords between time and correlation, which helps to summarize the research focus in this field. By drawing a keyword co-occurrence map of relevant literature on digital research of cultural heritage (see

Figure 1) , the main research directions in this field can be summarized as follows: (1) For digital collections of cultural heritage, clustering is carried out by keywords such as digital storage, archives, library, and protection. (2) The museum Digital transformation under the integration of technology is clustered by keywords such as museum, augmented reality, education and monitoring. (3) Cultural heritage modeling and simulation based on machine learning, clustered by keywords such as machine learning, point clouds, models, virtual reality, and 3D reconstruction. (4) Research on the semantic organization of digital cultural heritage based on ontology, clustering keywords such as ontology, archaeology, digital library, and digital humanities. (5) Online registration and information management of digital heritage, clustered by keywords such as digital heritage, accuracy, visualization, art, and registration. (6) The information model of cultural heritage buildings is clustered by photogrammetry, compilation, image and other keywords. (7) Digital cultural heritage information acquisition oriented towards user behavior, clustered by keywords such as behavior, knowledge, and information search. In the clustering of the above seven research directions, from the perspective of digital presentation carriers, it mainly includes two fields: the construction of online heritage digital platforms and the implementation of offline museums in Digital transformation. The advancement of technology has increased the breadth and depth of heritage protection. The development of computer vision, visual perception, and artificial intelligence technology has made the acquisition, processing, and use of data more accurate, efficient, convenient, and intelligent.

In order to understand the technology-driven change of research direction more clearly, this paper conducts keyword and emergent detection on the data of Digital Cultural Heritage Literature. Pop-up detection can detect variable values that have great changes in a short time, including the volume of articles, citations, keyword number, and so on, so as to master the new hot spots in this field. According to the starting and ending time, the research in this field can be divided into three stages (see Figure 2). The first stage is from 2003 to 2017, which can be summarized as the digitization of cultural heritage. This stage focuses on image, digital storage and culture, and focuses on the transformation of cultural heritage from entity to data. Although 3-d scanning technology was available at the time, it was too expensive, and most of the digitization was still done using static image storage, involving subjects like archaeology and WEMBO. The second stage for 2008-2017, can be summarized as digital technology development and data presentation. The key point of this stage is the advancement of Technology, data has more dimensions and processing methods, laser scanning, calibration, algorithm become the technical means of data acquisition and data enhancement. The keywords digital archive, visualization, search, and virtual museum show the interest in open data and its applications, including computer science, remote sensing, and mapping.

The third stage is from 2018 to 2022, which can be summarized as multivariate data morphology and depth data mining. Over the past four years, the protection of digital culture and heritage has focused on the reflection on the goal and significance of digital protection and the overall strategic thinking on digital ecology, keywords Sustainability, digital humanity, management, framework, HBIM reflect the increased engagement of communities and the relevance of everyday life in the digitisation of heritage, considering the relationship between Digital Cultural Heritage and social, economic and environmental sustainability, exploring its role in community cohesion and inclusiveness, and ensuring the sustainability and reuse of

digital cultural content, build a full life cycle framework from digital creation, management, and use.

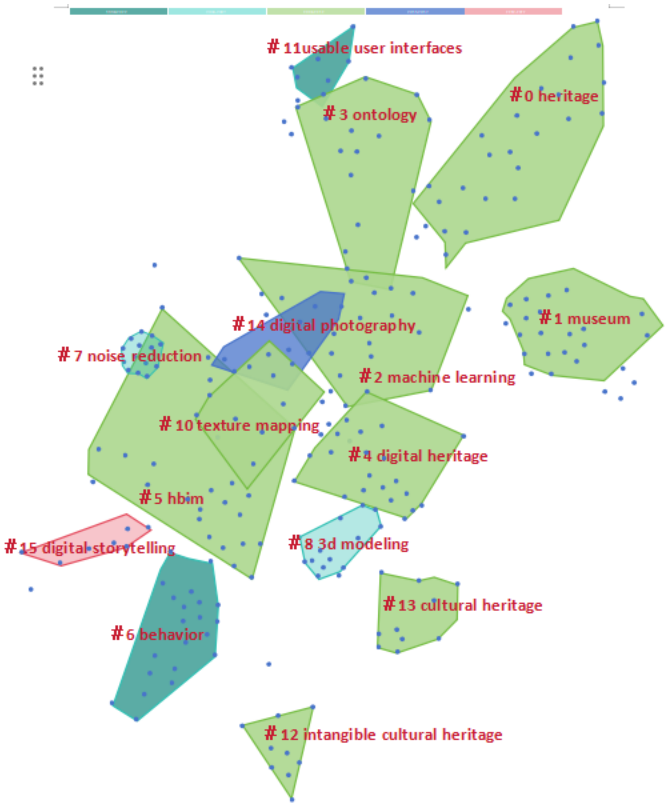

Figure 1. Keyword Co-occurrence Map of Digital Research Literature of Cultural Heritage

TOP 16 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	1998–2022	
image	1998	4.38	2003	2017		the first stage
digital storage	1998	3.92	2003	2012		
culture	1998	3.33	2003	2017		
visualization	1998	5.29	2008	2017		
laser scanning	1998	4.73	2008	2017		
virtual museum	1998	3.73	2008	2017		the second stage
digital archive	1998	3.69	2008	2017		
search	1998	3.5	2008	2017		
calibration	1998	3.28	2008	2017		
algorithm	1998	3.8	2013	2017		
sustainability	1998	4.73	2018	2022		
hbim	1998	4.54	2018	2022		
bim	1998	4.22	2018	2022		the third stage
digital humanity	1998	3.94	2018	2022		
management	1998	3.77	2018	2022		
framework	1998	3.4	2018	2022		

Figure 2. The Most Prominent Keywords in Cultural Heritage Digitization (Top 16)

2.2. Digital Protection of Intangible Cultural Heritage

The research literature on digital protection of intangible cultural heritage first appeared in 2013. As of January 6, 2022, a total of 64 English literature were obtained from the WoS core collection, maintaining a slow growth trend year by year. However, this direction is still a niche research field in cultural heritage protection. The i-Treatures (2013-2017) funded by the European Commission is one of the most famous digital protection projects for intangible

cultural heritage in the world, with industry representation. Due to the limited number of literature on digital protection of intangible cultural heritage, it is not possible to perform sudden detection, and keyword co-occurrence clustering analysis is also difficult to highlight its characteristics. Therefore, this article selects a time zone map to analyze its trend of change. Overall, the research on digital protection of intangible cultural heritage can be summarized into the following hot topics:From 2013 to 2015 and earlier, the main research directions can be summarized as on-site exploration and digital archiving of intangible cultural heritage, including keyword archiving, dissemination, on-site research, and recording. At this stage, various types of intangible cultural heritage data collection mainly focused on experts were initiated, and digital intangible cultural heritage archives of various types and regions were developed.

From 2016 to 2017, the main research direction can be summarized as the co construction and dissemination of web-based intangible cultural heritage digital platforms, including keyword networks, the Internet, co creation, and social networks. Relevant literature explores how to stimulate cooperation and co creation of cultural values through digital platforms and tools, how communities can jointly plan and carry out digital records of intangible cultural heritage, and actively attract tourists to creatively participate in heritage interactions in cultural tourism.[1]

The research hotspot in 2018 was the digital interaction experience of intangible cultural heritage based on kinesthetic and kinesthetic technologies, including keyword usability testing, kinesthetic interaction, user experience, and kinesthetic controllers.[2]Based on the dynamic characteristics of intangible cultural heritage, we introduce kinesthetic interaction methods such as body, movement, and gesture to create a more interactive user experience and promote users' cultural knowledge learning.

From 2019 to 2021, the research focus was on the application reflection and sustainability of intangible cultural heritage digitization, including keywords critical heritage, critical design, evaluation, storytelling, and sustainability. Relevant literature considers the impact of digital technology on intangible cultural heritage at the level of cultural dissemination and social value, evaluates the effectiveness of cultural dissemination, and delves deeper into the participants and processes involved in digital protection of intangible cultural heritage, exploring how to better tell the cultural story of communities.[3]

2.3. The Development Status of Digital Culture under the Integration of Culture and Technology

Digital culture, with the digitization of cultural heritage as its important content, essentially has the nature of cultural and technological integration. With the assistance of technology, digital culture has achieved significant results in three aspects: reconstruction technology, cultural big data, tools and platforms.

2.3.1 Intelligent and Convenient Digital Reconstruction Technology

Since the first LiDAR scanner was introduced at Carl Zeiss in 1997, cultural heritage digitization has a history of 25 years. The application technologies of digital reconstruction of heritage include laser radar technology, structured light 3D scanning technology, photographic 3D scanning technology, laser 3D scanning technology and popular photogrammetry

technology, which reflect the application trend of technology convenience and lightweight. From the use of scanning equipment that is often millions of to today, digital reconstruction of cultural heritage can be easily completed with only high-definition digital cameras. In 2020, the mobile application "Haven't Seen" launched by Huawei and the "Object Capture" launched by Apple in 2021 both marked the gradual opening up of digital acquisition and reconstruction technology to the public, increasing public awareness and participation in national cultural big data. Data collection is no longer solely dependent on cultural units and research institutions, but can truly achieve universal participation and sharing.

2.3.2 Massive and Rich Cultural Big Data

Key cultural collection units and cultural research institutions, represented by the Palace Museum, the National Museum of China, the Hunan Provincial Museum, and the Dunhuang Research Institute, have successively carried out relevant digital cultural relics protection work, accumulated a large amount of important cultural data, and constructed a database of Chinese traditional cultural classics, a database of Chinese ancient books, a database of Chinese classical ancient books, and a Chinese cultural relics chronicle Various Chinese cultural databases such as the Chinese Local Historical Literature Database. The results of the first national cultural resources census show that there are 590000 collections of art museums nationwide, with a total data volume of 6.9TB; There are 108.15 million movable cultural relics/set nationwide, with a data volume exceeding 140TB. Massive cultural data is an important component of building national cultural big data assets, but isolated data storage poses obstacles to data reuse, and the lack of correlation and unified standards between data is an urgent problem to be solved. In 2019, China established the National Cultural Big Data Industry Alliance and released 11 standards, including "Classification and Code of Cultural Resource Data", "Cultural Data Service Center Technology", and "Digital Collection Technology of Cultural Heritage", providing core guidance methods for digital collection methods, data standard system construction, and cultural data services.

2.3.3 Diverse Digital Innovation Tools and Platforms

The improvement of computer processing capabilities has promoted the development of digital tools and the emergence of digital display platforms. Real time rendering technology can now almost rival the realistic effects of traditional ray tracing rendering. Real time 3D rendering tools such as Threejs, Marmoset, Unity, Unreal, and online virtual display platforms represented by Sketchfab, Quixel, Bovidian twins, and Dynamic 3D have expanded cultural data display channels and application scenarios based on mobile and web platforms. The improvement of computer 3D rendering capabilities is also accompanied by the emergence of new 3D data processing and production tools, which ensure the integrity and high fidelity of cultural data in the extraction and reconstruction of cultural elements, and also bring new tools and methods for innovation on the cultural supply side.

2.4. Design Participation Goals in the Development of Digital Culture

Due to the interdisciplinary participation in the protection of digital cultural heritage, and the fact that design is an emerging discipline, the position of design in the overall research spectrum mentioned above is not prominent. However, the advantages of the design discipline in publicly oriented data applications are becoming increasingly evident, especially in

exploring more effective ways of cultural data management and display, as well as more socially valuable and meaningful technology application models. Cultural big data has driven a breakthrough leap in the development of digital culture from quantity to quality, and the early digital culture protection supported by technology has achieved static protection of cultural resources and accumulation of data volume; The digital culture driven by design dynamically interprets culture, achieving the digital activation and widespread dissemination of static, historical, and regional cultural resources; Under humanistic thinking, the integration of multiple disciplines blurs the boundaries of disciplines, with cultural creation and development as the core goals, accelerating the formation of new forms of culture and ecological construction (see Figure 3). Design is gradually moving towards the stage in the construction of digital cultural ecology. Overall, the goals of participating in the development of digital culture and promoting innovation in digital culture include the following aspects.

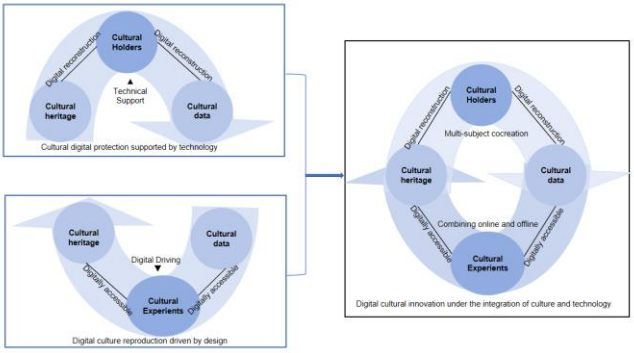

Figure 3. Evolution of Digital Culture Innovation Focus for Cultural Heritage

2.4.1 Applying Immersive Technology to Enhance the Accessibility of Digital Culture

The main user group for digital cultural platforms and offline display interactions is the non professional general public, who usually have relatively basic knowledge of cultural heritage. Whether it is online digital platforms or offline museums, their design goals have shifted from "objects" to "experiences", utilizing various channels to build connections between the past and present, the public and museums, and achieving a transformation from "collection based" to "public experience". Among them, augmented reality, virtual reality, and hybrid reality technologies provide support for building immersive and semi immersive user experiences. By embedding story narratives and following the meaning construction process in cultural learning, visitors can actively participate in multiple recall, explanation, and communication activities.[4] This helps to enhance the educational and entertainment value of cultural objects, enhance the accessibility of digital cultural products, and enhance the attractiveness of digital cultural exhibitions.

2.4.2 Carrying Out Collaborative Cooperation to Promote the Reuse of Digital Culture

In addition to restoring cultural objects as realistic and high-definition as possible, the constantly evolving digital technology can also tap into the innovative potential of cultural data from the perspective of new media. But data reuse involves multiple professional fields such as data standards and structures, data mining, data recognition, and data creative

programming. The EU's "Horizon 2020" project "inDICEs" explores the impact of digital cultural heritage reuse, including encouraging cross departmental cooperation. In order to promote data reuse, DARIAH-EU issued the Constitution on Reuse of Heritage Data to promote information exchange between heritage institutions and researchers. The five core principles include trustworthiness, interoperability, manageability, quotability and openness. In practice, Google's "experiment" in art and culture encourages those who master coding technology to apply it to the vast online information database, conducting exploratory experiments on the integration of art and technology for art, images, and music works in online galleries. Out of the 50 million pieces of data from the European Library of Culture, 20 million pieces can be reused for free. In order to expand its data application, Europeana Labs was established in 2014, and subsequently evolved into the "services and tools" segment, with the purpose of carrying out relevant services and developing corresponding data application tools to support the Digital transformation of cultural heritage professionals and institutions.

2.4.3 Mobilizing Public Participation to Promote Reflection on Digital Culture

More civilian digital technology has strengthened the two-way interaction between the public and cultural heritage, increasing the potential for the public to access information.[5] After the reconstruction of collections into the digital space, the Internet has changed the relationship between citizens and institutions, providing the public with the possibility of participating in historical narratives. The view that public participation experiences promote museums to play their social value is also increasingly widely accepted. The social value of digital culture is shaped and reflected in the public's co creation of meaning. Focusing on the cultural value of digital participation can solve the key problem of how society can better understand and utilize the past.

3. From Object to Relevance: A Design Perspective of Digital Culture Innovation

In order to gain a clearer understanding of the specific areas in which design participates in digital cultural innovation, this article applies bibliometric research methods to conduct further research. In terms of keyword selection, two sets of keywords, "design" and "digital * cultural heritage", were first selected for retrieval. When searching in the WoS database, the null character * was used to refer to possible digits such as digital, digitize, digitization, and digitally. In the end, 303 articles were obtained. However, during the process of reviewing the literature, it was found that the term "design" is not within the definition and scope of the design discipline in many literature, such as the design of financial toolkits, algorithm design, etc. Therefore, this article ultimately selected multiple specific design fields and "digital * cultural heritage" for literature acquisition, including 53 in the field of interaction design, 14 in the field of product design, and 34 in the field of service design, There are 86 articles in the field of user experience, a total of 187 articles, and 152 articles were obtained through deduplication. The first article appeared in 2004. After conducting keyword co-occurrence cluster analysis on these 152 articles, it can be concluded that design participation in digital culture innovation mainly includes six hotspots (see Figure 4).

From the perspective of using digital technology in design to enhance user cultural experience

for the general public, the following hotspots are included:

Design of a digital heritage information system for differentiated user behavior, clustered by keywords such as information search, behavior, personality, personal differences, navigation, etc. The open platform for online collections is the most common form of display. Public online platforms have been established at home, such as the Palace Museum, and abroad, such as the Metropolitan Museum of Art in the United States, to allow people to remotely access massive cultural information. Although many platforms use the search box mode to give users the opportunity to explore freely, for mass users who lack professional domain knowledge, it will be difficult to attract users to in-depth access without clear access goals and interactive guidance, so the access bounce rate of such platforms is generally high.[6] When the public faces access to massive cultural information, it is necessary to provide broad, diverse, and attractive interaction points, providing inspiring browsing clues. At the same time, it is necessary to study the behavioral differences of different types of users in cultural information search, reorganize the composition relationship of cultural knowledge in virtual space, create more exploratory interaction models, enhance the searchability of content, and provide deep analysis of content, thereby supporting users to learn, participate, and create cultural information online, all based on the cultural, social, emotional On the integration of multi-dimensional semantic associations such as design.

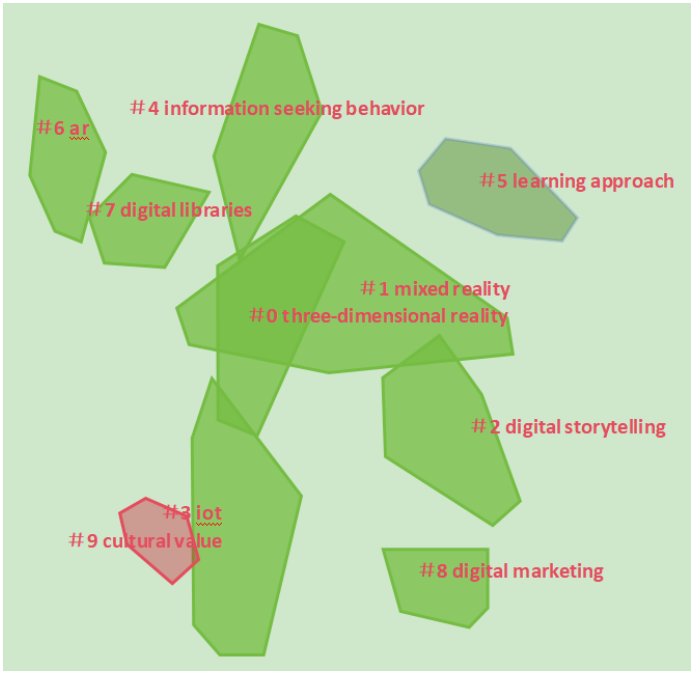

Figure 4. Keyword Co-occurrence Cluster Atlas of Design and Research Literature of Digital Cultural Heritage

The offline multi sensory and cross media interactive experience design of digital heritage is clustered by keywords such as 3D modeling, guidance, collectibles, augmented reality, visualization, visitors, and experience. With the development of interactive media technology,

in offline exhibition spaces such as museums and exhibition halls, in addition to digital media such as smartphones and interactive desktops, more and more designs are attempting to use technologies such as projection AR, headworn AR/VR glasses, and handheld AR devices. The application of design enables rich audio-visual imaging technology to truly serve the display of cultural objects, better narrate cultural stories, shape cultural scenes in all aspects, and effectively convey cultural connotations. While the application of technology brings stunning visual effects, the more important purpose of design is to truly establish a cultural based interactive narrative, enabling people to obtain complete cultural background and information in the story clues constructed by design, and deepen understanding by establishing their own connection with culture. At the same time, when leaving the web interface and entering the three-dimensional space of virtual reality, it is also an important work to conduct interaction design on the user's manipulation mode and establish effective interaction metaphor, which affects the fluency of the user's experience in the virtual scene.

Intelligent space design for cultural heritage based on the Internet of Things, clustered by keywords such as the Internet of Things, participating platforms, frameworks, and the Internet. Whether in small cultural spaces such as museums and exhibition halls, or in large spaces such as cultural sites and cities, digital cultural spaces that can intelligently respond to user needs can be constructed by developing and deploying IoT systems, combining passive technologies such as QR codes and RFID, or active technologies such as sensors. For the purpose of cultural interpretation, it is possible to create a sense of space based interaction and design a gamified and exploratory cultural interaction, such as combining forms such as escape in secret rooms and serious games; For the management of cultural spaces, tracking visitor behavior data can provide more personalized interactive navigation, develop intelligent service systems suitable for a large number of visitors, and improve exhibition design and service experience by analyzing visitor data; For a larger digital ecosystem, cultural data can be integrated into a wider network of smart cities, and through the correlation and integration of data, other fields such as culture and tourism, entertainment, economy, transportation, etc. can be comprehensively considered. For example, Spanish innovative enterprise HOP Ubiquitous (HOPU) is committed to supporting urban development and Digital transformation by using data driven tools based on the Internet of Things. The Be Memories developed by them have deployed smart interaction points in Seuti, Bilbao and Bristol to carry cultural content created by residents and provide tourists with more agile and fresh tourist experience. [7] In the field of computers, the application of the Internet of Things places more emphasis on optimizing technical issues such as recommendation algorithms, cold starts, and low power consumption, but the design perspective pays more attention to user behavior, interaction experience, learning effectiveness, and entertainment experience. Through the application of the Internet of Things, more vivid online and offline integration is gradually being achieved in the interaction with cultural relics and spaces, creating a physical experience. For example, the "8K Interactive Museum" collaboration between the Tokyo National Museum and Sharp showcases the "touchable and rotating famous tea bowl". By developing a controller that simulates the form of cultural entities, users can grasp untouchable cultural relics with both hands, and appreciate various details and angles of cultural relics with an 8K display screen, achieving a natural interactive experience of almost real control objects.

From the perspective of the cultural ecology development of digital culture promoted by design, it includes the following hot spots:

The digital narrative design of cultural heritage based on community and history is clustered by keywords such as history, community heritage, memory, co words, literature, and tools. In the past, it was mainly led by experts to explain and narrate cultural heritage, while currently more and more digital work is focused on exploring public participation in digital content. This concept emphasizes the concept of public culture where culture is produced, managed, and disseminated by people. Through the development of digital narrative tools, support participating communities to jointly build the public history of community groups through oral expression and other means. The non-profit organization Shift's online digital archive platform, Historypin, encourages citizens to upload historical images and stories based on Google Maps, and supports the establishment of thematic themes to build connections between different community stories. The platform's main users are concentrated in the UK, the United States, and Australia, and has expanded their digital narrative methods in communities for over 3000 cultural organizations. Similar projects include the application PastPort [8] for "Citizen's Heritage" in Melbourne Port and the crowdsourcing archive platform Soundsslike in Istanbul for symbolic urban voices[9]. There are still certain technical challenges in conducting citizen digitization projects in cities, and the technological gap in conducting bottom-up digitization projects in remote areas is even more evident. Giglitto and others carried out the digital recording of intangible cultural heritage[10] for the Bedouin people, a nomad in Egypt. In the participatory design practice, they recruited local students to participate deeply, and narrowed the cultural distance between designers and community members. In addition, in such projects, it is very important to pay attention to community interests and promote the motivation and self-expression of community members.

The cultural consumption and business model design of digital heritage are clustered by keywords such as participation, customer relationships, feelings, consumers, and communication. Currently, cultural institutions represented by museums are increasingly facing financial constraints. Many museums are actively exploring online access, promotion, and interaction channels, by segmenting user groups, conducting word-of-mouth dissemination, and establishing sharing mechanisms to enhance the social impact of cultural institutions. The International Association of Museums (ICOM) conducted two global surveys of museums worldwide in May and September 2020. The data showed that museums began to adopt various forms of digital communication, including online collections, online exhibitions, real-time activities, learning projects, news emails, podcasts, social media, etc., integrating digital cultural content into various online channels. For example, the European Library of Culture launched an online competition for the "Digital Narrative Festival"; The Birmingham Museum launched a digital subscription called Birmingham Museum on Demand in 2021, which pays a monthly subscription fee of £ 20 to receive exclusive professional lecture content; The Metropolitan Museum of Art provides 400000 pieces of collections for Nintendo game Animal Crossing players to decorate their virtual homes; The Boston Museum of Art, the British Museum, and the Leopold Museum collaborated with the LaCollection platform to create digital versions of some famous collections and sell NFTs (non homogeneous tokens), creating revenue while sharing the collections more widely. Traditional cultural institutions actively explore cross-border cooperation, promote cultural dissemination, improve customer loyalty, and drive digital cultural consumption through the construction of digital business models and marketing channels. The common challenge in this process is how to balance the public and industrial aspects of culture, as well as how to evaluate the economic value of cultural data.

The value evaluation and design speculation of digital culture driven by technology are clustered by keywords such as algorithm, bias, classification, and conditional valuation. The high construction and maintenance costs have led to differences in the digitalization conditions of different institutions and organizations. Currently, cultural big data platforms mainly rely on the accessibility of existing digital cultural content, and most cultural data aggregators use data selection and collection mechanisms based on expert knowledge, which leads to imbalances in data production and processing between different countries and regions within the same country. Therefore, in the face of massive cultural heritage, how to choose the level of technological investment mainly depends on the value judgment of cultural objects, including historical value, aesthetic value, craft value, educational value, entertainment value, etc. Especially in the field of digital ecology, there will be more emerging dimensions for evaluating its value. For example, Azevedo utilizes social media photos, calculates regional travel costs, and combines digital reputation analysis online to determine the entertainment value of specific cultural heritage[11]. The judgment on the value of different dimensions can more clearly guide the balanced development of digital culture between publicity and industrialization, and is more conducive to avoiding the emergence of "digital colonialism" and building a more inclusive digital cultural ecology.

4. Conclusions

Taking into account the six research hotspots in the field of digital culture innovation involving design participation (see Figure 5) , design participation has improved the processing and utilization of existing cultural data. Based on multiple technological paths at different touchpoints, following the five design principles of creating non-linear interactive narratives, enhancing users' sense of location, providing personalized participation experiences, providing contextual information, and creating connectivity between people and culture, the design meets the public's needs for cognitive and experiential goals, and enhances the creation of a digital experience that integrates online and offline, Balancing the dual track innovative development of culture between industry and public through reasonable cultural value evaluation.

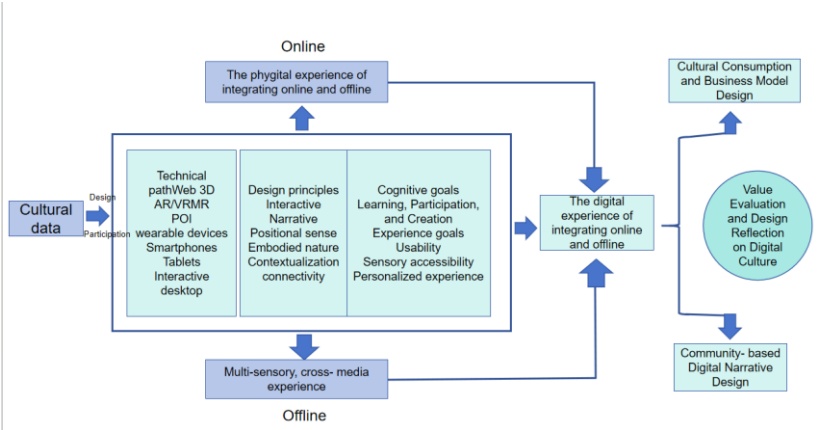

Figure 5. Design Participation in the Field of Digital Cultural Innovation

Starting from the creation behavior of primitive humans, the earliest design prototype embodies the exploration of the relationship between humans and the world. Design closely pays attention to people's creation of things and the interaction between the two. These early human wisdom crystals have become the cultural heritage we currently define. When carrying out digital protection and innovation work on it, the perspective of design lies not only in the dissemination of knowledge about the heritage itself, but also in the re creation based on traditional wisdom, enhancing the connectivity between people and heritage. Compared to the widespread digitization of cultural heritage, design participation is not only about focusing on cultural heritage as an object, but more importantly, creating connections around it. This correlation is reflected in several aspects: creating a well founded, authentic, and accurate reconstruction correlation between cultural objects and historical contexts; Establish an interactive relationship between cultural objects and digital contexts that is close to participant behavior and cognition; Establish collaborative participation, shared benefits, and community connections between different cultural entities. Only through innovative digital technology and continuous creation around the connection of cultural heritage can we truly realize the vigorous development of the overall digital cultural ecology.

In summary, the digital connotation of cultural heritage has been continuously developing over the past two decades. Cultural digitization is no longer just about digital transformation of culture in form, innovation is not only reflected in the deep exploration of digital cultural resources by digital intelligent technology, but also includes the re creation of culture in digital form. By sorting out the development context, research status, and future key goals of digital culture innovation represented by cultural heritage, it can better guide collaborative innovation and design participation in this field. Digital culture, with the digitization of cultural heritage as an important content, essentially has the nature of cultural and technological integration, and has achieved significant results in reconstruction technology, cultural big data, tools and platforms. To participate in the development of digital culture and promote innovation in digital culture, design should start from three aspects: improving the accessibility of digital culture through the application of immersive technology, promoting the reuse of digital culture through collaborative cooperation, and mobilizing public participation to promote reflection on digital culture. Under the integration of culture and technology, design participation promotes the public application of technology, freeing cultural objects from museums and returning them to the public. The design discipline is gradually building a more accessible, inclusive, diverse, and attractive digital cultural ecosystem that caters to public needs. This will continuously promote the widespread integration of digital culture into people's daily lives, as well as the continuous innovation and evolution of culture.

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