

## Postprint: Research Advances in Long-Term Preservation of Digital Games Abroad

**Authors:** Zhang Jingwen

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### Abstract

[Purpose/Significance] By analyzing the research progress of long-term digital game preservation abroad, this study aims to provide reference for the development of long-term digital game preservation in China.

[Method/Process] Based on literature investigation, the research content of the obtained literature is summarized and analyzed from four themes: the content of digital game preservation, legal issues of digital games, technology for long-term digital game preservation, and attitudes of various sectors towards long-term digital game preservation.

[Results/Conclusion] Long-term digital game preservation abroad exhibits four characteristics: broad scope of research entities but small number of researchers; technical research is mostly presented in the form of projects, with most research projects funded by research institutions/programs; diverse research methods; uneven research depth across different themes, without forming a complete system. China can obtain three aspects of enlightenment from this: comprehensively investigate the current status of digital game preservation in China; strengthen theoretical research to consolidate the theoretical foundation; strengthen cooperation among various sectors and participate in international cooperation.

### Full Text

#### Preamble

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Research Progress on Long-term Preservation of Digital Games Abroad  
Zhang Jingwen  
School of Information Management, Wuhan University, Wuhan 430072

**Abstract:** [Purpose/Significance] By analyzing the research progress on long-term preservation of digital games abroad, this paper aims to provide references for developing digital game preservation in China. [Method/Process] Based on literature review, this study summarizes and analyzes the collected literature from four thematic perspectives: the content of digital game preservation, legal issues surrounding digital games, technologies for long-term preservation, and attitudes toward digital game preservation across various sectors. [Result/Conclusion] Long-term preservation of digital games abroad exhibits four characteristics: broad research subjects but few researchers; technical research mostly presented in project form with most projects funded by research institutions/programs; diverse research methods; and unbalanced research depth across different themes, without forming a complete system. China can draw three implications: conduct comprehensive investigations into the current status of digital game preservation in China; strengthen theoretical research to consolidate the theoretical foundation; and enhance cross-sector collaboration while participating in international cooperation.

**Keywords:** digital game; digital resource; long-term preservation

## 1. Introduction

Although the attribution of the first game in human history remains disputed [1], it is undeniable that digital games have become an integral part of human social life since their inception. Digital games hold significant value in history, property rights, design, culture, art, and entertainment [2]. They carry the memories of a generation and embody social history, representing important digital heritage for humanity [3]. Game developer and researcher R. A. Bartle [4] noted that future scholars may need to use preserved games to understand our culture, learn technologies, and appreciate games from aesthetic and entertainment perspectives.

Like most digital resources, digital games face the risk of loss, but their lifecycle is even shorter than that of books and films [5]. Damage to storage media, technological updates, and the elimination of game companies can all lead to the loss of digital game software, along with related resources.

Currently, the value of digital games and the risks they face have attracted attention from some foreign scholars but have not yet drawn interest from do-

mestic scholars. In the literature, only Cai Shun [6] has introduced and analyzed the American Preserving Virtual Worlds (PVW) project in China, pointing out the stark contrast between the popularity of computer games (as representatives of virtual worlds) and the neglect of preserving them, which warrants our attention.

As the world's largest gaming market, and with the recent convening in Beijing of China's first academic symposium officially named "Game Studies"—the "From Games to Game Studies: Functions and Values of Games Symposium" [7]—academic research on games in China will gradually increase. Therefore, whether from the perspective of preserving social memory or providing original materials for academic research, China needs to strengthen long-term preservation of digital games. This paper aims to identify referenceable experiences for China's digital game preservation initiatives by summarizing foreign research progress.

Terms similar to "digital game" [8] include "electronic game" [9], "computer game" [10], "video game" [11], and "virtual world" [12]. Current literature on digital games lacks specific discussion on the distinctions among these terms, with some scholars even using different terms interchangeably. However, scholars do provide reasons for their choice of terminology. For instance, G. Crawford chose "video game" because "it is the most commonly used term" [11]. E. Aarseth noted in the inaugural issue of *Game Studies* journal that the term "digital game" is inclusive, representing a collection of many different media forms. The author believes that whether electronic games, computer games, or video games, all are created in digital form, and "digital game" better encompasses the other terms. Therefore, this paper adopts "digital game" as a general term for these concepts.

## 2. Foreign Research on Long-term Preservation of Digital Games

Using "game preservation" as the title, the author searched Web of Science, Baidu Scholar, and Google Scholar, expanded the search scope through reading relevant literature, and finally obtained 55 papers after screening and deduplication.

### 2.1 Content of Long-term Preservation of Digital Games

Foreign scholars' research on digital game preservation extends beyond the software itself to include other resources closely related to digital games. H. Lowood et al. [2] argue that while game software is the most important content for preservation, focusing solely on software while neglecting other documentary materials behind games would leave future developers without relevant resources to support their research, and the history and team culture of game developers would disappear.

K. Kraus and R. Donahue [13] surveyed digital game companies and found that the most protected categories were source code, compiled binary files, game assets, and artwork, followed by design documents and tools that support game creation. Only a few companies preserved game settings and related videos, and none preserved game magazines or clip files.

M. A. Winget and W. W. Sampson [14] proposed documenting the game development process. Through investigation, they found that traditional documents identified by collecting institutions could not fully demonstrate the game development process. Institutions should also preserve various versions of games and ancillary products generated during development, such as gamma and beta versions, and graphic elements in different presentation formats. E. Kaltman et al. [15] similarly argued that comprehensively preserving game history requires moving beyond single objects to explore game development history more deeply.

N. Esposito [16] proposed preserving the atmosphere when players play games—the physical environment in which players are situated. He believes the atmosphere players experience is an important memory, comprising six elements: era, location description, layout, typical elements (lighting, sound, furniture, other objects, people, etc.), descriptions of interactions in the virtual environment, and the games players play. M. Swalwell [17] proposed a similar concept of the “original experience”—the initial experience games brought to players, which belongs to player sentiment.

O. Sköld approached from an archival perspective, summarizing social and cultural elements of games (such as gaming culture, experiences, community life, and activities) as the expanded notion of games and argued these should also belong to archives [18]. He believed preserving records of player communities significantly impacts preserving game socio-culture [19]. S. Brown et al. [20] considered games as “activities and artifacts,” meaning physical hardware for playing games and gaming behaviors both have archival significance and deserve preservation.

J. Newman [21] argued that besides game code, game walkthroughs should also be preserved content. Walkthroughs reflect gameplay from another perspective and drive continuous game updates. Similar to walkthroughs are “let’s play” videos that record players’ gaming processes.

The author believes foreign research on digital game preservation content can be divided into three layers: the first layer is digital game software itself; the second layer extends to various resources generated during game creation; the third layer extends to digital game history, including digital game culture and derivatives. The relationship among these three layers is shown in Figure 1 [Figure 1: see original paper].

## 2.2 Legal Issues in Long-term Preservation of Digital Games

Legal issues are a common challenge in long-term preservation of digital resources, but they are particularly prominent and difficult in digital game preservation. J. Barwick et al. [22] investigated the current status of digital game preservation from three aspects—online activities, research institutions, and heritage institutions—and found legal issues troubled every organization involved. They noted that solving these legal challenges requires either involving game companies in preservation efforts or amending intellectual property law to enable museums to acquire these resources.

E. Hudson and A. T. Kenyon [23] identified digital games as a thorny area when providing digitization guidance for Australian cultural institutions. Video games comprise multiple works, each separately protected by copyright. For this reason, S. Corbett [3] believed it was impossible to obtain explicit responses from every copyright owner when preserving early digital games in New Zealand. Meanwhile, S. Corbett analyzed New Zealand’s cultural property law from the perspective of protecting digital heritage, noting that amendments were needed to protect digital heritage, but the democratic process would be lengthy. To prevent digital heritage loss during this process, he proposed temporary legal measures, including: establishing legislative provisions exempting digital heritage archiving from the 1994 Act to allow making multiple copies at any time; appropriately expanding the legislative definition of “museum” in the 1994 Act; and adding clauses permitting archiving of digital works whose intellectual property owners cannot be traced. This clause requires publishing copyright notices in newspapers a specified number of times; if copyright holders do not respond within the specified frequency, it indicates no infringement. S. Corbett acknowledged this measure was not ideal, as video games still could not be preserved if copyright owners refused archiving, but as a short-term measure, it would have some effect.

H. Lowood et al. [2] believed game companies’ primary support for libraries and museums in digital game preservation should be legal. While intellectual property protects game companies’ rights, it also limits long-term preservation technologies: migration and emulation. They argued copyright owners should grant special permissions to archives and libraries for long-term game preservation. In 2004, the Digital Game Archives proposed to German Federal Minister Brigitte [24] to exclude digital games from current copyright protection, but this proposal failed.

These scholars’ research on legal issues in digital game preservation shows that compared to general digital resources, digital game intellectual property involves complex legal relationships among game developers, copyright holders, and individuals. Currently, intellectual property poses the greatest obstacle to long-term preservation. Scholars’ recommendations mainly include two aspects: (1) amending current legal systems to create green channels for digital game preservation; and (2) calling on intellectual property owners to value long-term

preservation and provide access channels for memory institutions.

### 2.3 Technology for Long-term Preservation of Digital Games

Foreign research on digital game preservation technology focuses primarily on software preservation, with abundant results, mostly from research projects.

Among many foreign projects, the PVW (Preserving Virtual Worlds) project is the largest comprehensive research project. The PVW project [12] is a collaboration between Rochester Institute of Technology's Interactive Games and Media Department, Stanford University's Humanities Lab, University of Maryland's Institute for Technology in the Humanities, University of Illinois Urbana-Champaign's Graduate School of Library and Information Science, Illinois Library, and Linden Lab (Second Life), funded by the Library of Congress's NDI-IPP program as part of the Preserving Creative America initiative. The six-year PVW project has two parts: Preserving Virtual Worlds I (PVW I) and Preserving Virtual Worlds II (PVW II)—identifying significant properties for various educational games.

PVW I's main objective was to investigate preservation issues concerning video games and interactive fiction from different periods in computer history through case studies, and to develop basic standards for metadata and content description applicable to long-term storage of these digital artifacts. PVW I can be roughly divided into three phases: (1) scoping and background research; (2) framework establishment; and (3) case archiving implementation and packaging. Its research outcomes include applying the OAIS reference model to preserving computer games, video games, and electronic literature in academic libraries [25], and integrating FRBR and OAIS data models into a single Web ontology language based on XML packaging format [26]. PVW II aims to identify significant properties of various educational games, provide recommendations for best practices in future preservation actions (such as migration), and analyze how to best document preservation processes.

Besides the PVW project, many foreign research projects and individual studies focus on specific aspects of digital game preservation.

**2.3.1 Research on Digital Game Software Preservation Methods** The KEEP (Keep Emulation Environments Portable) project [27] focuses on developing a prototype emulation access platform to enhance preservation of digital objects, particularly digital games. Funded by the European Commission's Seventh Framework Programme, the project encompasses a large research team: the National Library of France, German National Library, National Library of the Netherlands, Tessella Company, SAS Company, University of Portsmouth (UK), and the European Game Developers Federation.

Unlike current emulator systems built on specific platform technologies, KEEP is built on virtual machines. The project developed a software architecture

compatible with existing emulators while minimizing dependencies to reduce obsolescence risks.

M. Swalwell from Victoria University of Wellington, interested in digital game preservation, assembled the NZTronix project team [28] in 2006 with four other experts (two computer scientists, one intellectual property lawyer, and one archivist) to explore digital game preservation in New Zealand. The team used locally developed games for Sega's SC3000 computer as a pilot case and received corresponding funding. Since the project's goal was to legally emulate and port software, the team encountered significant intellectual property challenges during the pilot. They ultimately adopted translation instead of emulation, compiling their own code translator to convert games developed by Sega in BASIC to Java.

M. Guttenbrunner et al. [29] evaluated technical methods for preserving console video games. They analyzed several technical strategies for protecting digital heritage proposed by UNESCO and concluded that emulation is the most suitable method for console video game preservation. Using the Planets preservation planning workflow, they evaluated different emulators and also assessed migration. Test results showed sample selection significantly affected outcomes—some emulators could perfectly reproduce one sample but not others. Video migration methods yielded good results for most samples but lacked interactivity.

M. A. Winget and C. Murray [30] analyzed migration and emulation applications in digital game preservation, noting that migration focuses only on files themselves, creating storage medium selection challenges for archivists. Compared to migration, emulation works at both system and software levels but can disrupt original game pacing, direction, quantification, and formatting, thereby distorting games.

**2.3.2 Research on Digital Game Preservation Metadata** Current organization and description schemas for digital games come from two main sources: (1) knowledge organization fields (providing description and metadata specifically for information objects and collections); and (2) organization and description from internet commercial systems. However, metadata from neither source is fully suitable for digital games. Therefore, the University of Washington Information School collaborated with the Seattle Interactive Media Museum to develop a metadata model for digital games [31]. Using a user-centered approach, the project identified six user roles—players, parents, collectors, scholars, game developers/designers, and curators/librarians—and created different scenarios to determine useful metadata elements for each group. The project listed 61 different information features and surveyed their importance across roles and usage scenarios. Based on results, they established a core element set that any system organizing and describing video games and interactive media should include. This core set comprises 16 elements: title, version, platform, format, developer, publisher, retail release date, number of players, online features, special hardware, genre, series/franchise, region, rating, language, and universal

product code. During the survey, the project found some difficulties in describing digital games were unique to games, while others were common to non-text information objects [32], including inconsistent, ambiguous, and undefined genre labels, lack of reliable sources for game release dates, and inconsistent descriptive information. To address genre description issues, the project specifically studied game genres [33], developing a more complex scheme with 12 aspects and 358 focal points for describing and representing video game genre information.

The GAMECIP project [34] conducted metadata requirements and citation practice surveys around institutionally collected computer games. A joint project of UC Santa Cruz Library, UC Santa Cruz Computer Science Department, and Stanford University Library, funded by the Institute of Museum and Library Services (IMLS), the team comprised metadata librarians, computer scientists, and game researchers, including former members of the Preserving Virtual Worlds (I and II) projects. GAMECIP proposed a core metadata scheme applicable to all parties, including 20 elements [35], providing for each element its SKOS-linked data representation URI in the Open Metadata Registry, definition, notes on element usage and/or cataloger annotations, examples marked as attributes in different schemas (crosswalks) to illustrate implementation, and similar properties in other schemas (including URIs to facilitate future mapping). The project team believed many elements should have controlled vocabularies, but any party could choose the most suitable vocabulary. They recommended using recognized, published controlled vocabularies and urged users to consistently use designated vocabularies. Currently, the team has developed two controlled vocabularies: computer game platform controlled vocabulary and computer game media format vocabulary.

G. Carta [36] treated video games as complex digital objects, hypothesizing that metadata forms the basis for distinguishing authenticity and accuracy of complex digital objects, and analyzed emulation frameworks. Using technical metadata to describe digital environments and objects in emulation frameworks, he concluded that while metadata cannot be considered the final solution for preserving significant properties of video games, they should be used within a broader framework. In this study, G. Carta also attempted to provide insights on video game attributes to help resolve debates about emulation.

Regarding digital game preservation methods, the complexity and interactivity of digital game software, plus protection barriers set by developers for intellectual property rights, create technical difficulties. Methods suitable for general digital resources do not apply to digital game software. Current research shows migration, emulation, and compilation are the main methods, but each has advantages and disadvantages. Selection depends on the ultimate goal—preserving the original state of digital games to provide players with original experiences, or preserving original game footage as part of game history regardless of whether players can continue experiencing the game. In metadata, current knowledge organization and commercial fields' organization and description of games are not fully suitable. Due to cultural differences, domestic games differ from for-

eign games, so China needs to develop its own digital game metadata sets and controlled vocabularies based on foreign datasets.

#### **2.4 Survey Research on Attitudes Toward Long-term Preservation of Digital Games**

K. Kraus and R. Donahue [13] surveyed both game developers and game enthusiasts through the International Game Developers Association's Game Developers Conference white paper, receiving 48 responses from the game industry. Results showed preservation activities in the game industry were chaotic, with preservation decisions seemingly made at individual developer levels without official guidance. The industry showed little interest in preserving games, while player communities actively preserved software for their favorite games.

A. Bachell and M. Barr [37] from the University of Glasgow conducted research with opposite conclusions. They surveyed UK independent game developers through online questionnaires and face-to-face interviews. Their online questionnaire used questions from Kraus and Donahue's survey. This research concluded that the independent game industry was interested and willing to preserve games, though noting the small scale was insufficient to generalize about the entire industry. A. Bachell won the 2014 UK Digital Preservation Award for Outstanding Student Work for this research.

J. Barwick [38] divided survey subjects into scholars/researchers, memory institutions, game industry, and preservation organizations, investigating 27 subjects. Results showed academic groups were important stakeholders who directly used game collections; game preservation communities were passionate about games, with fans currently completing 50% of preservation work, though the legality of their activities was questionable; the game industry showed no interest or motivation in preserving game history; memory institutions held two different attitudes—some believed preserving digital games was meaningful, while others questioned its significance.

These foreign surveys were small in scale, reaching both similar and contradictory conclusions. Therefore, extensive surveys are needed to understand attitudes toward digital game preservation. Foreign survey results show digital game preservation faces two problems: (1) the game industry and memory institutions have internal divisions in attitudes; and (2) player groups interested in preservation lack legitimacy.

### **3. Characteristics of Foreign Research on Long-term Preservation of Digital Games**

After nearly a decade of development, foreign research on digital game preservation exhibits several characteristics:

### 3.1 Broad Research Subjects but Few Researchers

Geographically, scholars come from the US, UK, New Zealand, Austria, Netherlands, Sweden, and other countries, predominantly the US. By research field, they come from LAM (library, archive, museum) sectors, computer science, law, history, and other disciplines. The broad scope of subjects is reflected not only in the overall research community but also in specific project participants.

Although preservation subjects span countries and disciplines, the number of researchers is small. This results in digital game preservation occurring within a small academic circle, hindering innovation and development.

### 3.2 Technical Research Mostly in Project Form, Mostly Funded by Research Institutions/Programs

Technical research on digital game preservation primarily takes project form. Projects can assemble organizations and talents from multiple fields, stimulating technological innovation more than individual research. Meanwhile, most large digital game preservation projects receive funding—for example, PVW funded by the Library of Congress, KEEP by the European Commission’s Seventh Framework Programme, and GAMECIP by the Institute of Museum and Library Services—all research institutions/programs. This shows digital game preservation requires substantial human and financial resources, and also demonstrates foreign research institutions’ emphasis on digital game preservation.

### 3.3 Diverse Research Methods

In technical research, scholars typically use several games or game categories as research objects to gradually develop preservation technologies. When exploring preservation content, they employ interviews, surveys, ethnography, and other methods to comprehensively understand perspectives on what should be preserved.

### 3.4 Unbalanced Research Depth Across Themes, No Complete System Formed

The literature review shows current research on preservation content is relatively abundant, while research on legal issues is scarce. Regarding preservation content, studies on specific resources are numerous, but holistic organization and classification of digital game preservation scope are limited, indicating no complete research system has formed. Additionally, after decades of development, the number of research papers remains small, suggesting slow progress in digital game preservation.

## 4. Implications of Foreign Research for China

### 4.1 Comprehensive Investigation of China's Digital Game Preservation Status

Understanding China's digital game preservation status can identify problems and provide foundations for research and practice, including surveys of attitudes toward preservation and investigation of the game industry's preservation practices.

**4.1.1 Survey Attitudes Toward Long-term Preservation Across Sectors** Foreign research shows digital game preservation involves multiple stakeholders: game industry (companies, independent developers), memory institutions, players, and research institutions (universities, institutes), with large research institutions as main funders. Stakeholders' attitudes affect their future participation possibilities. Comprehensive understanding of Chinese stakeholders' attitudes can help identify interested organizations to become preservation mainstays.

Foreign surveys reveal internal divisions in attitudes within the game industry and memory institutions, while players and research institutions show strong interest. Different survey scopes also lead to contradictory conclusions about the same stakeholders' attitudes. Therefore, Chinese surveys should emphasize sample selection, comprehensively covering different organization types (large vs. small companies, independent developers).

**4.1.2 Focus on Investigating Game Industry Preservation Practices** Currently, Chinese memory institutions primarily preserve national public resources, and literature shows no memory or research institutions preserving digital games. Therefore, investigating the game industry should be prioritized to understand current preservation practices and raise industry awareness.

Investigations should cover preservation regulations, digital game databases, challenges faced, and willingness to collaborate with other organizations to provide direction for subsequent research.

### 4.2 Strengthen Theoretical Research to Consolidate Foundations

China's research on digital game preservation is still blank. Theory forms the foundation of practice, and advancing preservation requires solid theoretical foundations.

**4.2.1 Define Scope of Digital Game Resource Preservation** Foreign research shows digital game preservation involves extensive scope, with PVW project reports noting difficulty in defining exact boundaries. Scope includes horizontal (which games to preserve) and vertical dimensions (which game-related resources to preserve). Defining scope affects stakeholder responsibility division, legal issue resolution, and technical method research.

- (1) For horizontal scope, adopt a user-demand-oriented approach combining broad player surveys and expert interviews, following a prioritized, step-by-step principle. Prioritization means first preserving endangered and excellent digital games; step-by-step means starting with small quantities of excellent games to accumulate experience before expanding.
- (2) For vertical scope, use ethnographic methods to involve archivists in game development processes, as E. Kaltman [15] integrated perspectives from game studies scholars, archivists, and developers on organizing, classifying, and storing development documents. Ethnography can identify preservation-worthy resources from archival perspectives while merging multiple viewpoints for more comprehensive scope definition.

**4.2.2 Strengthen Legal Research** Foreign surveys show players are enthusiastic about preservation, but their activities are often illegal, and even widely used technical strategies—migration and emulation—have questionable legality. Without sound legal systems, these illegal activities make developers more protective of copyrights, hindering preservation. Some scholars argue legal issues, not technical ones, pose the greatest obstacle. Therefore, healthy, orderly digital game preservation requires legal research and measures: incorporating computer games as whole, independent works under copyright law with unique IP rules based on functional characteristics [39]; extending fair use to digital game preservation; and establishing deposit systems for digital games.

**4.2.3 Strengthen Technical Research** Although China has achieved some success in digital preservation technology, digital game preservation is far more technically challenging than general digital resources. China should actively learn from foreign experiences and applicable achievements while developing preservation methods, metadata, and controlled vocabularies suitable for Chinese games given national differences.

### **4.3 Enhance Cross-sector Collaboration and International Cooperation**

Like all digital resource preservation, advancing digital game preservation requires joint efforts across sectors—single institutions cannot complete it alone. Most foreign digital game preservation projects involve multi-organization collaboration.

**4.3.1 Establish Cross-disciplinary Collaboration** Digital game preservation involves computer science, law, history, and LAM fields, requiring collaboration to overcome challenges. By organization type, game companies, memory institutions, and research institutions should establish broad cooperation. Game companies control resources, research institutions have high research capacity, and memory institutions have strong professional capabilities and preservation experience. However, facilitating cooperation is not easy. Approaches include:

(1) signing confidentiality contracts to allow university and memory institution personnel to access game company archives early, advancing preservation while saving company history; and (2) signing transfer agreements for companies to donate discontinued games and resources to other organizations to prevent loss, such as the UT Video Game Archive [40] preserving donated resources from gamers/companies, though public access remains restricted, reducing loss risks at the source.

**4.3.2 Establish International Cooperation** China's digital game preservation is in its infancy while foreign preservation has achieved results, particularly in technology. Universities are main research forces in foreign projects. China should seize the opportunity of building "world-class" universities to actively participate in international cooperation, absorb foreign talent, and conduct exchange visits.

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*Note: Figure translations are in progress. See original paper for figures.*

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