

Embracing the Metaverse: A Survey of Virtual Reality and Augmented Reality Practices at the United States' Top One Hundred University Libraries

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The purpose of this study is to learn more about virtual reality (VR) and augmented reality (AR) practices at the United States' top one hundred university libraries, as well as how they are engaging with the metaverse. We conducted qualitative and descriptive analysis on the websites of the top one hundred university libraries in the United States to determine the application fields and application proportions of VR and AR technologies and found good practice examples of using VR and AR technologies in this field. The findings show that 86 percent of the top one hundred US university libraries have implemented VR and AR technologies, with practice areas focused on: VR/AR studio and VR/AR makerspace; immersive learning services and virtual exhibitions/conference services; visual geographic information system and VR navigation services; virtual reading services and visual retrieval services; and VR reference services. The study provides university library administrators and professionals with the most up-to-date information and best practices of VR and AR engagement areas and the proportion of use, which can aid in the development of strategies to leverage VR and AR technologies to improve patron service and embrace the metaverse for the communities they serve.

Introduction

A number of incidents have led the metaverse to the forefront of global attention, including Roblox going public as a metaverse stock in 2021, Facebook renaming itself Meta and making the virtual reality social platform—Horizon Worlds free to users aged eighteen and up in the

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United States and Canada. The metaverse is like a digital universe, creating a virtual environment similar to various scenarios in the real world: a world where we can play games, go to shopping malls, travel, make friends. A world where people have their own virtual identities, perform a range of social activities such as socializing and working, and where people can get and create what they want. Accordingly, the metaverse has all the potential to be a significant concept and technology that will drive libraries in the future, leading to a transformation of libraries into highly immersive services, similar to how the internet has altered the way we live.

As early as 2003, certain university libraries in the United States developed virtual libraries in the online video game “Second Life” and offered a variety of services, marking the first practical research on metaverse libraries. The metaverse is regaining popularity nearly two decades later, and technological circumstances have improved. Today’s metaverse is a collection of new technologies, including virtual reality (VR), augmented reality (AR), gaming, networking, etc. VR and AR are two of the most important metaverse enabling technologies, and their use in university libraries is growing.

Literature Review

The term “metaverse” first appeared in the science fiction novel *Snow Crash*, where it is described as a virtual universe that exists independently of the real world and where an individual can access as an avatar.¹ Zuckerberg describes the future of the metaverse as follows: “In the metaverse, you’ll be able to do almost anything you can,” and “you will be able to teleport instantly as a hologram to be at the office without a commute, at a concert with friends, or in your parents’ living room to catch up.”² After a year of development, Mystakidis believes that the metaverse is a post-reality universe, a perpetual and persistent multi-user environment merging physical reality with digital virtuality.³ With respect to the library sector, most metaverse-related research that was identified was conducted primarily by Chinese scholars. Yang believes that VR, digital twins, artificial intelligence, and blockchain technology will be the technological directions worth exploring in the field of libraries science.⁴ Guo proposes an application scenario for future library social education that is more intelligent, immersive, and interactive, arguing that libraries can develop social education in the metaverse form in four ways: enriching educational contents, promoting services parity, broadening educational forms, and achieving integration. Through the literature analysis as well as theoretical research, VR and AR are crucial technologies for realizing the metaverse by fully taking over patrons’ sense of vision, hearing, touch, and motion capture to achieve information input and output in the metaverse.⁵

In 1935, the phrase “virtual reality” appeared in the novel *Pygmalion’s Spectacles*. The book describes “Pygmalion’s glasses,” which enable the wearer to enter the world depicted in the glasses, allowing the individual to interact with people and things in the glasses world—people can touch them, listen to their voices, and smell them. In 1989, Jaron Lanier, founder of VPL, first proposed the concept of virtual reality and manufactured the first commercial VR product for market, but the \$100,000 price hindered its popularity at that time. Now, VR is widely recognized as a simulation system developed by a variety of sciences and technologies, including network technologies, 3D modeling, and computer technologies, that creates a simulated world of user interaction and is presented or projected through wearable devices like the Oculus or HTC Vive.⁶ Augmented reality differs from virtual reality in that AR superimposes computer-generated objects onto real-world scenes using computer-connected devices such as monitors or glasses, so that virtual objects appear alongside the real-world scene in the

user's field of vision.⁷ VR and AR technologies are considered the most fundamental forms of the metaverse, as well as the technical infrastructure that allows the metaverse to be realized. Therefore, summarizing research on the application of VR and AR technologies in libraries can aid in the adoption of metaverse-related technologies.

Research on library's application and adoption of VR and AR technologies can be divided into three phases: theoretical discussion, expanding application, and popular application.

Theoretical Discussion

The "theoretical discussion phase" of VR and AR technologies application in libraries occurred between 1991 and 2006 and can be separated into three parts: concept introduction, tool application, and practical exploration. Initially, it was said that the experienter could engage with an artificial environment created in the library, resulting in integration with the virtual scene.⁸ Since then, several researchers have presented the concept of the virtual library, focusing on virtual libraries that are integrated with VR technology, as well as the importance of VR technology in the context of libraries. Poulter proposes the VR library, a novel type of online library that can be used in libraries that lack data repositories or are inaccessible to patrons.⁹ Due to the lack of VR-related concepts in library science, Charles explains VR, including the correct and incorrect usage of the term, and concludes that VR technology has aided in the establishment of virtual libraries.¹⁰

As for tool applications, researchers have mostly anticipated the use of VR and AR technologies in information retrieval. Various retrieval tools and applications based on VR and AR technologies arose in this time period. For instance, the VR information retrieval tool VR-VIBE extends the retrieval process to a 3D form, allowing for more information to be visualized at once and enabling more powerful interaction capabilities.¹¹ ARLib can assist patrons in completing advanced searches in libraries by locating books on the shelves. However, a laptop, a head-mounted display with a FireWire camera, and Studierstube 2.0 software are required.¹² As for practical exploration, Chen suggests the idea of upgrading digital library user pages with AR technology and attempts to apply it to work in libraries.¹³ Following that, a survey study at Texas A&M University's Sterling C. Evans Library found that VR can be a valuable tool for integrating "physical tours" and "web-based virtual tours," allowing patrons to navigate, watch, read, listen, and access information from afar.¹⁴

Expanding Application

Between 2006 and 2010, there was an explosion of research on VR and AR technologies in libraries, which fell into the "expanding application phase." This phase was dominated by virtual library research, Second Life research, and application-specific research. Early virtual library research focused largely upon the overall architecture of virtual libraries, such as the system of virtual libraries and the design approach. After clarifying the overall architecture, researchers began to summarize the purpose, characteristics, functions, and future directions of virtual libraries, as well as suggesting principles and benefits of virtual library collections.¹⁵ In Second Life research, Swanson argues that virtual environments based on Second Life revolutionize the delivery of information and services, as well as the sharing of information between librarians and library patrons.¹⁶ Ferry evaluates the range of activities in Second Life, classifies it as "gray literature," and discusses the tools used to discover, document, and preserve it.¹⁷ In terms of specific applications, Parhizkar investigates the use of AR technol-

ogy to preserve rare or special collection manuscripts in libraries, arguing that AR technology can model these valuable manuscripts and rare books and present them in a virtual format, allowing library collections to be better maintained.¹⁸ Additionally, practical applications of VR and AR technologies emerged between 2008 and 2010, such as China's first VR system in the National Library in 2008, which became its promotional feature. Some university libraries in the US were also gradually improving their virtual library services in Second Life.¹⁹

Popular Application

Since 2011, VR and AR research has moved into the "popular application phase." With the widespread adoption of various smart devices, the maturity of VR and AR technologies in libraries, and a shift of focus of VR and AR application from resources to services, current research mainly explores problems with VR and AR applications, mobile terminals research, and surveys on VR and AR technologies. In terms of problems research, Chinese scholars advocate that the development and extension of VR technology should be prioritized in view of the current problems such as the low commercial value of VR devices and the immaturity of technology.²⁰ Massis describes the benefits of using VR and AR technologies in libraries in the future and argues that VR and AR technologies should not be used only as a way to attract patrons, but to improve the information literacy of patrons.²¹ According to Hahn, while VR technology opens up many possibilities for libraries, most VR technologies have not been professionally tested.²² Hahn also notes that increased sales of VR products are contributing to the creation of virtual worlds and advises that the field of library science should not ignore this trend.

In terms of research on mobile terminals, Linoski conducted a study on the integration of mobile terminals and VR technology to evaluate their application in libraries and their impact on librarians, covering everything from smart watches, Google Glass, to GoPro wearable cameras. In terms of surveys on VR and AR technologies,²³ Oyelude investigates the usage of VR and AR technologies in libraries and museums, and found that Facebook was the leading investor in VR and AR technologies, with many people having the opportunity to try VR and AR technologies by using Facebook.²⁴ In a year-long study of the use of VR and AR technologies in academic libraries, findings revealed that 38 percent of American Association of Research Libraries (ARL) member libraries offered VR and AR services, with a focus on the use of Oculus and HTC Vive.²⁵ By investigating the VR experience area in the library of the Hong Kong Polytechnic University, Suen found that university libraries have limitations in terms of technical capabilities, spaces, and budget costs.²⁶

Through the above review, we find that libraries are gradually maturing in the practices of VR and AR technologies. Although there is extensive research on relevant topics, further research on the latest practice of VR and AR technologies is still needed in the coming era. Moreover, how should university libraries use VR and AR technologies to embrace the metaverse era? This paper aims to address these questions to explore the under-researched areas. The researchers conduct a series of surveys to understand the current state of VR and AR practices in the top one hundred university libraries in the United States. After analyzing typical cases, this paper clarifies the future development of this field and makes suggestions for how libraries can embrace the metaverse.

Research Question

VR and AR technologies provide users with an immersive reading and learning experience

that enriches the form of information conveyed. Users can acquire and understand the knowledge and information in various types of literature in a more intuitive and vivid way. At the same time, virtual reality and augmented reality—as an important part of the metaverse—can provide an immersive virtual environment and broaden the service space and interaction mode of libraries, thus better satisfying users' needs. Therefore, this paper will sort out the application of virtual reality and augmented reality in university libraries and try to answer the following research questions:

1. What proportion of the top one hundred US University libraries have used virtual reality and augmented reality?
2. In which areas do they primarily use VR and AR to benefit their patrons?
3. How can university libraries employ virtual reality and augmented reality to embrace the metaverse?

By answering these questions, we hope to help libraries improve user satisfaction, expand information presentation, and provide references for the technology introduction of university libraries.

Method

Sample

This study uses both descriptive and qualitative methods to analyze the website content of the top one hundred university libraries in the United States.²⁷ We entered the words “VR/AR” in the library web pages of these schools, and the relevant content appeared as follows: “Virtual Map Services,” “VR/AR Studio and VR/AR Makerspace,” “Virtual Reading Services and Visual Retrieval Services,” “Immersive Learning Services and Virtual Exhibition/Conference Services,” and “VR Reference Services.” We examined each of the websites from June 5 to July 13, 2022. Additionally, we conducted a secondary visit to the website to determine the authenticity and reliability of the data.

Approaches

The researchers conducted the analysis using the following steps:

1. Identify keywords to use in a search of the selected library websites (VR, AR, virtual reality, and augmented reality)
2. Utilize Google to search for “keyword + site: the university library website” and then open each of these library websites.
3. Enter keywords identified in Step 1 into the search box of the researched library website to identify how well they use these technology. If the websites could be searched to find appropriate locations where the school's libraries offered VR, AR, virtual reality, and augmented reality, or if it could be verified in the relevant news that the school's libraries offer these technologies, count that data and collect the various data needed for analysis.
4. As outlined in the first two research questions above.
5. Document the findings.
6. For library websites that did not give a direct answer, determine whether they used VR/AR devices by looking up their past events.
7. Have other members of our team repeat the above actions to ensure accuracy.
8. Double check and statistically evaluate the survey data.

Findings

A review of the websites of the top one hundred university libraries in the United States revealed that 86 percent used VR and AR technologies, while 14 percent did not mention it on their websites. Overall, 73 percent offered VR/AR studios and VR/AR makerspaces, 63 percent offered immersive learning services and virtual exhibition/conference services, 48 percent offered virtual map services, 42 percent offered virtual reading services and visual retrieval services, and only 31 percent offered VR reference services. Samples are given in Table 1 and the results are illustrated in Figure 1.

TABLE 1 Code List and Examples				
Contents	Options	Example No. 1, Princeton University	...	Example No. 100, University of Colorado Boulder
Virtual Map Services	1. Visual Geographic Information System 2. VR Navigation Services 3. Neither	1		3
VR/AR Studio and VR/AR Makerspace	1. VR/AR Studio 2. VR/AR Makerspace 3. Neither	1, 2		1
Virtual Reading Services and Visual Retrieval Services	1. Virtual Reading Services 2. Visual Retrieval Services 3. Neither	1		3
Immersive Learning Services and Virtual Exhibition/Conference Services	1. Immersive Learning Services 2. Virtual Exhibition/Conference Services 3. Neither	1, 2		1
VR Reference Services	1. Yes 2. No	1		2

VR/AR Studio & VR/AR Makerspace

VR/AR studios are venues where libraries provide equipment for patrons to experience VR and AR technologies, whereas VR/AR makerspaces allow patrons to not only experience VR and AR technologies, but also to innovate and produce utilizing the equipment provided. Among the one hundred American university libraries reviewed, 73 percent had VR/AR studios or VR/AR makerspaces. More specifically, 64 percent had VR/AR studios, 23 percent had VR/AR makerspaces, and 14 percent provided both. The results of the research are shown in Figure 2.

The prevalence of VR/AR spaces reflects focused attention on library space construction. For instance, Princeton University Library opened a makerspace that combines “making and innovation” with a variety of equipment for learning and exploration. The makerspace includes physical work areas such as “build and explore” and “print and create,” with head-mounted and hand-held devices, 3D printers, and collaborative workstations in each of these areas.²⁸ Stanford Library set up VR workstations equipped with Oculus, HTC Vive, 3D printers,

FIGURE 1
Percentage of Top One Hundred University Libraries in the United States Using VR and AR Technologies

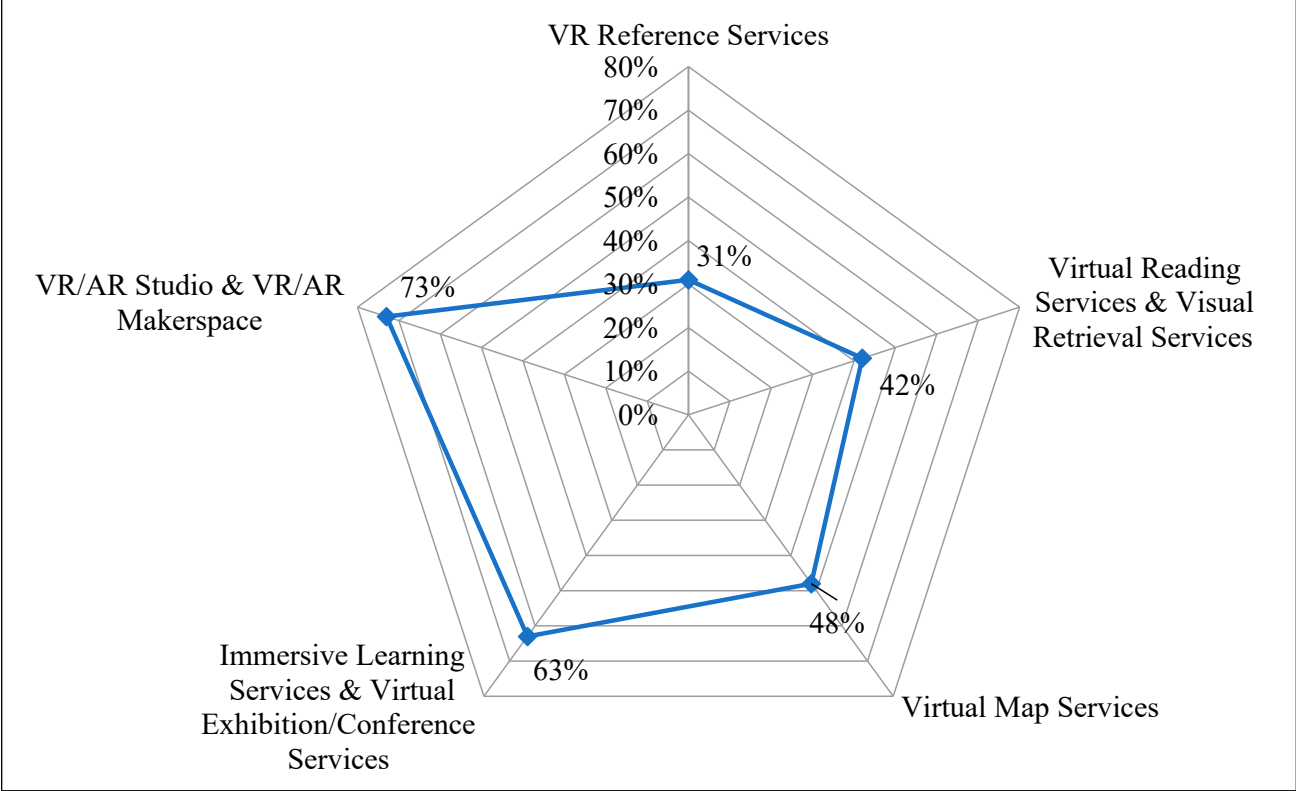
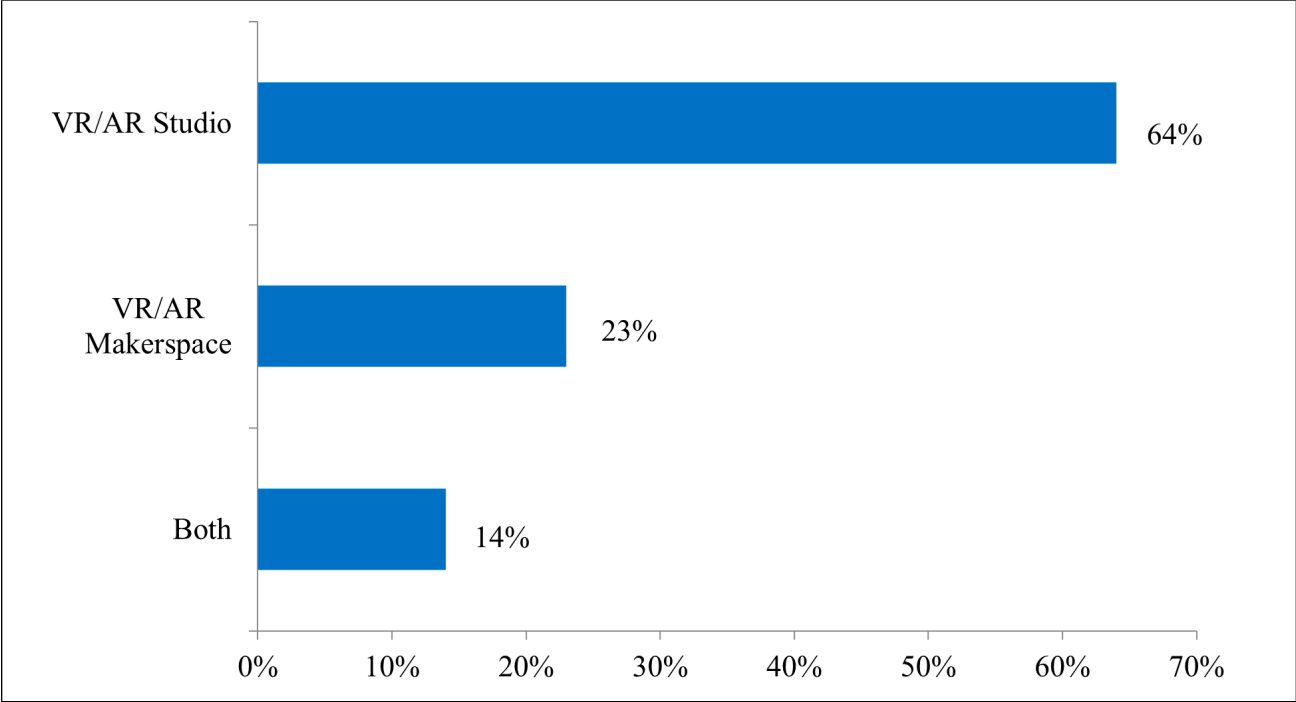
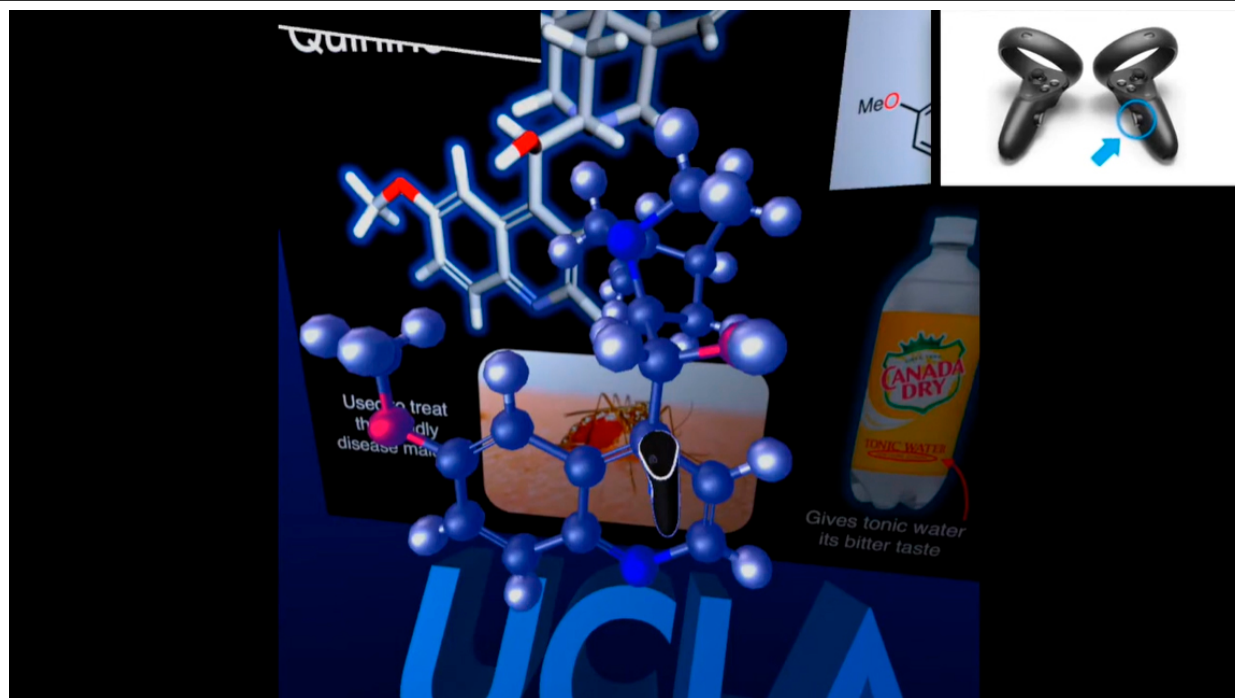


FIGURE 2
Percentage of Top One Hundred University Libraries in the United States With VR/AR Studios and VR/AR Makerspaces



and other devices, allowing patrons to experience life as a Stanford student through various devices.²⁹ The University of California-Los Angeles Garg Lab launched a VR immersive platform for chemical resources, where patrons can visualize various chemical elements that are not normally seen and can interact with organic molecules in 3D form to understand their relevance to daily life (see figure 3).³⁰

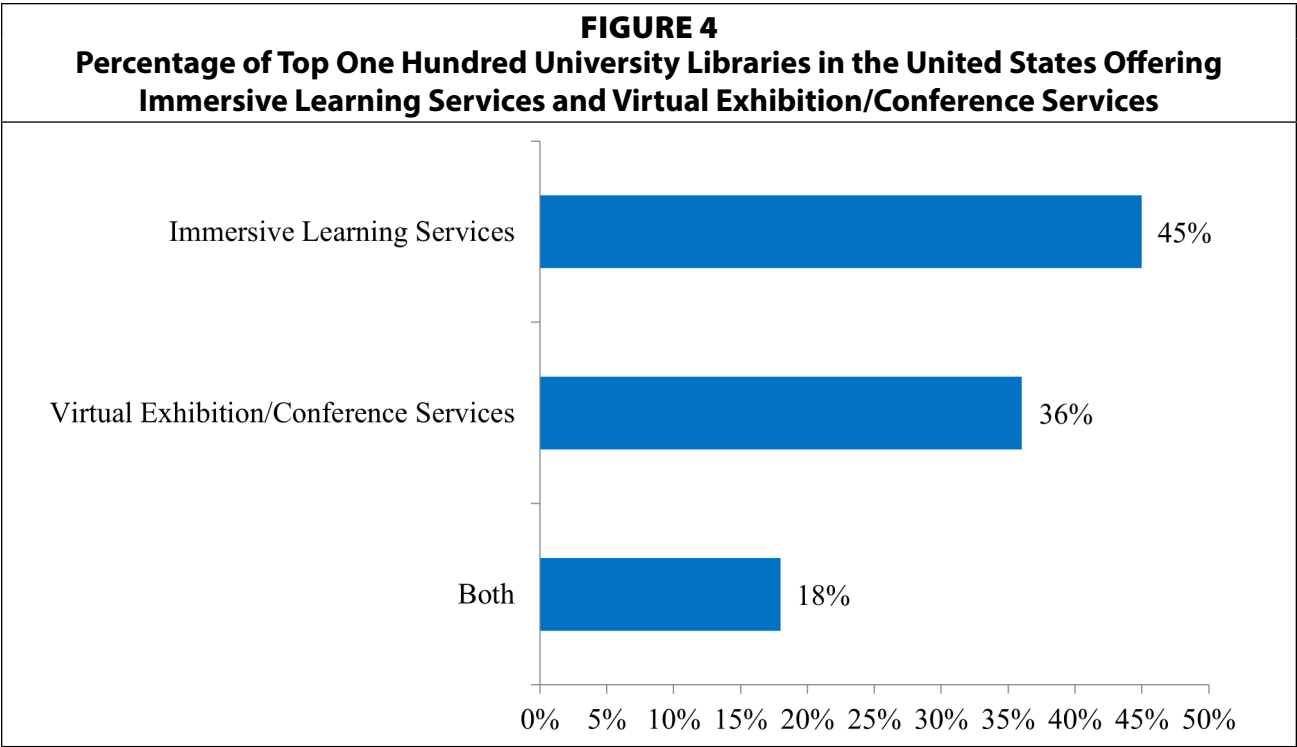
FIGURE 3
Video Demonstrating Use of UCLA's VR Immersive Platform for Chemical Resources



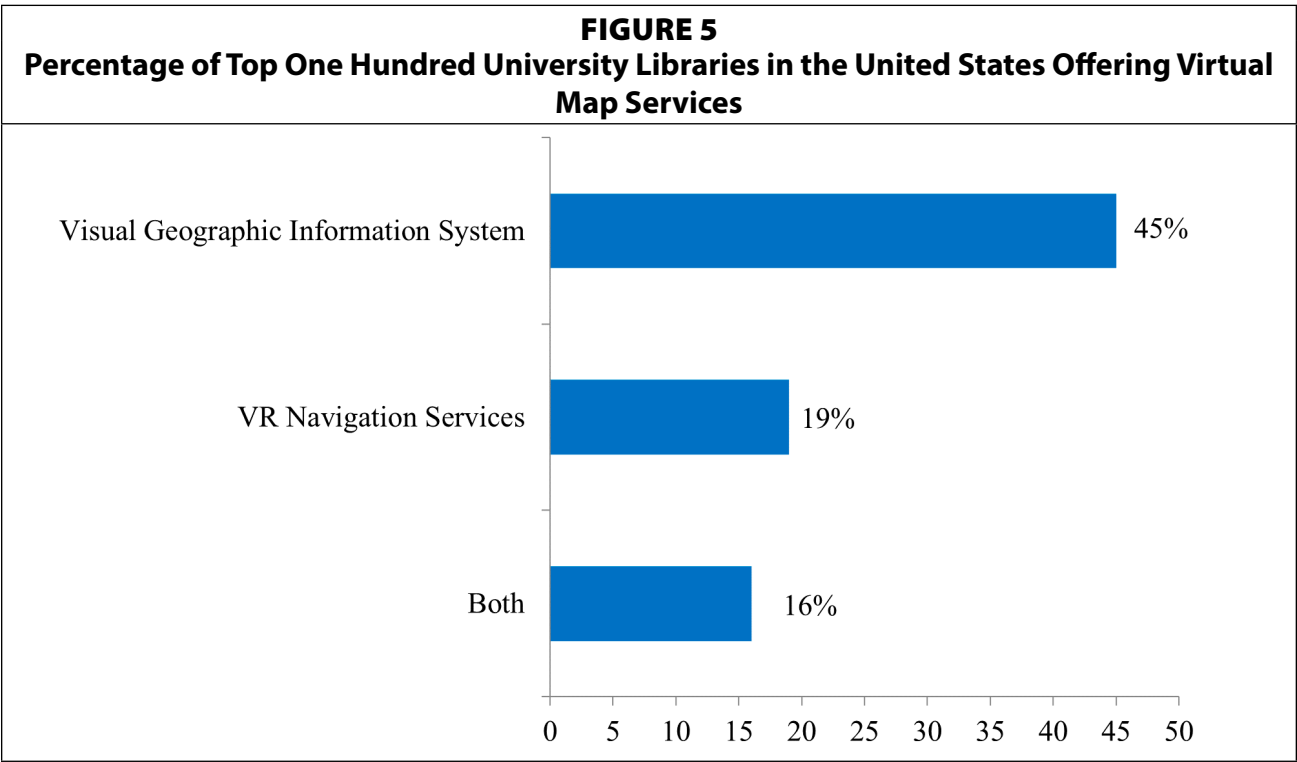
Immersive Learning Services & Virtual Exhibition /Conference Services

Immersive learning services are those in which libraries use VR and AR devices to enable patrons to enter virtual scenarios during the learning process, thus enabling deep learning. Virtual exhibition/conference services refer to the use of various devices to conduct 3D exhibitions of electronic or physical resources or provide conference services, allowing patrons to see realistic physical resources as well as enjoy face-to-face conference services without going to the library. Overall, 63 percent of libraries reviewed offered immersive learning services and virtual exhibition/conference services. More specifically, 45 percent of the libraries provided immersive learning services, 36 percent provide virtual exhibition/conference services, and 18 percent provide both services, as illustrated in Figure 4.

The noteworthy prevalence of libraries that provided immersive learning services (45 percent), reflects the importance of auxiliary teaching in the libraries. For example, the Stokes Library, a branch library of the Princeton University Library, offers both immersive virtual experiences and learning opportunities.³¹ Virtual experiences include historical event experiences, practice in public speaking skills in front of virtual crowds, and participation in realistic interactive environments. The Stokes Library also provides assisted instruction, exploration, and visualization of learning data through VR and AR technologies. Columbia University Library uses real-time visual simulation technology to allow



patrons to explore built environments that no longer exist, and encourages experiential interpretation and innovative pedagogy involving cultural heritage sites.³² The UC San Diego Library launches a virtual exhibition on the history of the Holocaust to the public, which deepened the public’s understanding of the past while preserving the memories of Holocaust survivors.³³



Virtual Map Services

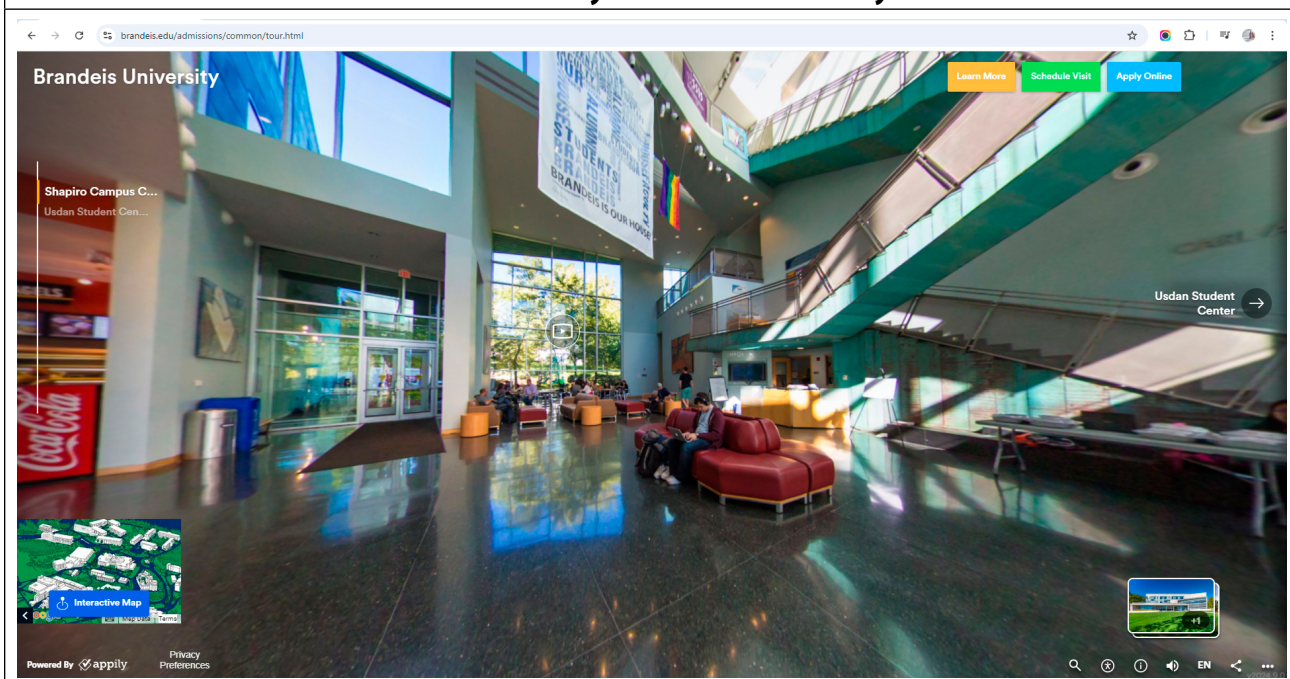
Early on, VR and AR technologies were widely used in Google Street View maps. With the development of interactive technology, an increasing number of libraries are currently providing virtual map services from which visual Geographic Information System (GIS) and VR navigation services have emerged. The visual GIS incorporates VR and AR technologies to turn the geographic environment into a 3D GIS; the VR navigation services serve as a virtual guidance service using VR technology, built upon the foundation of the visual GIS. Among the top one hundred university libraries in the United States, 48 percent offered virtual map services. More specifically, 45 percent provide visual GIS services, 19 percent provide VR navigation services, and 16 percent provide both, as shown in Figure 5.

US university libraries offer virtual map services primarily in the form of events that allow patrons to take a virtual tour of the libraries or campus. For example, Clemson University Library offers a visual GIS service that allows a virtual tour of every part of the university in full 3D.³⁴ Brandeis University Library utilizes wearable devices—such as the Oculus and HTC Vive—to allow students to be taken anywhere on campus to virtually experience labs, as well as other places that they may not be able to reach,³⁵ as shown in Figure 6. During the COVID-19 pandemic, some universities used VR and AR technologies to conduct activities such as virtual opening ceremonies and virtual orientation when they were unable to start school offline.

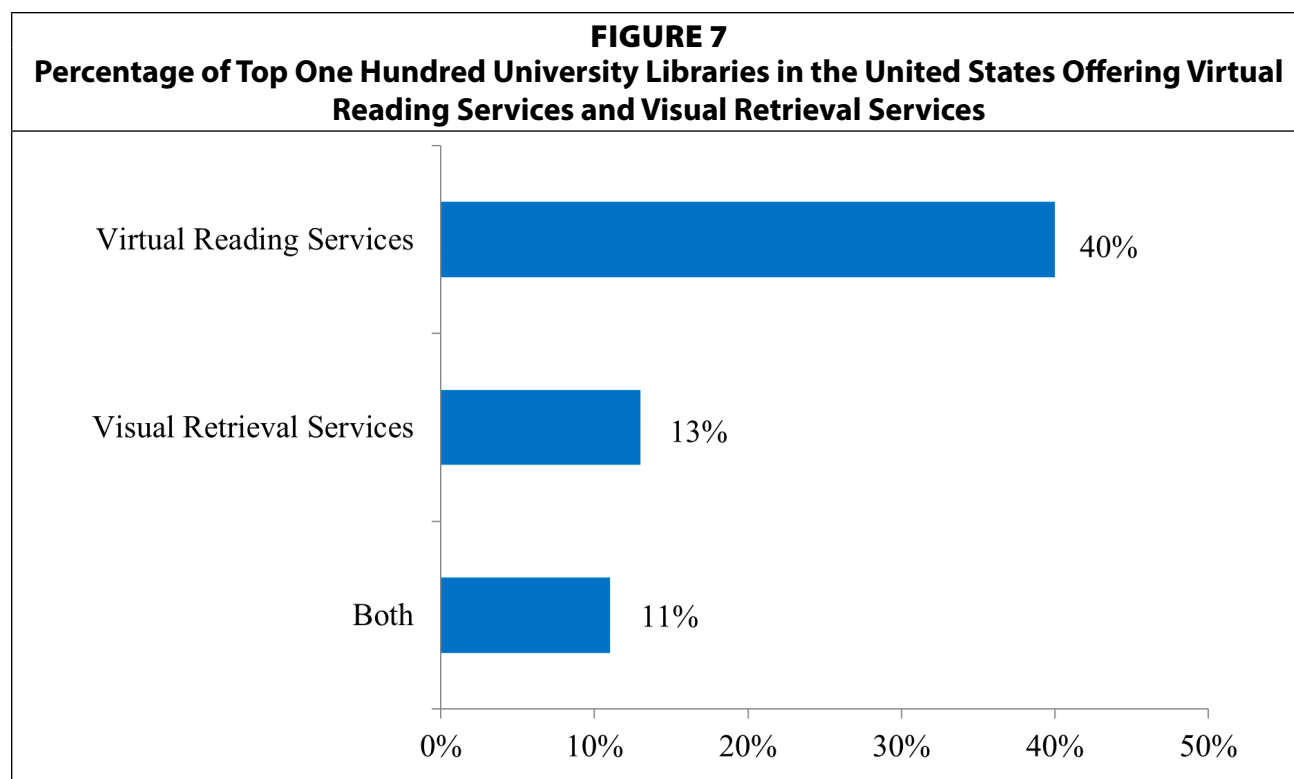
Virtual Reading Services & Visual Retrieval Services

Virtual reading services refers to the use of 3D modeling to transform two-dimensional electronic resources into 3D form so that when patrons use VR and AR devices to read electronic resources, they can get the same experience as reading physical books. Visual retrieval services improve the efficiency of patrons' access to resources by displaying the library's resource

FIGURE 6
Virtual Tour Offered by Brandeis University Libraries



catalog in 3D form through VR and AR devices. Overall, 42 percent of libraries reviewed offered virtual reading services and visual retrieval services. More specifically, 40 percent of American university libraries provide virtual reading services, 13 percent provide visual retrieval services, and 11 percent provide both, as illustrated in Figure 7.



Harvard University provides a virtual browsing function, offering the option of “shelf view” in the virtual library.³⁶ After entering the virtual library it is possible to preview the 3D model by index numbers, subject titles, library spaces, and to use this 3D virtual model to browse the documents in multiple branches. The University of Chicago Library uses AR technology to project texts from the core curriculum into public areas. For example, instructors and students selected twenty-nine excerpts from core course readings and then virtually projected these texts on the exterior walls of the University of Chicago to provide a unique course experience to the students.³⁷

VR Reference Services

Reference services—an important component of library services—have gradually evolved into visualization reference services through provided the internet and smart devices. VR reference services mainly provide visual face-to-face communication services for patrons with contactless services. Visual reference services may improve the efficiency of librarians in solving problems; however, only 31 percent of the surveyed American university libraries provided VR reference services.

Although the prevalence of libraries that offering VR reference services in this study is limited, there are some universities that offer distinctive services. For example, Berkeley Library offers virtual reference services in healthcare that enable medical professionals in the field to communicate with physicians in a more intuitive way.³⁸ The University of Washington

Library offers searches by topic or major, which matches patrons with staff members who have related expertise based on their needs, enabling one-on-one visual virtual consultations. The University of Massachusetts Amherst offers virtual media advising, facilitating virtual reference among students and faculty staff through ZOOM, a cloud-based video conferencing software.³⁹

Discussion

The researchers were surprised by the high prevalence of usage of VR and AR technologies among the top one hundred U.S. university libraries. According to the findings of the research, university libraries in the United States have made noteworthy progress in the use of VR and AR technologies, thereby creating opportunities for sustainable advancement.

The prevalence of VR/AR studios reached 64 percent in the surveyed university libraries. The construction of these innovative VR/AR spaces has brought about many new virtual library spaces and services, providing scenario support for the construction of metaverse virtual library spaces. The mature visual GIS service also provides an immersive experience for users. Activities such as virtual campus tours, or virtual library tours with high-definition panoramic roaming, will allow users to feel a strong sense of presence. Today's virtual tours also provide a practical basis for future immersive metaverse tours.

However, it is worth noting that the utilization rate of VR navigation services, VR/AR Makerspaces, and visual retrieval services is low. The practices of virtual exhibition/conference services and virtual reading services are not comprehensive, and the VR reference services need improvement. With the continuous development of technology, there is still room for improvement in university libraries. Therefore, based on the conclusions, this paper suggests that university libraries can provide support for the library construction of a metaverse in the future from four aspects: technology integration, auxiliary teaching, optimization of VR reference services, and virtual resources construction.

Promoting the Integration of Underlying Technologies

In the future, high-speed network connections will be able to support the vast number of application innovations needed for the metaverse. These applications will facilitate libraries in holding virtual exhibitions and online events using VR/AR that are realistic and immersive. Therefore, accelerating the integration of communication network technologies with VR and AR technologies should be prioritized. Moreover, a vast virtual geographic space is needed for patrons to choose and explore, which is inseparable from the role that artificial intelligence is likely to play in the metaverse-based libraries. In order to achieve the idealized metaverse-based library, the combination of artificial intelligence with VR and AR technologies is essential.

Adding Auxiliary Teaching Forms

According to the requirements of the metaverse, libraries need to be equipped with more immersive and resourceful education spaces, where patrons can digitally access a "twin model" of the physical education environment. In these virtual education spaces, patrons will be able to engage in immersive learning services based on virtual scenarios. Additionally, libraries may leverage the powerful cloud computing capabilities to import the visualized resources into the virtual education assistant and then save them to the intelligent data warehouse in the cloud, making it easier for patrons to access educational resources.

Optimizing Reference Services

VR/AR technologies could optimize reference services. For example, when patrons are seeking services, libraries could employ AR technology to make various services appear in front of them and then recommend additional related services based on their needs. When a patron's demands cannot be met, the libraries could set up a virtual one-to-one reference portal where the patron can have a real-time face-to-face interaction with an online librarian. When patrons have trouble finding resources, they could use remote help, where they would use wearable devices to summon librarians who could quickly retrieve the resources they need, and provide feedback so that patrons can find information resources more quickly and accurately next time.

Accelerating the Construction of Virtual Resources

There are two types of resources in most university library collections. One is the traditional print collection, which includes valuable original books, popular items, books that have become obsolete due to age, ancient books, and feature literature. The other is the university library's digital resource collection, which is likely to include databases and access to e-journals, e-book resources, and more. With a shift towards more digital resources, libraries could create virtual models to form virtual collections resources for teachers and students to query and read. Eventually these physical and virtual resources might be converted to a 3D format through VR/AR technology, while VR/AR devices may be used for daily activities such as children's picture book reading, online meetings, and multi-modal literature retrieval.

Conclusion

In order to understand the application of VR/AR technology in US university libraries we qualitatively and descriptively analyzed the website content of the top one hundred university libraries in the US. The results of the study show that there have been some excellent cases and practical applications of VR/AR application in American university libraries. These applications include helping teaching innovation in colleges and universities, improving the level of library subject services, and creating an immersive digital reading environment. However, the current application of VR/AR technology is still not widely popular at present, and the application of some specialized technologies appears slightly rough and homogenized. At the same time, this study was not verified by field visits due to geographical constraints, and the actual application of VR/AR technology may slightly deviate from the research results. The real-world application of VR and AR is rapidly changing with the continuous upgrading of library websites and media channels. With the maturity of technologies such as AI and Metaverse, the future of university libraries will usher in a new digital era. Students will be able to visit historical sites and conduct experiments to enhance their learning through virtual reality. The metaverse will break the limitations of geography and time, allowing people to explore and create freely in virtual space. The development of artificial intelligence will further promote the innovation and integration of technology. We look forward to this future full of opportunities and challenges, and together we will explore the infinite possibilities of digital libraries.

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