Virtual Reality and the Academic Library of the Future

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Introduction

Virtual reality (VR) and 3D scanning technologies are poised to expand the academic library's mission by enhancing access to information resources and providing new analytic tools that enhance understanding of spatial information (e.g., artifacts, spaces, molecular structures, architectural designs, etc.) (Cook and Lischer-Katz 2019; Lischer-Katz, et al. 2019). Using interfaces that engage the user's body more fully than typical mouse and keyboard configurations, these technologies promote "embodied understanding," a type of engagement with information resources that can promote learning and research in new ways (Cook 2018). These emerging tools enable researchers and students alike to engage with digital surrogates of physical artifacts in a way analogous to how eBooks and journal databases have expanded access to collections of texts and other traditional two-dimensional materials.

Recent VR prototypes and related 3D data types, deployed at academic libraries and in laboratories around the world, have shown the potential for these new technologies to function as research and instructional tools beyond the uncritical promotional hype of technocratic discourse (e.g., Lischer-Katz, Cook, and Boulden 2018; Pober and Cook 2016; Pober and Cook 2019). In this paper, we will first contextualize 3D/VR within the intellectual history of immersive media technologies, describe cases of technological innovation using 3D/VR technologies in academic library contexts, and finally, drawing on the previous sections, offer predictions about the role played by 3D/VR in the library of the future, in particular, describing areas in which libraries can serve as global leaders.

Briefly, VR technologies combine immersive and interactive interfaces with stereoscopic sound and image to produce the impression of being physically present in virtual environments among simulated phenomena (Bowman and McMahan 2007). In its most idealized form, VR would provide stimuli for all of the human senses, recreating all sensory aspects of human experience, including smell, taste, and the range of embodied sensations, fully transporting users to simulated worlds. Contemporary head mounted displays (HMDs), which comprise the VR hardware that most end users today are familiar with today, are defined by their ability to track head and body movement while re-creating a sense of depth perception via stereoscopic displays (two mini-video screens arranged in the headset direct slightly different images to the user's left and right eyes). Examples of these popular, affordable HMDs include the Oculus Rift, the HTC Vive, and the various Windows Mixed Reality headsets offered by manufacturers including Samsung, Acer, and HP.

The other side of VR technology is the content, which may take the form of 3D models, 360 videos, or other forms of data captured from the world or created in the design studio (see Lischer-Katz 2020 for a discussion of 3D/VR formats). 3D content includes scans of archaeological objects and cultural heritage sites, as well as computer generated 3D visualizations, such as complex protein structures and weather simulations, and hand-modeled 3D designs. 3D models of all sorts are becoming widely accessible through online hosting platforms, including commercial platforms such as Sketchfab[1] and academic platforms such as Morphosource,[2] and they are being increasingly incorporated into teaching and research in K-12 and higher education. As 3D and VR become more widely used in educational and research contexts, libraries are taking the lead in providing access for a diverse range of users and for

[1] http://www.sketchfab.com
[2] https://www.morphosource.org

curating and preserving these complex new information resources for a variety of present and future uses and users (Hall, et al. 2019; Lischer-Katz 2020; Lischer-Katz, et al. 2019).

In light of these trends of increasing adoption of 3D/VR in libraries, it is important to understand the emergence of VR technologies within the history of other immersive media technologies in order to ensure that they are incorporated into library services and resources in ways that support fundamental library values. This requires developing a critical discourse around technologies at the time of their adoption that considers the historical context of VR so that librarians can avoid uncritically importing the epistemological assumptions and cultural biases of the technologists who designed them. The field of media studies has widely understood that media technologies are never neutral conduits of perception. For instance, film and media historian Brian Winston (1996) has pointed out how early Kodak color film systems privileged Caucasian skin tones in their design.

Moreover, as information professionals committed to the ALA Code of Ethics, librarians must ensure that these new technologies serve all library patrons and do not directly or indirectly erect new barriers to accessing the most current information resources. Specifically, Article 1 of the ALA Code of Ethics specifies that librarians should "provide the highest level of service to all library users through appropriate and usefully organized resources; equitable service policies; equitable access; and accurate, unbiased, and courteous responses to all requests."[3] The following brief genealogy of immersive media technologies will provide the grounding for a critical engagement with emerging library technologies that is in dialogue with these library values.

A Brief Genealogy of Immersive Media Technologies

[3] http://www.ala.org/tools/ethics

The human desire to inhabit imaginary worlds predates the current interest in virtual reality (VR) technologies. If we stretch the definition of "immersive media," we could even trace the birth of VR to early fireside storytelling, in which flames and tales presented orally were the first multimedia experience for humans. We can follow the development of techniques for producing immersive experiences through the elaborate history of storytelling and theatre, as humans have long desired to inhabit imaginary lands and virtual worlds fashioned through the various arts and sciences available at the time. In the modern era, two intellectual trends have been particularly instrumental in the conceptual development of what we today call "VR": the rationalization of physical space through geometric projections and measurement, and perceptual research and the quest for verisimilitude.

The Rationalization of Space

The development of three-dimensional digital technologies is based on the rationalization of physical space. 3D data is derived from measuring the world (typically using optical or radiation-based devices, although sounds waves have also been used) and this process depends on breaking space down into standardized units that can be precisely measured with reliable instruments.[4] The rationalizing of space has historically been used to support bureaucratic state administration and imperialist action (Damerow 2016).[5] It is telling that the first applications of 3D data collection techniques served surveying, mapmaking, and military purposes. A popular

[4] The epistemological foundations for these techniques can be linked to broader trends in Western society, including the rise of quantification as a dominant mode of thinking emerging in the early modern period, or in the words of Alfred W. Crosby (1997), "a new way, more purely visual and quantitative than the old, of perceiving time, space, and material environment" (p. 227). To emerge, the rationalizing of space relied upon a system of equally spaced intervals (e.g., the Cartesian coordinate grid), precise means of measurement and a science of metrology that could cross cultures and geographic boundaries (Wise 1997), standardized units of measurement (Alder 1998), and conventions of trust, i.e., belief in the veridical and objective status of the numeric representations that scientists produced (Porter 1996).

[5] Effective bureaucratic administration relied on a constellation of techniques and technologies, including "the creation of permanent last names, the standardization of weights and measures, the establishment of cadastral surveys and population registers, [and] the standardization of language and legal discourse" (Scott 1998, p. 2).

technique of today for constructing 3D models, *photogrammetry*, was developed in the mid-19th century for surveying and measuring large geological and architectural features (Luhmann, et al. 2014). Photogrammetry uses a set of photographs (today these can number in the hundreds or thousands) produced by cameras that are systematically positioned and calibrated to produce accurate measurements of things in the world.[6] See Figure 1 below for an example of a 19th century patent for an airborne photogrammetry technique using hot air balloons. These techniques of measurement emerged within discourses that framed the physical properties of the world as calculable and knowable via geometric functions (Schemmel 2016) and optical technologies (Crary 1990).

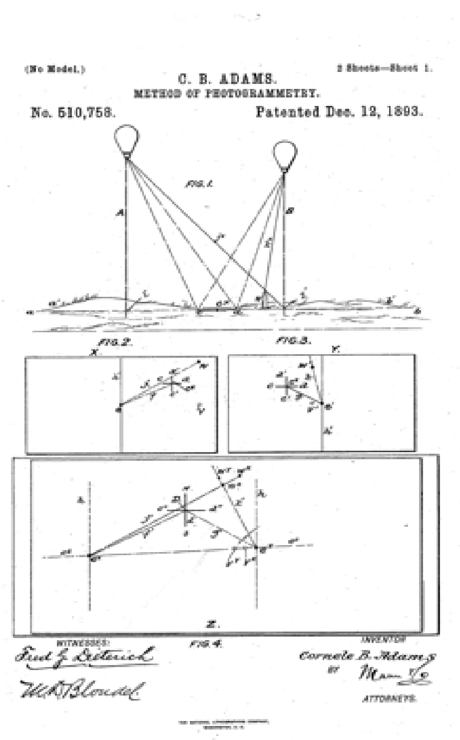

Figure 1 - Photogrammetry Technique via Hot Air Balloon by O. B. Adams (1893). Source: U.S. Patent Office

[6] It became clear early in the development of photographic technologies that photographs could be used as measuring tools if the scaling ratio of the photographic image to the profilmic space was calculated. This enabled the calculation of accurate x,y coordinates (well suited for measuring architectural facades, along horizontal and vertical axes). French military officer, Laussedat began experiments with photogrammetry as early as 1849 (Luhmann, et al. 2014).

The movement towards scientific abstraction and measurement had early analogs in conceptions of vision, as promoted by Renaissance painters, such as Leonardo da Vinci, who broke the visual world up into geometric abstractions in order to make them more amenable to painterly visualization (Mitchell 1992). W.J. Mitchell (1992) argues that this type of geometric thinking as a technique for spatial rendering is rearticulated in the calculations of the digital computer: "The numerically encoded geometric models that are stored in computer memory and transformed into perspective views may be conceived and organized as collections of zero-dimensional lines, two-dimensional surfaces, three-dimensional solids, or combinations of these" (119-121). The Renaissance conception of space as reducible to geometric primitives is thus still operative in today's approaches to perspectival representation in digital systems. In addition, Leone Battista Alberti's perspectival system of vertical and horizontal lines, which constructed perspectival space as measurable and recordable for artists, reemerges as the "grid," which acts as both a tool and metaphor for the structure of modernist epistemologies. Elizabeth Patterson (2007) links the grid of painting and natural philosophy with the military-industrial systems of command and control and weapons systems: "The grid is a process of systematization. It orchestrates a reorganization of the image on the level of representation, dividing the image into minute units, segmented and modular—an organization seemingly outside the constraints of subjective perception. Based on sampling and quantization, it assumes that representation takes place through precise numeric values rather than steady gradation" (143). Imposing the regularity of the grid onto the spatial information of the world around us enables precise calculations of terrestrial phenomena and structures, which has been most clearly and expertly deployed through the systematic coordination of state action from a distance. We can see the rationalization of space most vividly today in the birth of drone warfare, whereby military craft are directed via databases of satellite and radar data towards human targets who appear to distant operators as grainy clusters of light flickering across grids of video screen pixels. We need to ask, to what degree do VR and 3D technologies reproduce these systems that have historically rationalized space and made it amenable to command and control and other mechanisms of power?

Perceptual Research and the Quest for Verisimilitude

Beyond modern representational systems that rationalize space, VR and 3D technologies also emerge from trends in modern perceptual research that conceptualizes the human visual apparatus as a manageable set of inputs, outputs, and signal processing systems. Understood as signals, perceptual stimuli can then be produced by artificial processes, producing simulations of real world experiences. From this perspective, if they are sufficiently close to real world experiences, the simulations could become indistinguishable from real world phenomena for a human perceiver. Perceptual research has been based on modern scientific models of perception, which have shaped the information and communication technology used to encode, store, and transmit perceptual information, again, often for military or state purposes. For instance, the history of MP3 audio compression format, as outlined by Jonathan Stern (2012) is entwined with earlier perceptual research that involved dissecting the ears of living cats in the late 19th century and was motivated by the need for transmitting more signals over the limited bandwidth of telecommunication networks. The correspondence that this type of research established between biological systems of perception and electrical signals paved the way for the scientific conceptualization of the entire human sensorium as composed of an array of sensory inputs (Crary 1990). After the development of high-fidelity sound and image recording technologies in the early 20th century, the next step was to synchronize and present these signals together in order to replicate all of the sensory dimensions of human perception.

While methods of visual depiction and the invention of visual devices predate theories of perception, the era of modern scientific development saw increased efforts to capture "true-to-life" images of the world.[7] This quest for verisimilitude parallels the scientific rationalization of visual, aural, and haptic perception. Media historian, Jonathan Crary (1990) has shown how discourses on optical devices, such as the camera obscura and stereoscope, articulate 19th century ruptures from earlier models of vision, by reconstructing the "dominant model of what an observer was in the nineteenth century" (7). Through an analysis of the material practices and technological tools of vision, assumptions about the nature of vision and the notion of the observer can be reconstructed within networks of historical artifacts and discourses. Within these trends we can place a series of 20th-century visual technologies that have moved, haltingly and often retrogressively (e.g., sixty years of low-resolution, "standard definition" broadcast NTSC television is not an abnormality), towards increasing verisimilitude.[8] From 3D and widescreen cinema (e.g., *This is Cinerama!* released in 1952), to efforts at "smellovision," to theme park rides, etc., complex spectacles have been engineered that immerse the viewer and attempt to transport them to "another world." Experiments, such as Ivan Sutherland's "Sword of Damocles"

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[7]For instance, the 19th century thaumatrope, a spinning disc that superimposes two discrete images has been traced back to prehistoric times, given new archaeological evidence. http://www.dailymail.co.uk/sciencetech/article-2207596/A-night-pictures-caveman-style-Prehistoric-artists-used-cartoon-like-techniques-make-paintings-move.html

[8] This is not to say that the "quest for verisimilitude" is the dominant logic shaping the development of media technologies. Verisimilitude as an ideal to strive for in the development of media technologies has been inconsistently articulated in media discourse, often at odds with other discourses. High-definition television, for instance, took 30 years to go from prototype to widespread adoption (Winston 1996). Furthermore, Jonathan Stern (2012) is quick to point out that the highly successful MP3 audio format defies the assumptions of the "quest for verisimilitude," showing instead that the success of this media format depended on other logics, such as how easily the MP3 file could be shared across computer networks and the evolving practices of media circulation and consumption that developed around it.

device that he developed in 1968, can be seen as a precursor to today's approach to VR in which a single user wears an apparatus that replaces sound and vision from their environment with the stimuli of a simulated world. This vision of VR almost became widely available in the 1980s and 1990s with a failed attempt by the consumer electronics industry to bring VR to the consumer market.[9] At the same time, researchers in higher education were experimenting with other techniques, investing their time and money into very expensive, room-sized VR systems, such as CAVEs (Cruz-Neira, Sandin, and DeFanti 1993), in which multiple users engage with the VR technology simultaneously. Ongoing trends in decreasing cost and increasing computer graphics processing power have brought VR back into the mainstream, reigniting debates about the benefits and risks of using VR to enhance human knowledge and experience (Bailenson 2018; Lanier 2017).

Taken together these histories of 3D and VR technologies can be seen to construct a new visual subject for the 21st century, one who is both centrally incorporated into technological systems (e.g., imagine the VR user with the headset fully engulfing their head) and yet is also kept at a distance from what is actually happening inside those systems (e.g., the fact that machine learning produces its own computer code that computer scientists often have no way of interpreting). Perceptual research and the quest for verisimilitude construct this new visual subject as split between, on the one hand, the imaging system, computer storage and processing/display algorithms, and on the other, the human observer, for whom data must be presented in a way that accounts for human perception and psychology. These trends can easily lead to "views from nowhere" that privilege machine vision over human perspective. W.J. Mitchell (1992) explains how 3D models are produced for various purposes that often leave

[9] For a brief history and prehistory of VR headsets, see Campbell (2017).

behind the human observer: “It may or may not be the case that the perspective station point corresponds to that of an actual observer or recording instrument. Sometimes the point of image synthesis is to get the image to match the world, sometimes it is to get the world to match the image, sometimes it is to predict what the world will be like at some moment in the future or to show what it might have been like if history had taken a different turn, and sometimes it is just to produce a convincing portrayal of a purely fictive place” (118-119). Thus, we may ask ourselves, are we creating new knowledge that enables humans to understand the world, or *views from nowhere* that privilege disembodied and disconnected subjects?

The Return of VR in Academia

Having established the historical trends that have shaped 3D and VR, we can turn to recent developments in the field and see how they might impact libraries and other academic contexts. Beginning with the Kickstarter-funded release of the Oculus Development Kit I in the Spring of 2013, inexpensive and user-friendly immersive visualization hardware has steadily entered the mainstream.[10] In addition to popular enthusiasm within the video gaming community, VR technologies are seeing renewed and growing interest in academic contexts. Technology that was once confined to research laboratories is now available for use by consumers and academics. These HMDs (head mounted displays) are far more affordable than the room-scale visualization systems that were once considered the cutting-edge equipment for VR research in the academy (e.g., CAVE systems). Academic libraries are providing access to VR in newly-created makerspaces and digital scholarship centers, and through check-out services at library circulation desks. In an increasing number of colleges and universities, a broad range of stakeholders - including graduate and undergraduate students, research faculty, and library staff - have easy

[10] https://www.kickstarter.com/projects/1523379957/oculus-rift-step-into-the-game

access to head-tracked, stereoscopic viewing hardware that provides the means to readily engage with 3D content for the purposes of enhancing research and learning.

Scholarly Applications and Benefits of VR

Researchers and students in disciplines concerned with spatial data are already finding uses for VR in their work. For example, in 2002, a team of archaeological researchers discovered new relationships among 250,000 components of a 3D-modeled excavation site by viewing the entire site in VR (Dam, et al. 2002). More recently in 2018, the Cancer Research UK Cambridge Institute started developing a highly detailed visualization of cancerous tumor growth for the purpose of understanding the spread of individual cancer cells.[11] VR and 3D content are also being used for research purposes in medicine (e.g., Anderson, et al. 2015), architecture (e.g., Portman, Natapov, and Fisher-Gewirtzman 2015), geology (e.g., Donalek, et al. 2014), and cultural heritage preservation (Bozorgi and Lischer-Katz 2020).

Research has shown how the capabilities of VR to immersively present spatial data can benefit a range of disciplines and tasks. In engineering fields, for example, researchers have explored the benefits of immersive visualization on product prototyping, enabling the identification of "assembly-related problems such as awkward reach angles, insufficient clearance for tooling, and excessive part orientation during assembly" (Seth, Vance, and Oliver 2011). In the field of architectural design, students who were able to virtually inhabit and navigate through their design solutions during the design process were found to be more likely to achieve a higher final project score (Angulo 2013). Students in interior design courses may also benefit from using VR when designing spaces, with research suggesting that using VR for design can support "scale perception, error recognition, and communication" activities (Pober and Cook

[11] This research is ongoing, and more information can be found here: https://www.cruk.cam.ac.uk/research-groups/imaxt-laboratory

2019). Finally, neurosurgeons who worked with interactive, 3D monitors that employed stereoscopic depth cues were found to improve on their skills necessary for analyzing and evaluating vascular structures compared with neurosurgeons using 2D screens (Kersten-Pertel, et al. 2014). These examples show the broad applicability and range of immersive benefits of VR technologies for research fields that rely on spatial analysis skills.

These widespread benefits of VR are linked to the technology's capability to simulate real-world depth cues and provide a highly immersive interface, which traditional computing platforms (i.e., mouse, keyboard, and monitor workstations) are incapable of rendering (Donalek, et al. 2014; LaViola, et al. 2017). Ragan, et al. (2013) found that under controlled conditions, "participants performed significantly faster when the display provided both stereo and head-tracked rendering" when presented with small-scale spatial judgement tasks (895). By providing enhanced visual information through stereoscopic depth rendering and embodied interactions via headtracking and other sensors, VR has been shown to augment the analytic and pattern-recognition capabilities of human perception. Many of these studies emerge from the fields of electrical engineering and computer science, but recent research has sought to replicate the associated benefits in teaching and learning environments, with particular work being conducted in the context of academic libraries (e.g., Lischer-Katz, Cook, and Boulden 2018).

Virtual Reality in the Academic Library

VR is re-emerging at a time when academic libraries are changing how they allocate their scarce resources. They are quickly shifting their focus from traditional collection development to the establishment of centralized, collaborative workspaces and technology-oriented service centers (Massis 2010). In the era of comprehensive online databases of journal articles, Google Scholar, and other online discovery and access portals through which much of the universe of contemporary peer-reviewed research literature is now instantly available, researchers are rarely visiting academic libraries for the purposes of solely locating secondary source material (Dewan 2012; Turner, et al. 2013; Van Orsdel and Born 2002). Instead, scholars are relying on academic libraries to provide meeting spaces, specialized computer software and hardware, research data management, digital scholarship support, and a range of other research and teaching services. Recognizing this shift in usage, academic libraries are investing in research and development initiatives that aim to provide new services and technologies, including virtual reality, to further support research and teaching (German and Namachchivaya 2013; Saunders 2015). VR stands out among these new services because it can impart special analytic and teaching benefits, while providing access to important 3D research data that researchers are creating at an increasing pace.

Because academic libraries function as centralized hubs for scholarly activity and must be discipline-agnostic, serving patrons from all research fields, they have the potential to be effective sites for hosting VR for a range of users (see Figure 2 for an example of how VR is being used to support student learning at the University of Oklahoma Libraries). By centralizing VR technology in the library, myriad academic units can readily access VR hardware without taking on the added operational overhead associated with staffing, maintaining, and upgrading rapidly evolving technological systems (Cook and Lischer-Katz 2019). Moreover, libraries themselves are starting to function as research sites in which the impact of VR on research and learning can be studied. Thus, academic libraries can serve as an “intermediary deployment zone," a centralized location through which to expand access to the documented benefits of VR to all disciplines through research and development activities.

Figure 2 - Students Using Virtual Reality Equipment at OU Library's Innovation @ The Edge

Case Study of VR Deployment in an Academic Library

The effectiveness of VR as a teaching tool in higher education is quite promising, but there remains a lack of research that systematically evaluates the benefits of VR in naturalistic settings, i.e., outside of controlled laboratory settings. In 2017, researchers at the University of Oklahoma (OU) Libraries conducted a study to see if the documented benefits of VR found in laboratory studies could be transferred to a learning activity integrated into an introductory-level anthropology class (Lischer-Katz, Cook, and Boulden 2018). In the study, undergraduate students who were enrolled in an introductory anthropology course were given an extra credit assignment that made use of digital surrogates of fossilized hominid skulls deployed in virtual reality. Researchers worked closely with the faculty member to design a classroom assignment that would support course learning objectives by engaging students in analytic tasks designed around the documented benefits of VR, including identifying, comparing, judging, and counting elements of the hominid skull models.

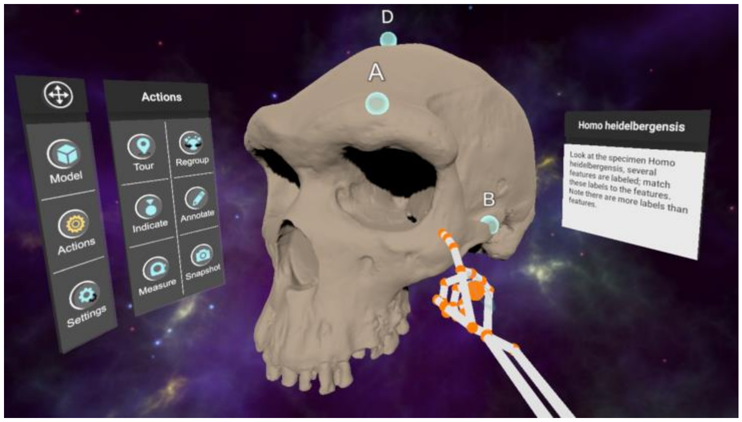

Figure 3 - Anthropology Student Engaged in the VR-based Course Assignment

Following the VR activity (see Figure 3 for a screen capture of what these anthropology students saw during the activity), the students reported higher degrees of self-efficacy with regards to their ability to perform discipline-specific activities associated with spatial navigation and identification of fossil specimens, indicating the benefits of VR as a means of supporting students as engaged and empowered learners.

In this example, VR also enabled the library to provide wider access to the anthropological specimens, since the existing physical skull replicas are too costly to provide for all of the students in the class. This supports existing research on 3D models that shows how they can enable digital access to physical specimens that are otherwise too distant, fragile, or rare to be handled directly (Limp, et al. 2011). This study was designed based on earlier research conducted by Laha, et al. (2014), which examined the impact of VR on participants' ability to quickly and accurately complete spatial tasks, with the goal of identifying "abstract task categories cutting across various scientific domains" (521). Participants in the Laha, et al. (2014) study consisted of a mixture of 56 undergraduate and graduate students, each with no previous experience analyzing volumetric (i.e., 3D) data sets. Findings suggest that VR improved participants' speed and accuracy in completing spatial analysis tasks, and it seems likely that these benefits may be transferable to other disciplines that work with spatial materials. The results of these studies suggest that VR has the capacity to enhance students' spatial analysis abilities in a range of disciplines. Furthermore, by carrying out empirical research on VR in an academic library context, researchers at OU Libraries have shown the potential for expanding the role of the academic library into the future as a fruitful site for research and development that helps to establish and expand innovative, VR-based research tools.

Major Trends Shaping the Future of VR in the Library

The future of VR in the library will be shaped by three major trends currently unfolding: the rise of ubiquitous 3D/VR hardware; the development of vast collections of 3D assets; and the extension of traditional library discovery services through techniques of virtual browsing.

Ubiquitous Hardware

Futurists expect the uses of VR in everyday life and in academia to become less exotic and increasingly mainstream as VR technology diffuses throughout all sectors of society and becomes ubiquitous and potentially "disruptive." Co-founder of *Wired* and prolific futurist, Kevin Kelly (2017) situates VR at the end of a chain of widely disruptive technologies that we take for granted today, suggesting

> the first technological platform to disrupt a society within the lifetime of a human individual was personal computers. Mobile phones were the second platform, and they revolutionized everything in only a few decades. The next disrupting platform - now arriving - is VR. (231)

This statement anticipates the coming ubiquity of VR hardware and draws parallels between the rise of virtual experiences and other once innovative technologies that have since become ubiquitous, such as smartphones and laptops. In spite of the dominant role played by the video game industry in its development today, VR now has the potential to become more than just another gaming platform. Rather, it is a fully interactive digital environment wherein the embodied user is able to engage with digital content in ways that more closely resemble how humans interact with physical objects in the real world (Prabhat, et al. 2008).

Unlike traditional computer interface paradigms that rely on limited interface mechanisms often abstracted from intuitive bodily motions (e.g., clicks, swipes, etc.), VR makes full use of the embodied sensorimotor and proprioceptive capabilities of human beings (Stern, Wachs, and Edan 2008). This type of high-fidelity immersion - i.e., an increasingly seamless linking of digital content and the human perceptual system via embodied interfaces - has profound implications for the future of academic libraries and their collections, especially as libraries begin to adopt 3D scanning technologies and host 3D data sets (Lischer-Katz, et al. 2019). However, as VR technologies become as common as smart phones and laptops, and on-site access to library collections becomes an underutilized library service, libraries will need to continually assess how to remain relevant in this evolving technological field, while staying true to their professional ethics.

Given their developmental histories outlined earlier, VR and 3D technologies also run the risk of contributing to growing inequality in access to technologies for underrepresented groups. These technological trends raise ethical questions about how libraries will effectively support disabled and other underrepresented users who want to use these new complex devices, which make assumptions about the perceptual and physical capabilities of the user. In the short-term, libraries will continue to provide access because the cost and complexity of VR systems is currently limiting VR diffusion among the consumer market, and this equipment should be accessible to all users, following accessibility standards.[12] Existing accessibility standards are not

[12] The Web Content Accessibility Guidelines (https://www.w3.org/WAI/standards-guidelines/wcag/) maintained by the W3C Web Accessibility Initiative offers specifications for designing digital resources with accessibility in mind.

designed with VR in mind, so additional library research will be necessary in this field to ensure that VR is fully accessible to users with a range of perceptual and physical abilities (Clark and Lischer-Katz 2020).

Growing Vast Collections of 3D Assets

One area where the future of VR technology and the mission of libraries significantly overlap is the development of collections of scholarly 3D content. The size and scope of digital 3D asset collections is growing in parallel with the development of VR hardware and software. For instance, in July of 2018, Sketchfab - a commercial, community-based online hosting service for 3D content - surpassed 3 million individual models, rivaling the scale of the physical collections held by cultural heritage institutions.[13] Currently, only a small portion of these models consist of scholarly content that is produced in documented and transparent ways or is presented with the necessary metadata to ensure academic rigor and citability; however, more and more cultural heritage institutions, especially museums, are making selections from their collections available to encourage public engagement (Boyer 2016). Sketchfab currently supports easy web-based viewing of 3D models in low-cost portable VR headsets (like the smartphone-based Google Cardboard) without requiring the user to download additional plugins or invest in expensive visualization hardware, which is encouraging wider adoption of the platform. This publicly accessible 3D platform, while lacking the academic rigor of a curated, scholarly collection, effectively demonstrates the scalability of networked, VR-ready 3D asset collections.

Academically-oriented 3D asset collections are also being developed individually within specialized disciplines. Consider Morphosource, an online repository dedicated to collecting morphological data sets (e.g., fossils) from fields like archeology, paleontology, and

[13] https://blog.sketchfab.com/over-three-million-3d-models-online/

anthropology.[14] Unlike Sketchfab or other commercial platforms, Morphosource tracks specimen metadata, assigning a unique accession number for each upload to the site and linking each digital specimen back to the originating physical specimen. Making large sets of digitized scientific specimens available online provides ready access for many scholars to study the same specimens simultaneously. Making data sources publicly available helps to ensure transparency and reproducibility of research findings, such as those drawn from the measurement of fossil features, through the use of citable, persistent identifiers. When combining the large scale and ease-of-access provided by commercial platforms with the academic rigor of discipline-specific online repositories, it becomes easy to imagine future library collections that will contain vast quantities of well-curated scholarly 3D models.

Virtual Browsing

VR also has the potential to shape the library of the future in terms of the ways in which patrons access traditional library collections. Consider the value of embodied browsing activity in the physical book stacks. Serendipitous information retrieval, or “the chance encountering of information,” has been shown to benefit early-stage research and instruction, compared with common query-based search and retrieval paradigms (Foster and Ford 2003). A significant amount of potentially salient source material can be parsed efficiently in the physical book stacks by simple, intuitive body motions like craning the neck, bending down, or turning one’s head. Each of these natural search behaviors can be replicated in virtual reality, which means that collections can be browsed and analyzed without needing to first learn the special keyboard combinations or software-specific interfaces necessary for using computer-based catalogs and other retrieval systems. As book collections are increasingly moved to off-site storage, academic

[14] https://www.morphosource.org/

libraries can maintain their capacity for rich information discovery by providing virtual browsing through VR (Cook 2018).

Virtual browsing in VR can also transcend the physical arrangement of the traditional library. The presentation of 3D assets in a virtual browsing environment need not be limited to mimicking the library stacks and reproducing their limitations as physical arrangements of books. Instead, perceptual cues developed in the field of data visualization, such as the use of semi-transparency, “fog,” edge depiction, and other visual indicators, may support the display of scholarly materials beyond the typical bibliographic plane - i.e., the physical library stacks with their grids of book spines as access points - to include the depth axis (z-axis) of the visual field, differentiating the relevance of search results based on visibility and the placement of resources in the background or foreground (Kersten-Pertel, et al. 2014). Multiple layers of 3D models can be deployed simultaneously in VR, and users can make use of embodied locomotion (e.g., walking) to navigate through content in every direction in infinitely expandable space (Cook 2018). These approaches have great potential for making library collections more accessible to groups such as children and disabled users who would otherwise have difficulty navigating the physical stacks, as the flexible interfaces of VR can be adjusted based on relevant human ergonomic factors. Through different combinations of sound, image, text, and haptic feedback, browsers of all abilities can be provided customized interfaces for navigating the stacks. Thus, virtual browsing in VR has the potential to expand upon traditional library services, maintaining the relevance of libraries and expanding their mission of equitable information accessibility to formerly excluded groups of patrons.

In summary, if VR follows the same adoption curve of personal computers and smartphones, and 3D digital asset collections continue to grow through streamlined, academically rigorous digitization processes, then - as is the case with virtual browsing - VR and 3D technologies will begin to shape the overall academic library experience.

Conclusion

What, then, will be the role of librarians and libraries in a world where everyone has their own virtual reality headset and ready access to vast 3D collections instantly accessible online? Given these current trends, we expect that VR hardware will be as ubiquitous as the smartphone and that the library will become responsible for the organization, preservation (see: Lischer-Katz 2020), and accessibility of 3D digital collections of scholarly content. Rather than merely caretaking a storehouse for 3D models and other VR-ready content, librarians in the future will be working alongside scholars across the disciplines to actively support research and instruction by developing new and more sophisticated applications that make use of the specialized features of VR. Academic libraries and librarians will one day oversee an entire 3D/VR research ecosystem that supports the full research lifecycle of 3D creation, analysis, publication, and curation (Limp, et al. 2011).

3D and VR offer powerful tools for providing access to highly-detailed simulations of things, places, and events in real, imagined, or reconstructed worlds,[15] such that future research may be primarily based on digitally captured 3D data, rather than on direct physical contact with the things in themselves. Furthermore, the library of the future will have to support the research lifecycle of these new forms of data and provide access to them using rich, immersive technological platforms, such as VR, as well as augmented reality (AR) and “mixed reality” technologies which blend a user’s perceptions of virtual spaces and objects with material aspects of the world.

[15] For an example of a reconstructed VR project, see Bryan Carter’s *Virtual Harlem* project (Park, et al. 2001).

At the same time, past experiences with visual technologies in Western contexts suggest the ways in which visual technologies can embed the epistemological and cultural assumptions of their creators in the form of assumptions about the nature of perceiving subjects, leading to exclusions in terms of the types of knowledge that can be produced and the range of knowing subjectivities that can be supported (e.g., excluding indigenous knowledge and conceptions of space-time, See Smith 2012). We certainly do not want to recreate the inequalities and exclusions, dominant worldviews and power dynamics that plague scientific epistemologies from earlier eras; nor do we want to recreate the corporate boardroom in VR and the visual signifiers of global capitalism that Robert Markley (1996) warned of during the first wave of virtual reality in the 1990s.

Furthermore, Bahrat Mehra (2015) cautions against libraries and library systems becoming “nothing more than mere tools to support political and corporate control that furthers a hegemonic agenda” (181). Instead, Mehra (2015) suggests a balance of social idealism and pragmatic realism, arguing that “aspects of the business model (e.g., outcome-based assessment, efficiency, user-centric services) have their place in library and information enterprises, but it is important not to forget the spirit of the social justice mission, which is to design systems and services that are equitable, meaningful, and empowering for marginalized and disenfranchised people” (181-182). Taking into account the cultural biases and corporate mentality that have shaped the development of these technologies, and taking steps to actively address them, can help to ensure that we consider the needs of traditionally marginalized groups as the library adopts VR and other emerging technologies.

Given the focus of VR technologies on the senses and the body, one glaring area that social justice sensitizes us to consider in the design of VR systems is the needs of disabled users.

Given the library's mission of providing equitable access to information resources, librarians and library researchers need to take an active role in ensuring that VR can fully support users with different abilities.[16] A team of librarians and researchers at Temple University Library, led by resident librarian, Jasmine Clark, are developing the first VR program that will be compliant with existing accessibility regulations. In their VR case study, they identified "gaps in [library] staff knowledge of basic disability, as well as in DSC [Digital Scholarship Center] service policy when it comes to providing equitable services to visitors with disabilities" (Clark 2018). In addition, the International Conference on Disability, Virtual Reality and Associated Technologies provides a forum for new research in this area, offering a source for librarians to identify the latest research on the use of VR by disabled users.[17] Librarians seeking to bring VR into their institutions need to follow developments in this field or they risk reproducing exclusions for a range of library patrons (Clark and Lischer-Katz 2020).

Given these challenges, how do librarians and their institutions move forward and act as leaders in this still nascent field? First, there is a clear need for managing, curating, and preserving VR and 3D data, and academic libraries are poised to take the lead in developing standards and best practices in this area. Second, libraries can use 3D/VR to expand access to existing library collections and services, as well as provide support for new applications, including a growing ecosystem of 3D/VR research data. Finally, new technologies need to be integrated into existing library services, while supporting the ethos of librarianship, in order to be sustainable and equitable. Librarians must closely monitor the continuing developments in the

[16] Libraries may also have legal obligations to provide equal access, under such regulations as the American with Disabilities Act, state law, or institutional policies. Guidelines for Federal agencies are codified in Section 508 of the Rehabilitation Act of 1973, https://www.access-board.gov/guidelines-and-standards/communications-and-it/about-the-section-508-standards

[17] The proceedings of this conference are available online: https://www.icdvrat.org/archive.htm Much of the research in this area is focused on using VR to benefit disabled people, particularly in terms of its therapeutic possibilities.

implementation of VR and 3D across different library communities, carry out research projects that critically interrogate the embedded assumptions of these technologies, and communicate effectively with a growing network of library researchers who are establishing the standards and best practices necessary for supporting VR in library contexts.[18]

The future of academic libraries is intimately linked to the future of emerging technologies and their application to research and teaching. In an age in which university budgets are being increasingly squeezed and academic units must continually defend their existence by demonstrating increasing "return on investment," the future of academic libraries depends in large part on the ability of librarians to adapt to rapidly evolving scholarly and pedagogical practices and the rise of ubiquitous and constantly changing digital technologies. The emergence of new types of research methods, data, and pedagogies, and the continuing centrality of the library within academic life, require libraries and librarians to lead the way in this area, adopting organizational techniques and creating new administrative units (e.g. makerspaces, digital scholarship labs, visualization labs, etc.) that foster a culture of innovation, while still staying true to the essential library values of inclusion and equitable access to all forms of information.

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[18] The library community is already taking a leadership role in the preservation of 3D and VR-related research data and learning materials. In 2018, three research projects were funded by the Institute of Museum and Library Services on the preservation of 3D data: Community Standards for 3D Data Preservation (Washington University, University of Iowa, and University of Michigan; https://osf.io/ewt2h/), Developing Library Strategy for 3D and Virtual Reality Collection Development and Reuse (Virginia Tech, Indiana University, and the University of Oklahoma; https://lib.vt.edu/research-learning/lib3dvr.html), and Building for Tomorrow (Harvard University; https://projects.iq.harvard.edu/buildingtomorrow).

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