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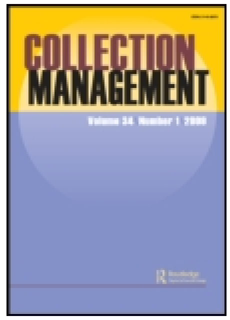

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ABSTRACT

Extended Reality (XR) introduces a new way to preserve, record, and manage content. Collections traditionally focus on content in the form of books, documents, and multimedia. XR is a new form of media that can be difficult to integrate into current collections. In addition, through linked data, we can preserve the context that surrounds the content as well. Finally, XR media can incorporate digital manifestations of items from a library collection within its application. This technology review will explore the possibilities of XR in collection management, focusing on XR as a user interface, the impact on inventory management, and digital preservation.

Virtual Reality, Augmented Reality, Mixed Reality, Extended Reality

INTRODUCTION

Extended reality (XR) is an umbrella term that encompasses Augmented Reality (AR), Mixed Reality (MR), and Virtual Reality (VR) technologies. Currently, the use of XR in libraries is more focused on public services applications like virtual tours, internal navigation, and makerspaces (Oyelude 2017; Huang et al. 2016). However, opportunities to apply XR technologies in the areas of collection management are rapidly emerging, especially as the hardware needed to experience XR becomes more accessible and devices become more affordable than ever before. As recently as three years ago, VR systems were relegated to enthusiasts with powerful computers. Today, a new generation of self-contained VR headsets are coming to market that cost as little as $200.

Major technology companies like Facebook, Apple, Microsoft, Google, and Amazon are investing in XR applications and are moving to capture market share through corporate acquisitions and the development of new proprietary technologies. Facebook recently purchased VR hardware manufacturer Oculus Rift, and Microsoft has heavily invested in the development of MR technologies through their HoloLens platform. With these leaps forward in capability and affordability come new opportunities for libraries of all types to experiment with this technology and explore how XR will impact the way our users discover and interact with our collections.

This technology review will explore the possibilities of using XR in three broad areas related to managing library collections. First, we describe the potential for using XR to enhance the discovery of library materials and to provide innovative user experiences. In section two, we explore the impact these technologies can have on inventory management and collections maintenance. Finally, we consider the implications of virtualizing library materials and extending access to library collections, especially archival materials, special collections, and items in storage that would otherwise be difficult for patrons to use.

As this is a new and evolving area, it is particularly important to first define the terms that are used to describe the interrelated technologies that make up XR. Virtual Reality (VR), a completely controlled, immersive environment, exists in computer-generated space. Augmented Reality (AR) co-exists with and overlays real-world spaces with layers of information. Mixed Reality (MR) exists in the middle of this spectrum and incorporates elements of both VR and AR. These technologies exist on a spectrum with VR occupying one end and AR the other (Milgram et al. 1995). We will refer to XR as a general term to cover the multiple types of experiences and technologies across VR, AR, MR, and any future similar areas ("Definitions and Characteristics of Augmented and Virtual Reality Technologies" 2018).

EXTENDED REALITY AS USER INTERFACE

XR makes it possible to allow the library to virtualize any physical type of interface and makes it possible to overlay a user interface onto any object. As the technology improves, we also start to see new ways to interact with technology. This section will focus on user interfaces that are being developed for XR technologies, and how they may change the way we look at collection development in the academic library. Bruce Massis in "Using Virtual and Augmented Reality in the Library" discusses some basic user interface conventions using currently available XR applications (Massis 2015).

Imagine the future access to the Library of Congress as a single room with an XR interface. A visiting student enters the room, activates the XR interface, and is immediately placed in the Library of Congress. The student, not familiar with the LOC, asks the room to retrieve his college library as his user interface. Even though the Library of Congress collection is much larger than his college library, the interface automatically adjusts to simulate the physical location so that the student can browse a familiar environment. The student starts to browse the shelves, navigating the preferred Library of Congress Classification until he finds the item he needs. In physical reality, he is still in a room, and deep beneath him is a high-density storage facility that can retrieve the user's requested object. As the borrower gets closer to the desired object in the XR interface, the automated retrieval system is getting closer to the object and ready to retrieve it. The retrieval system is preparing a shelf of items that can be delivered to the student once they are ready to checkout.

Meanwhile, the student finds the title and is now browsing the surrounding materials. As the student browses, he dynamically reorganizes the collection to the Dewey Decimal System, and then to Book Industry Subject and Category (BISAC) Subject Headings to see what other related items might be clustered together. As he does this, the virtual shelf is re-sorting itself according to each selected classification system, and the student can tap to select items he is interested in. As he adds more items to the shelf, there is an indicator in the periphery of his vision that provides a visual image of the subjects from each item being selected, represented visually as an expanding Venn diagram. When he is finished browsing, he turns his attention to the diagram and selects the overlapping area. The virtual shelf adds items from the records represented by the selected area and adds them to the end of the virtual shelf he is browsing. He quickly glances at the new titles and swipes items that don't seem relevant.

Once he is satisfied, he indicates that he would like to save and end his session. The XR interface fades away, saving his current search and preferences so that he can pick up where he left off when he returns. All that is left are the physical books, retrieved by the retrieval system, on a shelf in front of him. As the student retrieves his items and exits the room, the library and storage unit underneath switch to preservation mode, automatically switching to the optimal settings to preserve the library items.

This is just one possible future application of XR in a library setting. Although this application may still be a few years away, the individual technologies that would make this possible are already being developed. Examples include the Hunt Library bookBot at North Carolina State University that automates book retrieval, and maze-based immersive virtual environment (MAVE) which provides users with a portable walking simulator (Lee, Jeong, and Kim 2017). XR technology can compress physical spaces into a smaller footprint, relying on a user interface to simulate the space, without any physical restrictions. We may start to look at local libraries and collections as a user interface that we can bring with us, whether it is the physical space, the organization of the collection, or just personal familiarity.

THE IMPACT OF XR ON LIBRARY INVENTORY MANAGEMENT

XR shows promise for collection managers who are responsible for laborious and time-intensive inventory management activities like shelf reading, inventorying, and lost/missing item processing. XR technologies demonstrate great potential for automating and streamlining these activities which would enable staff members engaged in these tasks to focus on other higher-priority initiatives.

In 2011, Bo Brinkman and Matt Hodges of the University of Miami debuted ShelvAR. The project used spine labels that were machine readable to power **a** VR shelf-reading system. The technology was capable of finding lost and misshelved books and providing reshelving directions. The demonstration project was able to analyze a dozen books with half-inch tags. The team had plans to improve the system to handle 75 to 150 books with quarter-inch tags (Aaronson 2011).

[Insert figure 1 here]

Unfortunately, efforts to bring ShelvAR to market were impeded by existing Amazon patents (U.S. Patent and Trademark Office, 2013) and the project was ultimately suspended. This is an example of how XR commercialization has impeded development of library applications. This technology had the potential to provide a technical services solution to shelf-reading and collection management, and would have benefited library users by overlaying suggestions, identifying related items, and presenting other value-add information. This type of AR layering is available today through technologies such as HP's Reveal (formerly Aurasma). However, in most cases the layering relies on recognizing a unique visual image and a unique location.

Most library shelf-reading systems would inevitably rely on optical recognition tags printed on book spines. Reliance on such a system could be impractical as every item in a collection would need to be relabeled. In addition, some items such as children's books, are too thin to support spine labels and usually carry labels on covers. If the tag cannot be seen, it cannot be read. Another solution that is in widespread use is radio-frequency identification tags (RFID). These tags that are required for self-checkout services can also be used by shelf management systems such as Lib-Best (BookTec Information 2018) that use a scanner and base station to inventory library shelves or conduct specific title searches. Again, the disadvantage of such systems is the need to apply the RFID tags to every item in a collection. Costs for tagging existing collections vary but can easily exceed .30 cents per item ("RFID Costs, Benefits, and ROI" 2012).

AR technologies may offer other solutions to this expensive problem by utilizing sensors and existing metadata known about every item in a collection. For example, Light Detection and Ranging (LiDAR) is a technology that applies the principles of RADAR to light from a laser. LiDAR has been used in self-driving car systems for collision avoidance and navigation, used to track position and estimate size of objects. LiDAR systems have proven to be fast and reliable technology, and was recently deployed as an effective tool for archaeological surveys (Clynes 2018).

In our hypothetical AR powered future, LiDAR could be used to generate a 3D map of library shelving. That map would be a representation of the dimensions of each book on a shelf. Libraries already record a linear representation of their holdings because of the book measurement tags in the MARC record 300 fields. Combining the scanned shelves with the catalog would allow a system to identify probable missing and mis-shelved books by looking for anomalous results. The system could be made aware of checkouts, temporary locations, and other status changes that might result in missing items from shelves.

[Insert figure 2 here]

Such a system of cameras and LiDAR arrays could even be automated. Autonomous cleaning systems such as the Roomba vacuums can map out large indoor spaces using infrared sensors (U.S. Patent and Trademark Office, 2010). Such a robot could crawl the stacks sweeping the shelves with its sensors at night, looking for missing items. A report could be created detailing probable missing books for follow up by library staff. This automates the time-consuming task of shelf-reading and makes all other library processes that rely on accurate shelving more efficient.

DIGITAL PRESERVATION AND EXTENDED REALITY AS A NEW MEDIA TYPE

Cataloging print works involves describing the work and the volume it occupies, while XR requires additionally describing how to recreate the work. An entirely new vocabulary is needed to describe the object so that it can be experienced in virtual environments. Librarians need to create standards and procedures for describing this content. Various standards exist for describing print, electronic, and digital materials (AACR1, AACR2, RDA, etc.) but not for VR content. How should we describe an object's physical attributes such as texture and reflectivity in such a way that it can be re-created in a virtual environment? Can we safely ignore sensory data that cannot be recreated, such as smell? Are 'best guesses' enough?

Consider this scenario: A library wishes to re-create a copy of the first edition of The Hobbit. The book was published in 1937. We have access to extensive data regarding the manufacture of paper and binding processes from that time. We know how the paper would have aged based on fiber length and the effects of acids (Library of Congress). Is an approximation sufficient to re-create the experience of interacting with a first edition for a Tolkien scholar? XR relies on the human senses to compensate for missing information to maintain the immersive experience. The paper representation can be close enough to still provide an authentic experience.

XR still has limitations in the ability to recreate the original, but it can produce a digital surrogate that may meet the needs of a majority of researchers. In addition, digital surrogates would allow researchers to interact with materials from anywhere in the world. To compensate for XR limitations, libraries may need to create new record fields that can be used to describe the physical presence of collection items. This might include a new classification system to describe tactile feedback or visual feedback.

XR creates new ways for users to interact with digitally preserved library resources. Physical items can now be preserved beyond two-dimensional descriptions, and they can be accessed in their original contexts and forms. A good example is the Larkin Administration Building in Buffalo, NY, designed by Frank Lloyd Wright, that was demolished in 1950, and was recently recreated as an immersive digital animation (Frank Lloyd Wright Trust 2018). This could easily be adapted to a full XR application allowing anyone to experience architecture as it was originally intended, as a physical space that can be explored from within. The Theodore Roosevelt Birthplace National Historical Site also in Buffalo, NY, recently took steps using 3D scanning to recreate a VR surrogate to preserve their space (Theodore Roosevelt Birthplace National Historic Site 2017). Memorabilia can be shared across continents without ever leaving the archives of a library. Drexel University contracted with 3Dream studios to develop a repository of 250,000 augmented, virtual, and MR learning objects across disciplines, including digital anatomy models used for coursework (Gianakaris 2018).

Physical preservation often makes compromises to provide user access. An XR environment would provide a wider range of options for user access without sacrificing physical preservation standards. Items can be recorded in such a way that they can be reproduced in an XR environment for users to handle and examine without risking the degradation of the item itself. Archivists would replace their white gloves with VR gloves to process and handle archival materials, while the physical item can be sent to a secure storage facility. Libraries may also need to become an authority that provides evidence of authenticity of XR objects and media, as most digital objects may go through multiple derivatives in the wild. Just like the open access and open educational resources, libraries can be an institutional repository for XR media to protect content from being commercialized or privately owned.

CONCLUSION

XR is still a new technology, but it is already a part of our daily lives. The world is still adapting to the idea of having XR technologies in the household. Major media corporations are moving to monetize XR media with restrictive licensing through proprietary technologies. Like the hyper-text transfer protocol (HTTP), that changed the way we experience the Internet, XR has the potential to become a dominant format we use to interact with information. Libraries need to be prepared to meet users in this new environment. Similar to how we incorporate virtual reference methods, we may need to incorporate XR tools within our services. The difference is that XR affects all facets of the library, including content, access, and support for users. Libraries have to accommodate the full process of information delivery in an XR environment. Open linked data may be a way to indirectly prepare library content for XR applications. Kim

Griggs demonstrates that geotagging digital collections can be a low-cost endeavor and would allow existing records to be adapted for XR applications (Griggs 2011).

We can now record physical reality. Technology that can reproduce reality may still be a few years away, but the tools to record physical reality are now available. So how will libraries prepare to preserve reality for future generations? We believe that libraries already have the necessary foundation to adapt to the XR technology. However, libraries will need to develop an awareness of XR and how users will interact with information in the near future.

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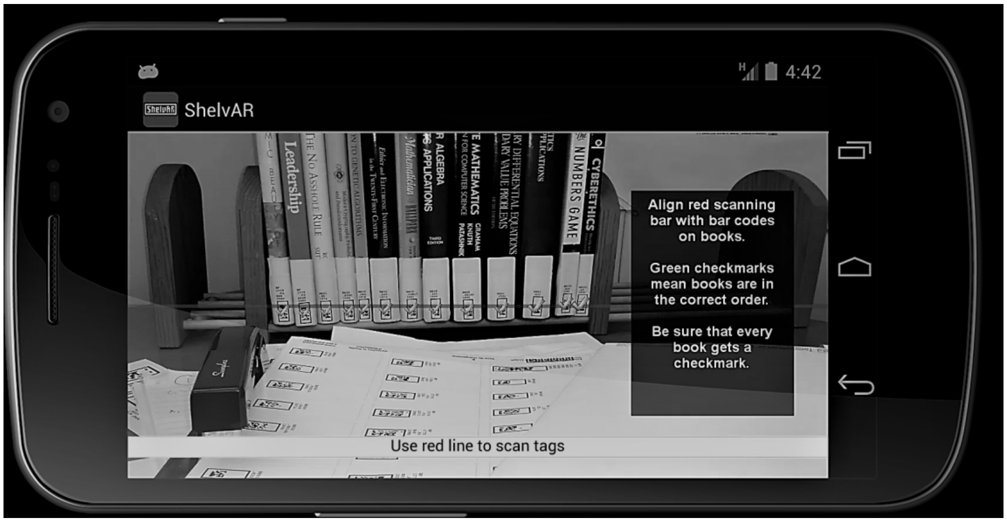

Figure 1: ShelvAR spine tags - http://www.shelvar.com/

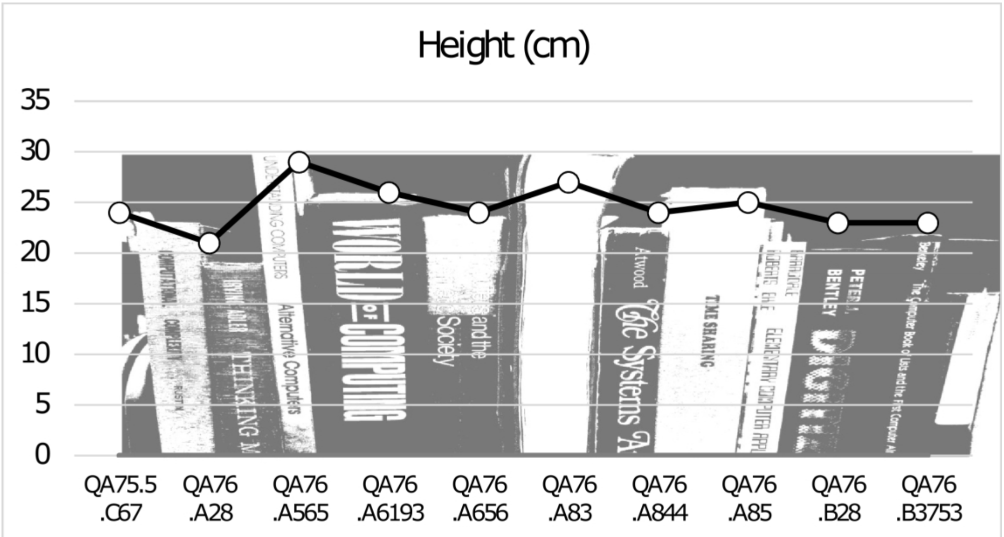

Figure 2: MARC data overlaid with visual imagery