Virtual Reality learning environments: Development of multi-user reference support experiences

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Structured Abstract

Purpose: The purpose of this paper is to report the results of a case study on Virtual Reality (VR) learning environments, focused on the development and integration of multi-user reference support.

Design/methodology/approach: This paper used a case study methodology to understand applied software development incorporating textual browsing experiences within the HTC Vive virtual reality headset. An open corpus of text from the HathiTrust Digital Library accessed via the API was used as a data source.

Findings: In collaboration with students from a senior undergraduate Computer Science project course the project team developed software in order to pilot a multi-user VR experience, with functionality for users to search, discover, and select e-books and other digitized content from the HathiTrust digital library.

Originality/value: Overall, the system has been developed as a prototype e-book experiment in order to model several VR affordances for browsing, user support, and educational endeavors within libraries. Within the VR reading room pilot, users are able collaboratively explore digital collections. Aspects of reference librarian user support were modeled in the VR system

including communication in real-time using chat features and text highlighting and manipulation tools that are unique to learning in VR environments.

Introduction

This paper reports the results of an undergraduate senior projects computer science course collaboration whose aim was to develop textual browsing experiences, among other library reference functionality, within the HTC Vive Virtual Reality (VR) headset. In this case study, readers are introduced to applied uses of VR in service to library-based learning through the research and development of a VR reading room app with multi-user support. Within the VR reading room prototype, users are able to collaboratively explore the digital collections of HathiTrust, highlight text for further searching and discovery, and receive consultative research support from a reference specialist through VR.

Aspects of reference user support that were modeled in the VR browsing system include communication in real-time using voice chat features within VR, as well as word and phrase highlighting for PDF annotation and search tools unique to VR learning environments. The pilot system has been developed as an e-book browsing and user assistance experiment in order to model several VR capabilities that broadly relate to educational endeavors within libraries. This case study enumerates VR pedagogies from partnering with a senior undergraduate computer science project course that supported feature development for aspects of this system as a part of an undergraduate studies capstone project. The project course was a year-long effort, featuring two semesters of undergraduate project group work. Library staff met with the project team weekly over the sixteen weeks of both semesters to first scope out the functionality of the system and vet requirements. The team subsequently implemented a pilot of agreed upon features using the HTC Vive development tools within the Unity developer environment, a popular scripting

and layout software program commonly used for game development in VR (Van de Kerckhove, 2016).

In *Understanding Virtual Reality: Interface, Application, and Design* the authorssuggest that VR uses are best designed for solving a problem and further advise that if VR software does not address a specific problem to be solved, then it is simply a "technological novelty," (Sherman & Craig, 2003, p. 414). Problems which VR can help address include: "improved ability to examine and explore 3D data," and "conveying ideas …", as well as the ability to realize cost savings (Sherman and Craig, 2003, p. 414). The abundance of e-resources available through digital libraries makes VR a compelling technology in which to visualize the resources available, and manipulate collection data for learning and research purposes. The library research team further hypothesized that incorporating reference-like support in the VR environment can support library learning. There is ample evidence in the library literature which underscores the importance of reference interactions as learning and instructional experiences for university students (Avery & Ward, 2010; Ward, 2011; Lenkart, Krogman & Ward, 2017).

This case study progress next with a more fulsome definition of VR within a review of literature in educationally focused VR environments related to this project, followed by a brief methodology review. Next, an implementation section for the case, including details on technologies and software used. The paper then reports the results of the case study, concluding with a discussion of lessons learned, future work, and implications for libraries interested in replicating this partnership.

Literature Review

Virtual reality has been defined as "an interactive technology setup (software, hardware, peripheral devices, and other items) that acts as a human-to-computer interface and immerses its

user in a computer-generated three- dimensional environment. Virtual reality is the environment or world that the user experiences while using such a system. Although the term "virtual" implies that this simulated world does not actually exist, the term "reality" refers to the user's experience of the simulated environment as being real," (Roman, 2013, p. 1). *Library Hi Tech News* further defined VR as "…the computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seeming real or physical way a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors," (Oyelude, 2017, p. 1). This case study reports in the Implementation section more detailed equipment requirements, though the reader will also be interested to know that VR development and use are typically not possible without the pairing of a high-end graphics enabled computing system along with the corresponding VR headset. The software components of the system, and the software development tasks involved in such an undertaking are the focus of this paper and are detailed in the Results section. Overall, some of the common functionality of Virtual Reality incorporate the following four areas: "a virtual world, immersion, sensory feedback (responding to user input), and interactivity," (Sherman & Craig, 2003, p. 6).

The e-book book browsing project that is the subject of this case study utilized digitized content from the HathiTrust digital library. The HathiTrust digital library offers a searchable public domain corpus of text. It is the largest digital repository of scanned books outside of the Google Books project (Christenson, 2011). The digital repository is, "a shared secure digital repository owned and operated by a partnership of major research libraries. The repository is best known as a means of preserving digital materials created via large-scale digitization projects. By pooling their collective resources and expertise, the partners have created a robust and scalable infrastructure to efficiently store, manage, and preserve their collections of digital books and

journals in common," (Christensen, 2011, p. 95). The HathiTrust corpus allows for several methods of discovery of content, including, "a number of end-user services, such as basic and advanced bibliographic search, full-text search based on extracted text, and a collection builder tool…", (Christenson, 2011, p. 98.). This project targeted the HathiTrust API for searching the collection and accessing texts (HathiTrust, 2018). The viewing, manipulation, and highlighting of e-books within VR are the focus of the software development case study on e-book viewing. The research team sought to develop such interactions as sharing, collaborative annotation, and saving PDF for future use.

The education literature has seen a variety and growing maturity on research advocated for the applicability of VR systems to learning (Franks, Bell, & Trueman, 2016; Cho, & Lim, 2017; Johnston et al., 2018). Several of research papers reference the virtual world "Second Life," as a target area for service development. Second Life has been traditionally thought of as an environment where users explore a multi-user online world through the use of avatars representing the user (Peters, 2008; Stimpson, 2009; Sheehy, 2010). Second Life has been a focus of library learning for some time, previous efforts in some cases were desktop-based experiences, whereas current practices make use of the availability of new consumer electronics notably the Oculus and the HTC Vive, among others (Hahn, 2017).

Educational benefits to immersive worlds include offering a deeper presence in engagement with rare or non-accessible artifacts. Sequeira & Morgado, describe their Virtual Archeology project as employing, "a blend of techniques and methods employed by historians and archaeologists using computer models for visualizing cultural artefacts and heritage sites," (2013, p. 2). The authors note that VR has proven a valid use in simulation training for educators (Sequeira & Morgado, 2013). Access to rare artifacts also introduces the possibility of providing

increased virtual access to special collections of libraries using emerging virtual technologies. Maria Beatriz Carmo and Ana Paula Cláudio suggested in their article that the 3-dimensional modeling that is possible in VR makes special collections more accessible and tangible to patrons of special collections. The authors write that, "In the cultural domain, 3D virtual environment and models are used in a wide range of situations with different purposes, such as: reproducing destroyed buildings, accordingly to ancient images or textual descriptions, to provide a means to discover their primitive appearance and sometimes an historical evolution of their architecture; simulating ancient environments, to get insight into the way they could be used once; integrating interactive activities in museums as a means to attract visitors, especially young people, and enrich their visit offering educational contents in a recreational way…" (2013, p. 233).

Methodology

This paper utilized a case study methodology with a focus course collaboration among library professionals with undergraduate students from a computer science capstone project. The paper details implementation of a pilot software development project, including partnership strategies in working with upper level undergraduate courses. Technical aspects of the VR development project are reported as a component of the case implementation. The value of this paper is in providing a deep exploration of the educational aspects and lessons learned from partnering with a computer science project course targeting VR development along with implications for formal and informal computer science course pedagogies. The generalization of these pedagogies to other courses and schools are noted in the case Discussion.

Implementation

The purpose of this case study was to understand how best to develop software in which a university student within a virtual room using the VR headset could search and explore the contents of digital books, specifically the publicly accessible e-book content of the HathiTrust digital library. A design choice of this project was for the user to be able to receive assistance through the headset from a library reference expert who had joined the multi-user environment via a second VR headset.

The HTC Vive headset is paired with a high-end graphics capable computer, a set of base stations, and handheld controllers, which when the user puts on the headset, are required to be intuitive since they cannot be seen. The base station technology emits infrared pulses which support the tracking functionality of where both the headset and controllers are located. The tracking is made possible after calibration by the HTC Vive setup software on the user's desktop. When paired with the base stations, the headset and controllers do combine to make a compelling VR experience that is immersive and engaging for the research team, library patrons, and students.

An HTC Vive can be used in a full room, but to do so, it requires ample space to setup the base stations. Base Stations can be a more challenging part of the setup, since the base stations are flexible for either a full room setup or a seated desk setup. The desk setup was used in this research, which still allows a user to stand, if desired, but only in front of their computer – shown in image 1.
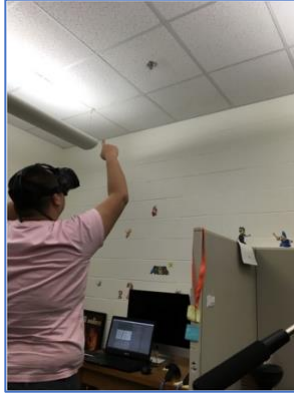
Image 1 - Lab environment of the VR setup.

Virtual Reality Computer System Requirements and Setup

The minimum requirements for VR are usually centered on graphics processing. Most

contemporary computers do ship with specialized graphic processing units, but only the higher-

end graphics processing units (or GPUs) can support rending the immersive VR experience.

The higher-end graphics cards include devices such as the NVIDIA GeForceTM GTX 1060 or

AMD RadeonTM RX 480, equivalent or better. The desktop system that was built for this

project used the GeForce GTX 1070, which was slightly above the required minimum

specifications. After purchasing and installing the higher-end card, the research team did not

encounter any issues with graphics rendering during the software development project.

Collaboration: Library as Client

Specific to this course collaboration, computer science students in their final year of study are

given the option of several client projects on which to work. The Undergraduate Library has

been a collaborator with senior computer science course projects for several years, beginning in

2012-2013 with mobile application design and chat reference software re-engineering (Hahn,

2015).

Case Study Results: development of a VR Reading Room

The project team's initial focus was display of e-book text in the form of a PDF document rendered in VR. Specifically, the team was focused on understanding PDF page modeling and display within a VR environment. These features are elements of VR interaction design. In consultation with the computer science project team, the HTC Vive was selected as the test environment since it is one of the best headsets at the time (late-2016) available for reading text. The HathiTrust API was used in order to display content from digitized books. An early pilot of text display through the HTC Vive is shown in image 2. The image is readable through the headset but throughout testing on duration of reading in VR have not yet been completed, since the focus of the case study was on piloting VR interaction with digitized text.
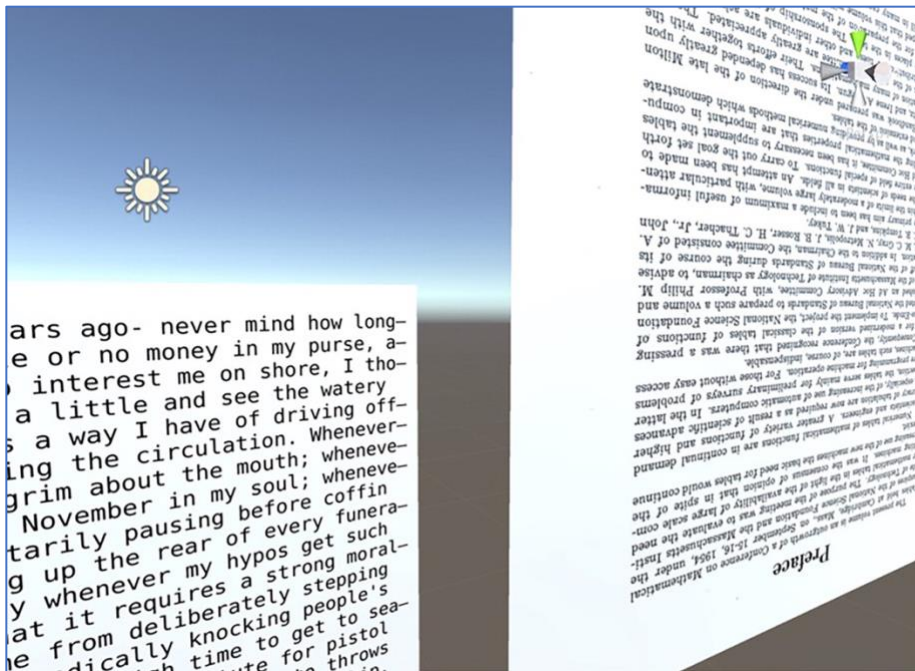

Image 2 - Initial document modeling of PDF text displayed in a virtual world.

Computer Science Course Collaboration: Technical Details and Outputs

Here several of the technical work details and outputs that were the focus of the computer science project team are delineated. These outputs include server networking features, project data sources from third-party APIs, and finally, manipulation of PDF text from the VR environment.

- *Multi-user networking:* The project required a server that could act as a type of switchboard in which more than one user could communicate through voice chat and then share PDFs and participate in collaborative research with a reference specialist. There were some hurdles in networking the two systems since the research team intended to share data using ports. There were several components of the code that enabled "multi-player" VR experience including developing in C# as well as Python server side code . The server side code implements a peer-to-peer network simulator; and will forward any received messages to all clients. This was desirable instead of direct connection between clients, because clients may not have access to public facing internet ports.

- *Project APIs:* In addition to using the HathiTrust API in this project, the research team explored the possibility of integrating several image and text manipulation tools within the VR experience including Google Cloud Speech APIs and the Google Cloud Vision API. Within Google Cloud Speech APIs the team wanted to use speech to search by voice. When using the headset, the user is not able to see their keyboard or mouse. Voice-to-text allows author, keyword or title searches. An example of the prototype voice to text searching is shown in image 3.
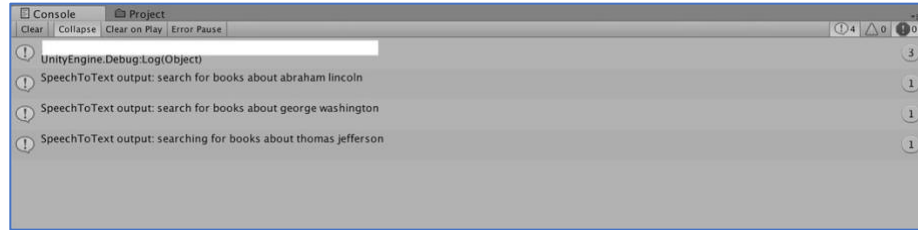
Image 3 - Console logs that were generated by the experimental speech to text functionality.

Within the Google Cloud Vision API (Google, 2018) the research team learned that Optical Character Recognition (OCR) will translate PDFs ad images into text for highlighting and for keyword search. This will allow users to select and highlight words/text samples. Google OCR returns bounding boxes, which will then be translated into 3D coordinates in Unity. If a user points at the bounding box, they can begin selecting the word. The team designed the system so that user highlighting would be recorded to a session log, and shareable to clients via the multiplayer server developed for this project. The design ideas also introduced the functionality to email the results of searching and book views, to read over the results of a research session at a later time. This would not require VR for the remainder of the research process. The research team acknowledges that users are not required to use the VR system for all research tasks, and that user actions and data should be portable outside of the VR environment.

- *PDF text manipulation with controllers:* this was an aspect which the group gained the most information from in terms of understanding user interaction. There was not a simple, intuitive one-to-one transfer of movement of a physical text in the physical environment to the virtual environment. Thus, after observing several users of the VR

book browsing system the team was able to begin to refine the mechanics so that page

manipulation could be more easily understood by library patrons.

<u>Discussion</u>

In the research team's two semesters of collaboration (from Fall 2016 – Spring 2017), they

gained additional expertise in the library on how VR systems can be developed. Overall, the

team learned that Virtual Reality programming uses some familiar technologies as well and

novel areas of programming for 3D environments. The hurdles the students had the most trouble

with was code integration – e.g. combining various individual software parts towards the end of

the semester. The students also were challenged by the public HathiTrust APIs, since the system

was developed to call the HathiTrust APIs from within the Unity programming environment, and

developing API calls in C#. This was a novel use of the HathiTrust search APIs for the students

and a new area for the research team as well. The library team believes that with additional

focused developer time that a more fully functional search and discovery tool could be developed

for the VR system, but that the work is non-trivial to complete since it does require sustained

focus and attention by software developers familiar with C# programming as well as with the VR

system overall.

There are alternatives to Unity C# programming, notably WebVR, an open source

specification for VR programming on the open web. According to the WebVR project website,

"WebVR is an open specification that makes it possible to experience VR in your browser. The

goal is to make it easier for everyone to get into VR experiences, no matter what device you

have," (WebVR, 2018). The web framework, "A-Frame," is the JavaScript web framework for

VR coding in a VR capable browser with the WebVR specification (A-Frame, 2018; AframeIO,

2018).

A-Frame has seen maturation as a platform agnostic and device agnostic software programming environment. The WebVR webpage notes that the specification supports HTC Vive, Oculus Rift, Samsung Gear VR, Google Daydream, and Google Cardboard (WebVR Rocks, 2018). Open web platforms are consistent with library values and educational goals of sharing work that can be foundational in implementing VR learning experience both in VR environments and shareable on the web, too.

Revisiting Student Collaboration Strategies

In revisiting collaboration strategies when working with student software development course projects, the research team suggests the following best practices:

- Schedule weekly check-ins with the project team and address any hurdles in development early in the process.

- Due to students' schedules it is best to front-load the majority of software work earlier in the semester so that toward the end of the course, students have already completed the most important parts of the semester.

- The research team did not plan for non-participation from one student member. While attempts at re-integrating his work into the project were made, ultimately the project team suffered because of lack attendance. This type of behavior has been, in the team's experience is rare, but it should be planned for so that it does not bring the project too much uncertainty if project team members are not participating.

- While it may come down to a question of software development resources and technical developer cycles, the research team recommend's having a technical point-person in addition to any library staff involved. Having a senior developer

at the table for the check-in meetings can help keep the project moving forward as well as forestalling any potential roadblocks which, absent an experienced developer, are likely to surface during the course of any partnership.

Pedagogies for Virtual Reality

The focus of this case study also included understanding pedagogical aspects of computer science teaching and learning with VR technologies. These findings can be applicable outside of this specific university, since there are likely commonalities in other computer science virtual reality courses. Some of these findings include the nature of Virtual Reality interaction. Page manipulation was an area of VR interaction which the team iterated several approaches in their design. This leads us to understand that gaining confidence in programming for the VR controllers and headsets will be an important aspect of any project. Controlling interaction in VR is particularly challenging. The three pillars of VR design include, "immersion, interactivity, and information intensity", and that with regard to interactivity with which handheld controllers play a role, "Interaction comes from the computer's lightning ability to change the scene's point-of-view-as fast as the human organism can alter its physical position and perspective", (Heim, 1998, p. 7). The interaction issues that the groups observed were also found in a survey of library VR uses where the authors noted, "When conducting the Video 360 orientation to the library, several students admitted to dizziness when using Google Cardboard googles. These little incidents were reminiscent of the Oculus Rift issues with motion sickness", (Miltenoff, 2018, p. 197). Overall Miltenoff notes that pedagogically sound VR can result from a scaled approach that "follows the same patterns of inquiry as other educational technologies—start small, and gradually expand the scope and depth of the endeavor", (2018, p. 197).

Collaboration is another trend worth exploring as a pedagogy to VR development in student course work. A team at the University of California San Diego which used their 360 Degree videos in library instruction noted that after highly engaged student VR viewing sessions --- " The engagement of the students underlined how, when technology is used correctly in an academic class, it can increase collaborative learning through peer-to-peer and group activities, and supports the theory that learning is a social construct. Finally students could see the connections between race, environment, and performances of dissent through their interactions with the videos", (Moore and McAvoy, 2018, p. 213).

The research team gained several new perspectives in communication in VR systems that are applicable to the collaborative aspects of this project. In addition to the voice communication among reference librarian and library patron -- "also important is information passed via visual means. When we speak, we may augment verbal communications with body gestures. Occasionally the body gestures are the entire message," and that, "… a person's mere presence may be enough to communicate information," (Sherman & Craig, 2003, p. 369). These design principles will help in supporting multi-user collaboration in the future.

In addition to the collaborative nature of VR viewing engagement the library clients would like to focus on code review management in future iterations of partnerships (Krusche, Berisha, and Bruegge, 2016), since reviewing branches of code collaboratively would be a way to produce higher code quality and address issues of code management noted earlier.

<u>Conclusion</u>

For libraries looking to implement or adapt already existing VR services, that one strategy for applying VR to a particular problem in your library is that of "converting an existing VR application into one suitable for your needs…" (Sherman & Craig, 2003, p. 420). Therefore the

project code is available online for re-use by other libraries. The pilot code can be inspected

using the instructions at the "Holobooks app," code repository (GitHub, 2018). The project team

in the library has identified the in software development and technical troubleshooting work are

enumerated below:

1. Continuing to improve the search, discovery, and download of e-books. The team intends
   to make this as seamless an interaction as possible.

2. Improve the project implementation of voice-to-text for information search.

3. Continue improving user interaction with VR HTC Vive controllers in Unity via user
   interaction studies and reference specialist input.

In the final system, the research team anticipates being able to fully incorporate reference

librarian functionality to guide students in navigating all electronic resources of the library.

System functionality will ultimately allow the user to search by voice the collections of the

HathiTrust digital library, and to view the results of their search through an HTC Vive headset.

The library team is designing for the final implementation for the VR user to be able to

manipulate PDFs of books with HTC Vive controllers. The current implementation is

demonstration/prototype software and the first system of its kind for multi-user assistance and e-

book navigation. With the release of the code in the open GitHub repository, the group hopes

that other libraries and like-minded technologists will feel inspired and welcome to contribute to

and enhance the building blocks and framework that has been undertaken in this case study for

implementing virtual reality learning environments in library settings.

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