Abstract

This paper discusses a project involving the translation of individual silent movie frames into ~~3D~~ three-dimensional virtual environments that can be viewed using augmented reality technology. The specific frames that were used were shot in one block of a neighborhood in Fort Lee, New Jersey, that was popular for film~~-~~making in the first decades of the twentieth century. After a brief overview of the project, several core technologies and concepts involved will be introduced, along with a short survey of prior related work to provide some background. The project's origins, motivations, and context will be discussed. Next, implementation of the augmented reality model ~~creation~~ will be surveyed, including details about the films and frames used, image preparation requirements, and the software selected to create and distribute the augmented reality experience. The paper concludes with an exploration of potential impacts, issues, and future steps.

Introduction

Emerging technologies are beginning to enable the ~~possibility for the~~exploration of the two-dimensional worlds of silent films ~~to be explored~~ as three-dimensional virtual environments. Considerations for this translation from film to spatial data include choices of representation, accessibility, data sources and processes, and the layered contexts of viewer experience. This work is emerging not from a film history perspective but rather at the intersection of computer science (computer graphics), visual design, and data visualization. Specific technologies in these fields are becoming more accessible to interdisciplinary researchers, allowing digital humanities research to move in directions previously not considered.

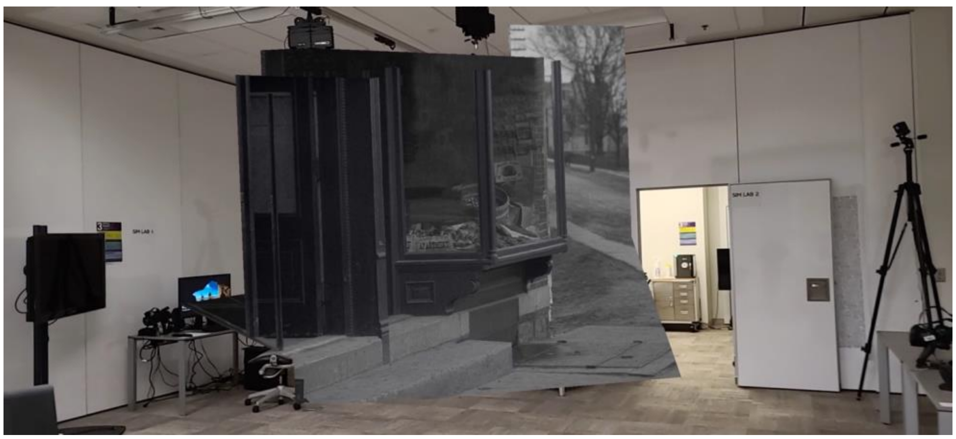

Figure 1.~~:~~ Virtual storefront from *The Cord of Life* experienced in a computer lab.

Figure 1 shows an example of transforming a single silent film image into a collection of 3D objects that can be viewed using augmented reality, or ~~“~~AR~~”~~. A video clip shows that this film frame of the storefront from the film *The Cord of Life* has been made into a 3D object that can be entered while looking through a smartphone.

~~Collecting a~~Additional silent film frames that show ~~additional~~ views of a set of buildings and storefronts ~~enabled them to be~~were collected and assembled to create a larger 3D model that can also be explored using ~~augmented reality~~AR. A virtual block such as this can be placed and resized anywhere, appearing like a hologram that can be seen by looking through a

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smartphone screen, like a window into the past. Using web technology to do this means that by sharing a link, a URL, or a QR code, ~~access can be provided to~~ people with smartphones ~~by sharing a web link, a URL, or QR code to~~can experience recreated historical locations such as ~~these~~this one.

Figure 2~~:~~. Virtual storefronts viewed using AR.

Figure 2 shows a view of the virtual block of storefronts assembled from silent movie frames. The buildings existed on the north side of ~~main~~ Main ~~street~~ Street in Fort Lee, New Jersey, around 1910. Here, the virtual model has been placed in a park in Missoula, Montana. A linked video ~~can be viewed that~~ was recorded from the screen of a smartphone.

The process ~~required~~ for someone to view this model in their environment requires just a few simple steps. An ~~internet~~ internet-connected smartphone or tablet manufactured in the past few years is needed. The user needs to visit a web~~-~~site in their device's web browser (e.g., by entering a URL like https://street-test.glitch.me for the example in ~~figure~~ Figure 2~~.~~). After the model quickly downloads, an on-screen button ~~should be~~is pressed to activate the~~ir~~ camera. The device's camera should be aimed at the ground to place the model. The 3D model can then be resized, rotated, and moved to be placed as desired in the physical space (Lewis 2022).

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The following sections discuss the design choices made, processes used, and challenges and impacts to be considered when creating an experience such as this. First, a few of the primary concepts required to understand terminology and limitations will be introduced.

Augmented ~~Reality~~reality

~~A brief explanation of Augmented reality (AR) is first necessary.~~ AR is a technology that has emerged from the combination of computer graphics, computer vision, and real-time mobile display hardware. It is frequently portrayed in science fiction films as futuristic holograms: virtual people, places, or interface screens become data, floating in the air everywhere in the world around us.

Figure 3~~:~~. Magic Leap One AR HMD.

In recent years, ~~Companies~~ companies such as Apple and Google ~~in recent years~~ have been primarily focused on supporting common handheld mobile devices for their AR software. A few companies such as Microsoft and Magic Leap have been at the forefront of wearable AR hardware, creating relatively expensive ~~head~~ head-mounted displays (HMDs) such as the HoloLens and the Magic Leap One (Figure 3). While none of the existing AR HMDs have been very financially successful as commercial products, many valuable lessons have been learned by the research community.

The research described in this paper has relied on more commonly available smartphones and tablets for displaying virtual ~~3d~~ 3D objects located in the physical world~~,~~ instead of hardware that is usually only available in well-funded research labs. The techniques and technologies used, however, will be just as applicable for HMDs when they ~~eventually~~ become more readily available.

~~For AR *software*, t~~There are a few ~~alternative~~ paths to choose from for AR software, with different pros and cons. Many AR projects make use of powerful commercial ~~game~~ game-authoring software like Unity to create software that can be distributed though commercial app stores. Other AR researchers use web-based, open-source software frameworks. As with all web-based distribution, this can make new work a bit easier to share with a more diverse group of people. The work described in this paper uses this web-based approach. A third, “walled garden,” approach is to rely on an individual company’s AR product~~/~~ or platform, such as Adobe’s Aero, Snap’s Lens Studio, or Meta’s Spark AR. These alternatives will be discussed in greater detail ~~later in the paper~~.

Regardless of the approach chosen for their modeling and delivery, virtual objects presented and viewed using AR technologies are data that must be created or collected and appropriately formatted to be displayed at interactive speeds. The next sections will talk about data and its location.

Data and AR

We historically think of data as charts, spreadsheets, and even maps. But today data can be just about anything that can be digitized, analyzed, communicated, or displayed. Smart objects sense and communicate with us, advertising companies sift through everything we say and do, and data scientists analyze everything from dancers to dramas. With the explosion of high-speed internet and streaming video, movies of all types have become one of the most analyzed and valuable forms of data.

~~The author~~I ~~has~~ have been involved with very diverse types of data including the visualization of birds and insects, buildings and vehicles, and plants and performers. All these new sources of data in turn require new forms of data collection, analysis, and visualization.

Figure 4~~:~~. Virtual AR tree and graph data.

Data created to be viewed with AR technology is primarily three dimensional. When 3D objects are created, AR can be used to place and view them in the physical world, as ~~is~~ shown in Figure 4. This virtual tree and bar graph in a hallway are examples of recent research projects involving the use of AR to place different types of data in a variety of spatial contexts. In this case, ~~tree~~ tree-planting possibilities can be considered in disadvantaged communities and humanities data can be located in educational spaces.

Locating ~~Data~~data

Placing media data at specific locations in the world has long been one of many challenges for implementing AR. Location-based AR games like Pokémon ~~Go~~ GO and Minecraft

Earth have been leading the way towards being able to experience experiencing and interacting with 3D content and experiences at specific outdoor locations around the world.

This field has been referred to in the past as locative media (Wilken and Goggin 2014). The concept of experiencing different media when only physically at a given location has been the subject of advertising, a great deal of artwork, and more generally speaking, a great deal of “surveillance capitalism” (Zuboff 2019). The aforementioned Pokémon Go GO is one of the more familiar examples, but even video billboards can be thought of as location-based data displays. Some other examples people might be familiar with include geofencing rented scooters, or proximity-based notifications involving Tiles or AirTags attached to devices to prevent loss. Many companies are now promoting software that locates data in space in different, contextually complex ways.

Technologies for determining the location of objects and people mostly fall into a few categories that can be thought of as analogous to strategies we might use. Devices may “listen” for wireless signals (e.g., GPS, Bluetooth, Ultraultra-wideband, or Wi-Fi) that allow them to guess where they are when they “hear” the direction and distance of familiar emitters. Alternatively, devices might use cameras to look at an environment and try to recognize known landmarks. Finally, a device might be able to maintain to sense ofinterpret direction and height, and how far it i’s traveling (e.g., “20 twenty steps north, up one flight of stairs, then 15 fifteen steps east.”). Many devices use a combination of these strategies to try to keep track of their location in the world.

Mirrorworlds

Kevin Kelly (2019) has written at length about a Mirrorworld containing additional layers of data overlaid and embedded in our physical environments. Locating metadata (i.e., data about data) about places, objects, and people creates what is known as a digital twin of the real world. Such data then allows the physical environment to be searched, even in real- time. Googling the world becomes an extremely impactful possibility with significant implications.

Like most things that we create in the world, located data experiences and interactions can be first designed and simulated virtually. Instead of needing to do all AR software and hardware research at an actual physical site to evaluate alternative choices, the locations themselves can be digitized into data and then simulated in virtual reality (VR). Unlike AR, which usually involves placing virtual objects within some real, physical environment, VR uses an head-mounted display (HMD) that completely blocks out the real world and totally immerses users in a virtual environment. For example, one might walk around within a virtual version of a real-world museum without needing to travel to its location.

When referring to both ofthe technologies of VR and AR collectively, the term "XR" will often be used. The "X" can mean "eXtended," or it can be thought of as the variable "X" that can stand for both (V)irtual and (A)ugmented reality. Given this brief introduction to a few concepts around XR and located data, the next section will describe the motivations, trajectory, and intersection with the humanities research topic that resulted in this project.

Problem~~-~~/~~-~~Opportunity Space

~~Having introduced necessary background concepts in the previous section, t~~This section presents the context and goals, both technical and scholarly, that led to the design solutions implemented. The first couple of years of the COVID pandemic led to a shift toward~~s~~ academic conferences being ~~increasingly~~ attended entirely online via video~~-~~conferencing software. At one such online conference about this subject, ~~the author~~I was introduced to film scholars with a strong interest in virtual technologies. This resulted in the collaboration that generated the work described in this paper.

Figure 5~~:~~. 360-degree spherical photograph of a space.

From a technological standpoint, the genesis of this photographic AR work emerged from the new accessibility of 360-degree "spherical" panoramic photography (Figure 5). That this work began with emerging camera technology is notable. While these new photographs allowed the capture and sharing of specific locations from a single viewpoint, it was the potential for using such photographs of spaces to create photo~~-~~real 3D environments that was particularly intriguing. After struggling with new beta software being developed for this purpose, a project was initiated to create a new workflow that could use ~~well-~~well-established software that was already familiar. The use of existing~~, available~~ tools made the process available ~~for use by~~to students and researchers alike who were interested in XR research.

Figure 6~~:~~. Virtual preschool classroom in VR, created by Emily Subr.

During the pandemic, research funding made it possible to hire a graduate student to assist with creating virtual spaces from photographs. Modeling a preschool classroom to test the feasibility of prototyping virtual technology systems was the first such funded project (Figure 6). But beyond creating realistic 3D models of spaces, the primary challenge was being able to walk around in them~~,~~ using VR. The eventual goal was to create a prototype and evaluate designs for candidate emerging technology systems within VR without needing to be in the physical spaces (e.g., connected “smart” light and speaker systems for the preschool classroom~~.~~).

Figure 7~~:~~. 3D data graph in VR and AR.

As full-time work from home began, conversations were initiated with other faculty about potential opportunities for doing collaborative data visualization in VR. Figure 7 shows initial work with Mike Rayo from the Industrial Systems Engineering ~~department~~ Department at ~~The~~ the Ohio State University. Possible ~~three-dimensional~~3D graph representations were ~~being~~ discussed, and we looked at the process of sharing designs using VR in recreations of familiar spaces that were no longer accessible to us during the pandemic. We also explored methods for placing 3D data models ~~at~~ in our home using AR (e.g., in the back~~-~~yard~~.~~).

Importantly, both experiences were shared using web addresses (i.e., ~~a~~ URLs) and mobile web browsers in smartphones and standalone VR HMDs. It should be emphasized that this process was chosen specifically for the ease of sharing via VR and AR while developing ~~prototyping~~prototypes. From a technology perspective, this demonstrated that resources and processes were available to create photo~~-~~realistic, web-based XR spaces ~~&~~ and objects using processes that foregrounded the ability to collaborate with people from other disciplines.

This XR research work ~~described above~~ was presented at the Beyond Zoom conferences held online at Dartmouth. This was where ~~the author~~I met Mark Williams and John Bell (2021), the directors of The the Media Ecology Project (MEP), a research initiative funded by an National Endowment for the Humanities Digital Humanities Advancement Grant. Discussions of their silent film data analysis work led to this work project of applying the above XR workflows to the problem of immersively visualizing silent movie environments. The initial data in this case was a set of newly restored film frames, discussed belowlater.