Demystifying the Future of the Screen

by

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ABSTRACT

Natasha Dinyar Mody
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Demystifying the Future of the Screen explores the creation of a 3D representation of volumetric display (a graphical display device that produces 3D objects in mid-air), a technology that doesn't yet exist in the consumer realm, using current technologies. It investigates the conceptual possibilities and technical challenges of prototyping a future, speculative, technology with current available materials.

Cultural precedents, technical antecedents, economic challenges, and industry adaptation, all contribute to this thesis proposal. It pedals back to the past to examine the probable widespread integration of this future technology.

By employing a detailed horizon scan, analyzing science fiction theories, and extensive user testing, I fabricated a prototype that simulates an immersive volumetric display experience, using a holographic display fan. Its construct was inspired by pre-television optical media like phantasmagoria, Kristian Birkeland's immersive cathode-ray environments, and NBC's original news broadcast in the early 1900s. The treatment was influenced by sci-fi film visualizations.

Keywords: volumetric display, technology, screens, television, graphical display, device, entertainment, blue-sky, interface, simulation, science fiction, design fiction, hi-fidelity, prototype, speculative design, phantasmagoria, Birkeland, holography, display fan, illusion, autostereoscopic, virtual reality, augmented reality, mixed reality

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Thank you to my editor, Anna Cox, for reminding me of the evils of passive voice and encouraging me every step of the way. Her edits not only helped my thesis come to fruition, but her sense of humour provided laughs when I needed them the most! I thank her whole-heartedly for keeping my sanity.

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Above all, I owe a tremendous amount of gratitude to my wonderful parents, Dinyar and Farida Mody who gave me courage to relentlessly persevere this arduous journey. Thank you for your unconditional love, for cheering me on, and for being my biggest source of inspiration!

DEDICATION

I dedicate this to all the designers and futurists, whose research and expression, lie in the unfolding and expansive potential of 3D volumetric display.

See you in the air, my friends.

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A. INTRODUCTION

Research Question

How might one create a 3D representation of volumetric display, which essentially is a technology that doesn't exist yet, using current technologies? What are the conceptual possibilities and technical challenges of prototyping a future, speculative, technology with currently available materials?

Summary

This thesis study explores the future potential of 3D volumetric display (VD) utilizing a horizon scan technique, a speculative design method and science fiction-theories, as well as a historical review of volumetric display's technical and cultural antecedents.

The horizon scan technique includes a current industry assessment and a detailed professional interview. The industry assessment includes a comparative review of competitors in the global market (with a focus on North America), providing insight into current industry trends as well as speculating how the it might adapt to volumetric display technology in the near future.

The use of speculative design allows for creative leaps in unpacking the conceptual possibilities and technical challenges of prototyping a future technology. Science fiction films and fictitious worlds currently utilize volumetric display and analyzing these fictitious iterations helps evaluate the plausibility of a mid-air, 3D *screenless* image. Diegetic prototypes—functioning objects/technology in a science fiction world, clarify how far volumetric display is from being a reality. Further analysis of sci-fi trends also help consider how we can best adopt and adapt to future technology.

Historical antecedents play an important role in future speculation because sometimes the best way to predict the future, is to understand the past. At first, it may seem nonsensical, but the implications and manifestations of volumetric display technology can be uniquely understood by looking backwards. While all technology has historical antecedents, the earlier and rudimentary attempts at immersive technology provide a unique roadmap to the problems and possibilities of creating future technology with the limitation of current materials.

Humans see in three dimensions, so it's perplexing that the dominant modality of entertainment culture (television and film) is, and has been, flat, two-dimensional screens. Perhaps when we no longer have to flatten content to transmit it, content delivery can align with existing neurological reality. In this sense, volumetric display aims to re-inflate what has, for most of the 19th and 20th century, been flattened.

Volumetric display is bigger than a mere shift in entertainment delivery systems. It is a return to neurological reality because it is autostereoscopic—it requires no special goggles or glasses. This

is what differentiates volumetric display from virtual and augmented reality, that currently require special equipment.

Finally, the study culminates in the creation of a speculative prototype, which mimics volumetric display, using existing two-dimensional technology.

Scope and Limitations

My research explores the creation of 3D volumetric display using current 2D technologies. It examines the conceptual possibilities and technical challenges of prototyping a future, speculative, technology with currently available materials.

The research also explores the potential of volumetric display to supplant the *screen* as the dominant entertainment delivery system within North America.

Simulating a plausible technology that doesn't exist yet is a significant challenge, but a bigger challenge, is creating content for a technology that doesn't exist yet. Content that resonates with the current market place comes with its own set of technological, formal and aesthetic limitations.

To address these confines, my research focuses on an exploratory prototype process that culminates in a high-fidelity design. The prototype illustrates how the technology might work while giving the viewer an insight into future possibilities.

Significance of the Project

The intent of my thesis stems from an interest in screen and display technologies based on my extensive professional background in entertainment (television and film). The thesis and prototype will contribute to future studies in screen technologies as well as Human Computer Interaction and forms of flexible *screenless* displays.

Although experts such as Prof. Roel Vertegaal (Queen's University School of Computing and Director of the Human Media Laboratory), industry specialists like Voxon Photonics, RealView Imaging and LightSpace Technologies, as well as a consortium of Japanese researchers who recently unveiled a groundbreaking project that utilized femtosecond lasers, the research in the field of volumetric display and its speculative future is a relatively recent undertaking and the intent is to contribute to a new area of research which is only starting to catch up with its own speculative future as portrayed in popular science fiction.

B. RESEARCH DEVELOPMENT

i. Context Review:

Historical Antecedents: Their Significance to Volumetric Display

When referring to progressive first world society, specifically in the North American context, digital technology transforms and infiltrates every aspect of modern life. From how we work, learn, shop, entertain, and research, digital devices facilitate our engagement with each other and the world. As image production technology evolves, so must the device that delivers the imagery. In other words, as the device becomes more complex, so does the image and the delivery system.

When we accept new technology, societal norms shift. Such shifts are not unique to the advent of contemporary hand-held screen-based devices. The acceptance of the television also changed societal norms by revolutionizing the entertainment industry and radically altering the North American domestic sphere.

Volumetric display technology is a perfect example of a potentially significant shift in imagery delivery and production. Because it doesn't fully exist, it's hard to accurately predict what kind of imagery this technology will transmit. So, to understand the kind of imagery could be viewed, it is useful to consider the type of imagery favored by volumetric display's conceptual precursors: phantasmagoria, magic lanterns (Fig.1.) early television broadcasts and finally Norwegian inventor, Kristian Birkeland's immersive experiments (Fig. 2.)

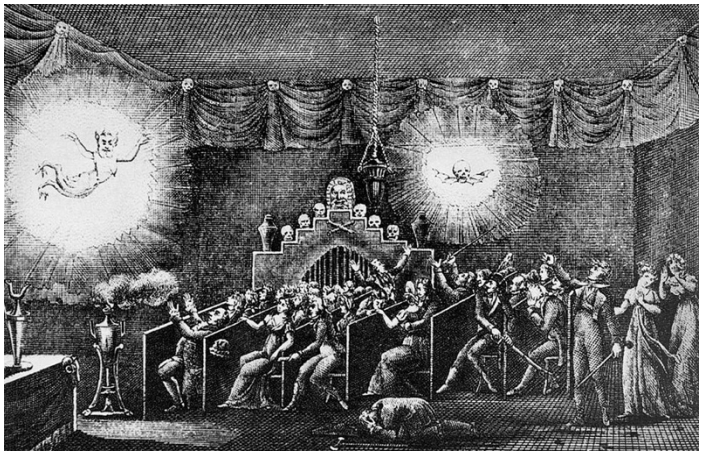


Fig. 1. From Etienne-Gaspard Robertson's 1834 study of technical phantasmagoria, via Ghostly Apparitions

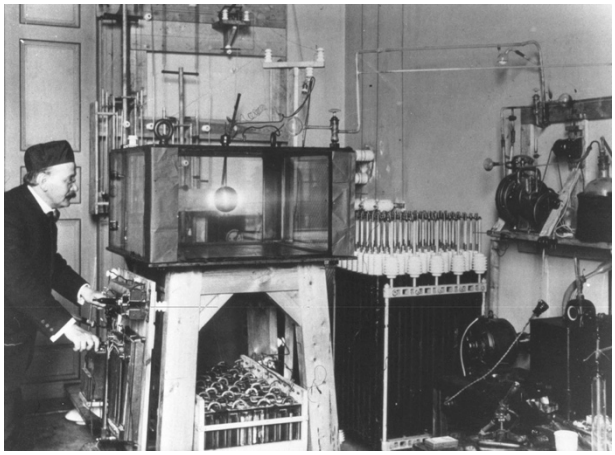


Fig. 2. Kristian Birkeland stares deeply into his universal simulator, via Ghostly Apparitions

Birkeland attempted to recreate celestial spaces using simple, terrestrial materials. He wanted to bring the stars to earth, funneling a maximal, celestial space (the stars) into a minimal, terrestrial one. When television launched in 1926 the first broadcast was news, something that sought to broaden people's understanding of the world. So while Birkeland tried to minimize a maximal space, NBC inverted this idea by bring the world into each North American home. Paradoxically,

I'm looking to the past so I can prototype the future.

Volumetric Display -

Introduction

Ever wonder why we see in three dimensions but our screen-based entertainment is flattened into two dimensions? Shouldn't the spectacle of television and cinema be as dimensionally rich as banal experiences like perusing canned fruit in the supermarket? Why do we accept one less dimension in our amusements than in our real life?

Volumetric display technology simultaneously answers these questions and revolutionizes future entertainment modalities.

Instead of looking at flat content on a flat screen, consider experiencing a nearly 360-degree volume-based display that you can walk around and the images change as you move!

"Imagine a world where you can view a three-dimensional digital hologram in high definition, from any angle, with no illusions and no special glasses."
~Lynton Manuel, Voxon Photonics, 2017

That, in a nutshell, is volumetric display.

This technology is more than entertainment liberated from screens; it is a coup of experience and content delivery. And unlike contemporary virtual and augmented reality, volumetric display is autostereoscopic, which means viewers experience the phenomena of volume and three-dimensionality without the hindrance of specialty glasses or cumbersome goggles.

This technology is still decades away from common, consumer utilization yet experiments relating to volumetric display occurred as early as the Renaissance.

Barry G. Blundell, in his 2011 journal article, *On Volume Based 3D Display Techniques* recounts, "The fundamental techniques used in computer graphics to map three-dimensional (3-D) image data onto the conventional two dimensional (2-D) display can be readily traced back to the Renaissance that flourished in Italy from the fourteenth to the sixteenth centuries… The Renaissance denotes an important turning point in western culture. During this period scholarly traditions were established, knowledge was widely disseminated, and the image depiction techniques that were gradually refined led to the creation of works which exhibit, and even transcend, photorealism. The depiction of images on 2-D tableaux, the inclusion of relief through carving and the creation of wholly 3-D representations via sculpture have, from the earliest times, provided outlets for a quest to depict and record our physical surroundings and also as a means of facilitating creative expression. However, various emerging *creative* 3-D display technologies

offer to support true 3-D image depiction thereby enabling the formation of images that possess the attributes that we associate with traditional carving and sculpture." (Blundell, 2011)

Blundell's insights into the history of 3D technologies is illuminating because he creates a timeline that traces the origins of this technology, in various forms, back to the Renaissance period.

Blundell also specifies "Volumetric display systems have been researched for many years, the first static volume system being proposed by Emile Luzy and Charles Dupuis in 1912. The swept-volume technique dates back to the pioneering work of John Logie Baird in the late 1920s. Since that time, numerous volumetric systems have been proposed and prototyped. However, many of these embodiments have possessed inherent design flaws.". Ibid

Research supports the consensus that this technology is in its nascent stage and will certainly require significant development before it will become an everyday device available to the public. However, the fact that volumetric display was first postulated in 1912 is perhaps evidence that this technology is less futuristic than science fiction would lead us to believe. Additionally, the inventor of the mechanical television, John Logie Baird, explored swept-volume techniques that are still being investigated and research into prototyping that technology has been ongoing for decades. Can we really consider a technology nascent if it has precursors in Renaissance?

However, volumetric display like any other technology, has a larger purpose and the sections to follow begin to contextualize and examine the potential of that purpose.

Its Speculative Potential in North America

While volumetric display has global potential, the resources supporting this thesis primarily reference it within the North American context.

Why focus on volumetric display in North America?

1. Volumetric Display – The next big revolution!

With the invention of the television, the experience of shared viewing began in North American households, as the first electronic *screen*, the television, significantly impacted North American culture. If the television was a *turning point in history* then volumetric display technology will probably turn everything inside out.

2. Home entertainment in North America

Research in the field of volumetric display has been explored in multiple industries such as medical, educational, military, and commercial but minimal investigation has occurred within the *entertainment* sector. This seems incongruous in relation to the following reports.

A recent M&E market report states "The U.S. media and entertainment (M&E) industry is a $703 billion market, comprised of businesses that produce and distribute motion pictures, television

programs and commercials along with streaming content, music and audio recordings, broadcast, radio, book publishing, and video games, along with ancillary services and products. The U.S. M&E market, which represents a third of the global industry, is the largest M&E market worldwide. The U.S. industry is expected to reach $804 billion by 2021, according to the Entertainment & Media Outlook by PriceWaterhouseCoopers. This snapshot is limited to the filmed entertainment, video, music, video game, and book publishing sectors which represent aspects of globally sought-after American culture, as well as global digital trends that connect the United States with the world and cement the industry's role as a respected leader in the creation and distribution of content, products, and culture." (M&E Market Report, 2016)

The United States is one of the largest M&E markets and the fact that it's meant to grow exponentially by 2021, indicates that it has great potential and also acts as fertile ground in which nascent technologies will thrive.

Digital technologies like television have revolutionized the North American entertainment industry and the same thinking can be applied to volumetric display. The M&E report suggests that the entertainment industry in the United States is worth a whopping $703 billion so it is prudent to study the potential impact of volumetric display within the largest and most powerful global market.

3. Volumetric Display Market Forecast

MarketsandMarkets, the world's number two firm in terms of annually published premium market research reports, suggests that the "Volumetric Display Market by Component (Projector, Motor & Position Sensor), Technology (DLP and LCOS), Display Type (Swept and Static), Application (Medical, Aerospace & Defense and Oil & Gas), and Geography is expected to reach $348.2 Million by 2020 at a CAGR of 33.28% from 2015 to 2020, which includes an in-depth analysis of the market by component, technology, application, and geography." (MarketsandMarkets Research Private Ltd., 2009-2018)

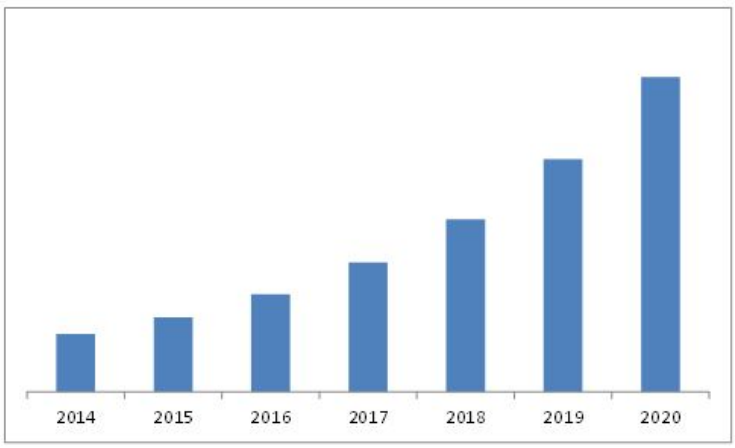


Fig. 3. Volumetric Display Market Size, 2014-2020

The *Volumetric Display Market - Global Trend & Forecast to 2015 - 2020* within the *MarketsandMarkets* report also proposes that volumetric display is a promising technology with

wide applications in medical, aerospace & defense, automotive, and industrial sectors but has major challenges associated with complexity, cost, and participation of several disciplines. Ibid

Although volumetric display is in its infancy, it has already been introduced in the fields of medicine, aerospace and defense. The competitive landscape of the market continues to witness new product launches, large scale collaborations, and agreements and partnerships across the value chain, with a number of major players around the globe such as 3DIcon Corporation (U.S.), LightSpace Technologies Inc. (U.S.), Voxon (U.S.), Holografika Kft. (Hungary), Zebra Imaging (U.S.), Holoxica Ltd (U.K.), Burton Inc. (Japan), LEIA Inc. (U.S.), Seekway Technologies (China), Alioscopy (France). (MarketsandMarkets Research Private Ltd., 2009 -2018)

Future technologies play a vital role within the North America entertainment marketplace. Volumetric display is speculated to rapidly develop in the near future, so it is reasonable to assume it has the potential, like many technological trends before it, to be integrated into the North American home.

Current Social Trends and Implications

Volumetric display will likely supplanting television as the dominant consumer entertainment delivery system. Therefore, it is useful to study current trends within screen-based viewing because changing consumer demands often predict future technological adaptation.

Current consumer behavior prioritizes two things. Viewing across multiple screens and the flexibility to watch wherever and whenever consumers want. OTP (over-the-top) content providers like Hulu, Amazon, and Netflix have already dismantled the previously accepted standard of rigidly scheduled programming and televisions, once statically placed in living rooms are now untethered; they are in our backpacks and our palms. Portability and flexibility are the new norms and the affordances of volumetric display technology not only extend this trend, they expand it exponentially.

Hollywood has increased 3D film production enormously and within the gaming industry virtual and augmented reality are common, so is it really that much of a shift to imagine volume-based displays in our near future?

In an issue of WIRED, *Six Trends Directing the Future of Television*, the authors Jeff Stier and Chris Gianutsos (Advisory team, Ernst & Young) address the emerging trends of consumers and discuss six trends that may *reveal the story arc of television's future*. As per the authors, storytelling, content mobility, event-based viewing, content delivery optimization, binge watching, *more participants, more creative risks*, all impact consumer behavior. As the cost of video screens fall, the demand for content mobility will rise exponentially. With a smartphone serving as the nerve center for the screen world, content will be able to follow a consumer from device to device, location to location. Although content mobility creates a number of back-end

headaches, it also creates new opportunities for ad impressions, provided they are properly targeted and calibrated for a multiscreen lifestyle. (Stier, Gianutsos, WIRED)

Event-based viewing has become a growing trend and will continue as future content creation builds on social experiences that go beyond the television and the living room. Hence, content delivery optimization will continue to radically transform the viewing experience.

Event based viewing is already being replaced by binge-watching and binge-watching is aided by viewer's access to on-demand streaming services. These behavioral patterns suggest a pattern of customizing consumer's experiences.

The advent of emerging technologies such as virtual reality, augmented reality and mixed reality, have brought about significant transformation in the viewing experience and these technologies are gradually appearing in the home entertainment space. Since consumers already demand to choose their content, it's only reasonable that consumers will want to be immersed in their content.

Comparison Analysis: The 3 Realities—Virtual Reality, Augmented Reality and Volumetric Display

This section of my research undertakes a comprehensive comparative analysis which is important in outlining advantages and disadvantages while exploring alternatives that question the technology's necessity and capabilities.

Having said that, to help position volumetric display, it is vital to evaluate the world it lives in among other emerging technologies from the perspective of its delivery and experience as well as its benefits and shortcomings. Here, volumetric display is compared to virtual and augmented reality because it is considered to fit within this proto-reality designation.

To further assist in the reading of this section, please refer to pertinent definitions in the *Glossary*.

A comparison of these three technologies from the point of view of their delivery and experience, their benefits, and their drawbacks and limitations are outlined as below.

Delivery and Experience

Both virtual and augmented realities are stereoscopic.

Virtual reality (VR) is usually delivered to the user through a HMD (Head Mounted Device), or hand-held controller that connects people to a virtual world allowing them to control and navigate their actions in an environment meant to simulate the real world. (Augment News, 2015)

Fig. 4. Virtual Reality, Augment News, 2015

Augmented reality (AR) is used in mobile devices such as laptops, smart phones, and tablets to change how the real world and digital images, graphics intersect and interact. They also commonly use HMD (Head Mounted Device) that place images of both the physical world and virtual objects over the user's field of view. Modern HMDs often employ sensors for six degrees of freedom monitoring that allow the system to align virtual information to the physical world and adjust accordingly with the user's head movements. (Augment News, 2015)

Fig. 5. Augmented Reality, Augment News, 2015

However, it is vital to note here that volumetric display, on the other hand, is autostereoscopic and does not require viewers to wear any special headgear. Even though, volumetric displays are still under development and are yet to reach the general population, the variety of systems proposed thus far make it possible to view volumetric display with the naked eye! Volumetric display has been achieved through multiple approaches like fog display, holographic fan, holography, mixed reality, Holovect, Voxon's Photonic Engine (ultra high-speed digital light engine and a highly optimized volume rendering engine), Looking Glass's Volume, LightSpace 3D volumetric display (a high-speed video projector, and a multi-planar optical element, MOE, composed of an air-spaced stack of liquid crystal scattering shutters).

Benefits

The benefits of VR are primarily to create and enhance an imaginary reality, enabling a user to explore places, things etc., to enhance training for real life environments by creating a simulation of reality where people can practice beforehand and that it allows a user to experiment with an artificial environment. It is a value-add to multiple industries. (Augment News, 2015)

AR is a form of escapism blurring the line between what's real and what's digitized. Surrounding real world data becomes interactive and can be digitally manipulated. People can share experiences with each other in real time over long distances. Also, reality with more information added to it that is in normal terms not available, increases knowledge through information. The headgear is not always required, making it more comfortable for the user to interact with the technology. It is also a value-add to multiple industries.

Volumetric display has multiple benefits as viewing is in *true* 3D form, it is autostereoscopic which means no head gear or eye glasses are required to view these displays. It can be viewed with the naked eye.

Volumetric display enables new user interface techniques from the point of view of HCI (Human Computer Interfaces) due to their inherent three-dimensionality. From the perspective of artistic use, Hologlyphics, an art form has been explored since 1994 combines music, video, film and holography, sculpture. The more recent volumetric video technique is being applied to movies as well as live audiences at art galleries and music festivals. Another significant use of this technology is seen in sci-fi films.

Drawbacks and Limitations

VR technology has many drawbacks unfortunately. For one, the use of headgear is very uncomfortable for the user. The equipment is expensive, the technology is complex, it is a guided technology that doesn't allow a user to move freely as we would in the real world, users get addicted to the virtual world and become disoriented, training in VR environment isn't real. There are multiple health and safety, privacy and technical issues as well.

AR brings with it a set of its own drawbacks and limitations. It is expensive to develop and maintain. There is a complete lack of privacy, spam and security as it records and analyzes the environment in real time and this leads to potential legal concerns. An AR device might reveal status, Tweets, and other personal information that may cause breach of privacy. It can also be inappropriate in social situations. Another concern is that of openness as it allows other people to develop their own content to display which could cause an overload in terms of information and augmenting without permission. Another grave concern is interoperability, a lack of data portability between AR environments such as wikitude AR and Layar AR browser.

Volumetric display's R&D is at the stage of infancy, the technology set up is very time consuming and the system is complex, with the requirements of large bandwidth to display imagery. In other words, the number of voxels required to produce images are much greater than that of pixels on a traditional screen.

This is supported by Gary Gonzales's book, Volumetric Display - Unabridged Guide, who states, "A standard 24 bits per pixel, 1024×768 resolution, flat/2D display requires 135 MB/s to be sent to the display hardware to sustain 60 frames per second, whereas a 24 bits per voxel, 1024×768×1024 (1024 "pixel layers" in the Z axis) volumetric display would need to send about three orders of magnitude more (135 GB/s) to the display hardware to sustain 60 volumes per second." (Gonzales, 2012)

So, the technology is still a long way off when it comes to reaching public masses.

Reflection

It is evident from this analysis that these technologies share some similarities. From a technology point of view, augmented, virtual and volumetric realities, all leverage some of the same types of technology, and they each exist to serve the user with an enhanced or enriched experience. (Augment News, 2015)

From the viewpoint of entertainment, all three technologies enable experiences that are becoming more commonly expected and sought after for entertainment purposes.

While in the past they seemed merely a figment of a science fiction imagination, new artificial worlds come to life under the user's control, and deeper layers of interaction with the real world are also achievable. The content in all three technologies aims to tell a story and leading tech moguls are investing and developing new adaptations, improvements, and releasing more and more products and apps that support these technologies for the increasingly savvy users. Additionally, these realities have great potential in changing the landscape of the medical field by making things such as remote surgeries a real possibility. AR and VR technologies are already being used to treat and heal psychological conditions such as Post Traumatic Stress Disorder (PTSD). There is recent work investigating the speed and accuracy benefits of volumetric displays, new graphical user interfaces, and medical applications enhanced by volumetric displays. (Augment News, 2015)

It appears that volumetric display's technology has some advantages over that of VR and AR. Not only is the viewing experience three dimensional and in the same physical space as the viewer, making it more immersive and a convincing simulation (being that it is closer to reality), but it is also not socially isolating or neurologically damaging like the modalities of VR and AR technologies.

While emerging technologies such as virtual and augmented reality have advanced and transformed our lives radically, they have not yet defined our everyday for many reasons.

ii. Methodological and Theoretical Approach:

Introduction

This thesis employs research techniques and methodologies typically supportive of future-facing digital research and include the following:

a. Horizon Scan Technique

Horizon scans detect early signs of potentially important developments, threats, and opportunities within new technologies. This technique determines what is constant, what changes, and what constantly changes. It explores problems and trends, as well as current thinking that may challenge past assumptions. It falls under the discipline of *futures thinking* studies because it forecasts the future based on current trends in society.

Within my thesis, a horizon scan of volumetric display, that focuses on current industry assessment as well as a professional interview, is useful in forecasting the technology's potential:

Current Industry Assessment

This section comprises of an industry assessment that helps situate volumetric display technology within the realm of current markets and emerging technologies. Current industry assessments are also important because they investigate a conceivable technology such as volumetric display.

The conducted research in this section considers the potential of volumetric display within both, the North American and global markets.

Professional Interview

A professional interview with Andrew Garcia, Art Director at Secret Location, an Entertainment One company, provides an industry perspective of predictions and assessments on the future of emerging technologies, in this section.

The interview elucidates an industry expert's perspective as well as his predictions and assessments about the current and future state of emerging technologies.

b. Contextual Analysis

A contextual analysis and other techniques derived from literature and cinema define this section. These techniques focus on theories that offer speculation of the future by looking through the lens of the past.

The subsequent portions of this section contextually analyze diegetic prototyping in Dennis

Villeneuve's 2017 film, *Blade Runner 2049*. This type of contextual analysis is common in the *Speculative Design* method—a system of analysis that frequently informs design fiction and futures thinking.

c. Speculative Design (Design Fiction)

Design Fiction is a powerful tool that helps explore the possibilities of the future. *Speculative Design* within the realm of *Design Fiction*, is the overarching theoretical approach utilized in my thesis, especially since its futuristic nature applies extremely well to my prototyping process.

By using a speculative design approach, contemporary science fiction cinema becomes another tool to imagine the future of volumetric display technology.

d. End User Feedback

The final step of the prototyping process, in the *Prototype Development* section of this thesis, utilized a user experience test and feedback. The feedback assisted in conceptualizing future possibilities of volumetric display as well as evaluating the conceptual possibilities and technical challenges of prototyping a future, speculative, technology with currently available materials.

The user experience test employed a *think aloud* approach and was conducted with five participants from the Digital Futures program at OCAD University, who were predominantly millennials. Millennials were chosen primarily because they grew up immersed in technology and are very adept at adopting and using emerging technologies.

Horizon Scan Technique:

Current Industry Assessment

Although volumetric display was first hypothesized in the early 1900s, most people hadn't heard of it until fifty years ago. Volumetric displays, as a fundamental aspect of science fiction, are currently in early stages of development and have yet to reach the general population.

Many systems within the realm of volumetric display have been proposed and used mostly in the fields of academia, corporations, military and research labs and remains somewhat accessible only in this capacity. It is however, gradually entering the healthcare, aerospace, automotive, gaming and entertainment markets.

To assess the stage of development and the level of effectiveness when it comes to prototyping volumetric display technologies from a global point of view, it is important to examine and assess what competitors are undertaking in the industry.

As per Market Research Future's research report *Volumetric Display Market Research Report -*

Global Forecast to 2023, "Major players are contributing in manufacturing volumetric display product and services across the world. Some of the prominent players in the global volumetric display market are 3DIcon Corporation (U.S.), LightSpace Technologies Inc. (U.S.), Voxon (U.S. and Australia), Holografika Kft. (Hungary), Zebra Imaging (U.S.), Holoxica (U.K.), Burton Inc. (Japan), LEIA Inc. (U.S.), Seekway Technologies (China), Alioscopy (France), Actuality Systems, Inc. (U.S), Soscho GmbH (Germany), Burton Inc. (Japan) among others." (Market Research Future, 2018)

Many of these listed competitors have toyed with the idea of holographic display as a form of 3D volumetric technology. Holography has been researched and existed for decades in different forms and applications, and even though holography in essence is the capture of a true 3D image, it is not a physical three-dimensional object in space that one can walk around and view from various 360-degree angles.

Much like some of these companies, I also heavily explored holography in my earlier prototype experiments with the intention and hope of creating a true 3D visual output. However, those weren't entirely effective.

While researching global competitors, I reached out to Voxon Photonics (Fig. 6.) as they are the "Creators of the world's most advanced 3D volumetric display." (Voxon Photonics)

Fig. 6. 3D Dragon, Voxon Photonics (https://voxon.co/)

With teams based in Australia and the U.S., Voxon has been in the area of intense research on 3D volumetric display for almost a decade. With assisted volumetric science, they have successfully created a true futuristic display technology that brings content to life and is capable of producing

3D digital images that can be viewed with the naked eye from a 360-degree angle making it autostereoscopic with no optical illusions. When enquiring about their technology applications and product cost, they mentioned that their basic device is primarily sold to the education, advertising and marketing, medical imaging, and gaming sectors at approximately AUS $10,000.

Voxon aims to bring the *digital* world into the *physical* world which is what my end goal is as well, when it concerns this thesis and my prototyping process. What's more, is that they have also made it interactive which is a huge game-changer.

According to the *Market Research Future* report, "3D technologies with a 360-degree spherical viewing angle in parallel with the adoption of LED and LCD technologies are largely contributing to and driving the market growth of volumetric display. They are widely used in the production of consumer electronics and expected to gain much momentum in the years to come… During the forecast period of 2017-2023, the global volumetric display market is expected to grow at USD $747 million at a CAGR of 34%. The regional analysis of volumetric display market is studied for regions such as Asia Pacific (China, Japan, and India), North America (the U.S., Mexico, and Canada), Europe (the U.K, Germany) and rest of the world. North America is one of the leading regions of the world in terms of market share. The volumetric display market in this region has a huge demand due to the technological innovations and technological advancements in 3D displays, which is propelling the market growth to a large extent." (Market Research Future, 2018)

Assessments and technology forecasting certainly help in giving consumers a sense of clarity on what to expect in our near future, and these statistics help in envisioning what the future of this technology might hold. The fact that 3D volumetric display is expected to grow exponentially during 2017-2023, and that North America as a leading region globally is a target market, really places this technology in good stead when it comes to future prospects.

Current industry assessments are important because they investigate a conceivable technology such as volumetric display. These assessments make it apparent that the technology is gathering much momentum and demonstrating great future potential.

Professional Interview: Andrew Garcia, Art Director, Secret Location (Entertainment One)
An in-person interview conducted with Andrew Garcia, an Emmy winning Art Director for Secret Location, a company acquired by eOne (Entertainment One) in 2016. Andrew works with digital experiences and narratives, which is an advantage over his industry peers who focus only on technologies.

The following interview elucidates an industry expert's perspective as well as his predictions and assessments about the current and future state of emerging technologies.

The Future of Storytelling

"Using emerging technologies and content to be able to tell an *authentic story* is what Secret Location believes in."

Andrew and I started by discussing the importance of storytelling and the possible futures of story telling beyond the screen.

Storytelling compels me because it's a central component of mainstream entertainment and the future of screens and screen-free technology will arrive into the consumer mainstream through the entertainment industry.

> "At its core, what is the most human way to converse with say someone else? It's to talk to them, it's the gestures to them, it's not to actually go onto the screen. …You want to escape, you want to be immersed, but why not be able to put on a pair of glasses and be able to do that no matter where you are?" …What if you could *interact* with your favorite character, and what if you could *live* with your favorite character? What if you can experience that world where you come home and that favorite character is actually there with you and asking about your day? Potentially, that could be something. That could be the world that we do live in and a lot of movies like Ex Machina (2015) have talked about this idea."

Andrew's reference to *Ex Machina* (2015) ironically ties into the look and feel of the futuristic head in my prototype content. Sci-fi films like *Back to the Future* and *Blade Runner* and episodes of the television show*, Black Mirror* point towards a fantastical world with speculative technologies. Artificial Intelligence and voice interaction are already important in the market (smart speakers, Siri, GPS, etc.) so a combination of AR, VR with AI could potential change the way we function on a daily basis. Andrew spoke about how volumetric display or a combination of mixed reality landscape could specifically affect entertainment.

> "Entertainment is like this cold medium. We sit there and we watch it, we escape as we're so immersed, but, it's being told *to* us…right now, people are used to that, and if volumetric display finds a way to become economical, it would be a way to physically experience a scene, or be transported into another world altogether.

Virtual reality, according to Andrew, attempts this, but it hasn't yet succeeded fully.

> "There are games, there are movies, but what's in the middle? When that becomes a thing that people demand, it will be a game-changer. It will be whatever technology enables that interaction in branching narrative, the cheapest and the highest fidelity."

If successful storytelling relies on human interaction, then it's safe to say that my prototype has

been influenced by this supposition. The prototype is a talking head resembling a piece of AI and volumetric display through the use of a holographic display fan, and this combined technology creates an impactful, interactive experience. In entertainment, we want to be super immersed but from an AI point of view, we want human interaction. So perhaps Volumetric Display technology won't work in silo but instead it will be a part of mixed reality—which is what my prototype does already.

The Future of the Screen

"We're an *emerging platforms* studio, wherever the technology can tell the most compelling story and connect authentically with humans, that's where we want to be!"

Andrew's work focuses on virtual, augmented and mixed realities and as someone who works for the leading entertainment tech company, this reveals what's hot in the tech and creative industry.

> "Secret Location works on a pipeline of getting content to theatres like Cineplex or AMC and theaters are going to be one of those early adopters for virtual reality and for things like volumetric display, because "It is a way to experience a new medium that people will pay for, since that technology is going to be expensive."

When I asked him the potential of 3D volumetric display being a revolution in screen-based home entertainment he responded "Massive!" and when asked if he can sort of envision this becoming an alternative to home entertainment, he said, "absolutely, a hundred percent!" He feels that in thirty to forty years,

> "Virtual and mixed reality are going to be the thing that ushers us into the next two decades and technologies like volumetric displays and holograms will progress to something that isn't right now—super easy, super affordable to install in homes and in spaces, and eventually become an evolution of it. And again, from a conceptual and storytelling point of view, it becomes a location-based experience like the VOID in the Rec Room in Toronto."

If emerging trends have defined so many technologies like VR, AR etc., then there's nothing stopping volumetric display from becoming the next big revolution! Companies like LYTRO already work in volumetric video to integrate different worlds, real/physical and imaginary.

Trends in Speculative Technology

Volumetric display technology is autostereoscopic, which means it doesn't require headgear, you view the experience with the naked eye. We talked about the question of whether or not screens will completely disappear and Andrew felt that there will always be screens but perhaps our concept of what a screen is, might shift.

> "Augmented and virtual reality is a good ten or fifteen years out to be super consumer friendly and there's the argument that if you can get glasses that make every surface a screen… how cheap is that? But at the same time, companies like Samsung make their money off of screens and selling more of that!"

He reiterated that if glasses were perfected, that could be the big screen for everything and then manufacturers would have less to produce and then the money will then be in the content. It would be easier to be able to, for instance, look at the table for a recipe, without the need for a headset. Andrew also referred to some holographic works with user interfaces that IKEA and IDEO have implemented, where they have an incredibly interactive kitchen table with built-in computers and sensors above, and the use of projection guides you through a cooking experience.

Finally, I asked Andrew "If you could create any kind of content using volumetric display, what would you create?"

> "There are 2 ways of looking at it—What would come first? And what I would want, or how I dream of it. What would come first, would be something that you cannot fully experience with traditional 2D screens. News comes to mind right away. Virtual reality is trying to do it, but again, no one wants to put on a cumbersome headset for news! If something happens in a country that I'm far away from or to a singer that I love or to somewhere I can't be, but its something that's quickly digestible, it'll be amazing to create that scene in your living room—to look around that scene, to see and *feel* what it's like to be there, in a unique perspective. I think that's something that should and would happen. But where I would love to explore something like that, would be entertainment, for sure, whether that be a show or any other traditional type of content. I would love to to see holograms or volumetric displays in this case, because it creates *persistent worlds* and you can really transform your perspective on everything."

Reflection

This interview not only assessed an industry partner's perspective as to the status of emerging technologies in connection with the nascent, volumetric display, but also to help me contemplate on many of these very relevant topics that in fact relate back to my core research question. Most likely theatres will be early adopters of volumetric display because it will be more economical. Also, this type of technology (volumetric display) would be great to be seen large scale.

Theoretical Approach and Contextual Analysis:

Speculating the Future Through the Lens of the Past (Informing Design Fiction)

All technology has historical antecedents, but what is particularly novel about volumetric display technology's technical precursors (television and pre-television) is the remarkable and on occasion, immersive, effects they produced with decidedly low-tech tools.

Volumetric display doesn't exist in the common marketplace, so the only way most people know about this technology is through fictive depictions in science fiction films like *Blade Runner 2049 (2017), Star Wars IV – A New Hope (1977)* and *Minority Report (2002).* As audience members seeking entertainment, we assume that such complicated technology belongs solely in the future and may not have roots in the past, but that assumption is erroneous.

Author Stefan Andriopoulos's book, *Ghostly Apparitions* focuses on connecting literature, media, and philosophy, while stipulating another archetype to prehistoric media studies.

Stefan Andriopoulos places the TV into a long queue of other *optical media* that backpedal to the bizarre Renaissance tests including innovatively actuated dreams and illusions, for example, concave mirrors, magic lanterns, confusing dividers of smoke, and other *mysterious nebulous visions* and *phantasmagoric projections* that were made by unusual gadgets. These were no doubt conjuring tricks, but they depended on complex understandings of essential effects such as light, shadow, and acoustics, influencing a crowd of people to see and imagine in a fantasy. (Andriopoulos, 2013)

A simplistic definition of volumetric display technology could be this: a technical device that produces believable illusions. Hewing to such a definition, the roots of volumetric display can be found in pre-television devices like phantasmagoria and magic lanterns. And while contemporary audiences may dismiss the imagery produced by such early devices as crude or ineffective, it is important to recognize that viewers at the time were utterly swayed. More importantly, these early inventors did a lot with a little; they visualized the future without the tools of the future. The ethos of this low-tech methodology is explored further in the prototype section.

Another antecedent to volumetric display technology is the cathode ray based experiments of Norwegian inventor Kristian Birkeland in the early 1900s. It is not unreasonable to say that without Birkeland, there would be no Blade Runner. Birkeland's immersive environments like his *spacious aquarium* that exulted galactic forms, pre-visualized and significantly predated depictions in contemporary science fiction. (Jago, 2001)

As the first scientist to understand the electromagnetic source of the Northern Lights, Birkeland was driven to create an immersive environment and he wanted viewers to experience the Northern Lights, in miniature. Lucy Jago details Birkeland's story in her book, *The Northern Lights*.

Jago further discusses Birkeland's determination to create a sort of astronomical television set, a *television-like* device whose inner technical workings would demonstrate the electromagnetic secrets of the universe. (Jago, 2001)

While spectacular, this was not Birkeland's ultimate goal.

Jago proceeds to inform us that Birkeland's definitive objective formulated while near-death in a hotel room in Egypt and it was to develop a vacuum chamber mostly unearthed into the strong shake of a mountain top, a crazy blend of tomb, church, and planetarium. (Jago, 2001)

The subsequent cathedral-like space, was an immersive landscape-scale television set carved directly into bedrock that would ideally be an artificial cavern within which glinting electric illusions of stars, planets, comets, and aurorae would sparkle for a spellbound gathering of people. Jago sums Birkeland desires, as endeavoring to bring the skies down to earth in the form of a 1,000 cubic meter television in part slashed from raw granite. (Jago, 2001)

The books of Stefan Andriopoulos and Lucy Jago, help us to consider the early origins of television and the fact that those origins were based on and rooted in, not just nature and the science of the universe, but all things mystical and phantasmagoric.

Ironically, those early inventions tie into current science fiction television and cinema. These historical precursors are particularly important because future volumetric display technology and current virtual reality and augmented reality, as well as science fiction on film and television, bare traces of earlier inventions, not directly in technology, but the persuasive power of constructed, immersive, and fantastical environments.

Design Fiction: Speculative Design (Informing Futures Thinking)

The term *design fiction* was coined by Bruce Sterling in his book, *Shaping Things* (2005), where he references a type of *speculative design* that emphasizes *world building*. (Sterling, 2005)

In view of Sterling's insights, I am applying a *speculative design* method within the realm of *design fiction methodology*, due to the futuristic nature of my thesis study. Speculative design method's efficacy is in imagining possible futures through the process of ideation and the physical creation of things. This in turn, helps in providing further insights and drawing facts based on speculation, which is vital in the validation of my prototype as it assists in exploring and critiquing the future potential of a technology, in this case, volumetric display.

To further define what speculative design is and how it overlaps with other emerging design approaches, authors Anthony Dunne and Fiona Raby in *Speculative Everything*, expand and analyse the essence of design fiction.

They state "Speculative design overlaps with several other emerging design approaches but design fiction is probably the closest, and the terms are often used interchangeably. It is a vaguely defined space where speculative, fictional, and imaginary design all collide and fuse. Although there are obvious similarities, we think there are some important differences." (Dunne and Raby, Speculative Everything, 2013, Chapter 6, Page 100)

Bruce Sterling defines design fiction as "the deliberate use of diegetic prototypes to suspend disbelief about change", which could also describe a precursor of design fiction sometimes referred to as *artefacts from the future*. As it is popularly understood, design fiction is a narrower genre. (Sterling, 2013)

Dunne and Raby further clarify, "It has grown out of the technology industry, and as the *fiction* part of the label references science fiction rather than general fiction, it places a strong emphasis on technological futures. Because of this, design fiction is increasingly being understood as a genre of future vision video (sometimes photos but rarely stand-alone objects) designed specifically for circulation on the internet rather than in exhibitions. Another variation is Brian David Johnson's idea of sci-fi prototyping, which is a more applied version that focuses specifically on using fiction to quickly explore implications for technology in workshops. Inevitably, design fiction suffers from some of the issues associated with film props mentioned at the beginning of this chapter, namely, a dependence on referencing the already known. We are more interested in using fictional designs to suggest things can be very different indeed, consequently our fictions are glitchy, strange, disruptive, and hint at other places, times, and values." (Dunne and Raby, Speculative Everything, 2013, Chapter 6, Page 100)

Dunne and Raby emphasize, "The physical prop is the starting point for a chain reaction developed through other media rather than a reality anchor for the video." Ibid

The exploration of physical props in my sci-fi prototyping process, utilizes the same school of thought, in that it is a start for a chain reaction. The physical props and technology used all through my prototype development are based on MR (mixed reality, a hybrid of two realities - the real and virtual worlds) mediums that advance from simple to complex hi-fidelity models, while being cognizant of speculative design that informs futures thinking.

Dunne and Raby also state, "Like Margaret Atwood's preference for the term speculative literature over science fiction, we prefer the term speculative design over design fiction. Although, strictly speaking, we produce fictional designs, they have a broader purpose than the design fiction genre allows. Another difference that separates design fictions from the kind of fictional design we are interested in is that they are rarely critical of technological progress and border on celebration rather than questioning." (Dunne and Raby, Speculative Everything, 2013, Chapter 6, Page 100)

Materials such as glass disguised screens and display fans, along with techniques such as holography, motion graphics and projection mapping, aim to create a three dimensional volume seemingly in mid-air to give viewers the illusion of volumetric display in my prototype samples. Dunne and Raby's platform of critically analysing technological processes provide useful insights that examine the importance of the speculative nature of design which is essential in addressing my overarching research question that focuses on the creation of a 3D volumetric display, a future technology using existing resources, as realised further in my prototype development section of this thesis proposal.

Science Fiction and Their Trends

To contextualize *science fiction* in the realm of this section, it is important to first define it.

One definition offered by pioneering sci-fi author, Arthur C. Clarke states "the science fiction moniker applies to any fiction dealing imaginatively with concepts borrowed from science."

The Cambridge Companion to Science Fiction describes it as "the discourse of science fiction is about our relationship to the world and the universe" (James and Mendlesohn 2003, 9)

A definition that relates to the following sections, is by Mae Jameson - "I think science fiction helps us to think about possibilities, to speculate - it helps us look at our society from a different perspective. It lets us look at our mores, using science as the backdrop, as the game changer."

Why do we envision the future and what shapes do our future visions take?

Science fiction films specialize in building imaginary worlds and creating the impossible. Often, the very technology that seems viable only within the imaginary confines of a film world leaps from screen to reality. This section explores the journey from improbable fiction to actual iteration.

Blue-sky interfaces (i.e. not grounded in the realities of the present as per Merriam Webster dictionary) are prominent in films such as *Minority Report (2002), BladeRunner (1982, 2017), Star Wars (1977) and Her (2014).* In addition to film, publications such as *Make It So* by Nathan Shedroff and Christopher Noessel, and *Speculative Everything* by Anthony Dunne and Fiona Raby investigate the adaptation and occurrences new and speculative technology into real world.

How does fiction inform real-world design efforts? Dunne and Raby offer three answers to this question.

Their first answer is that "Whether we like it or not, the fictional technology seen in sci-fi sets audience expectations for what exciting things are coming next." (Shedroff, Noessel, Make it So, 2012, Chapter 1, Pages 6 and 7)

This statement holds true. Much of what we see in sci-fi films— the so-called *blue-sky* tools that utilize electronic gadgets alongside 3D technologies and other mid-air surface-based interfaces— have, over the years, been introduced to our physical world. Current technology like touchscreen cell phones, iPads, laptops, and television screens, prove the shift from make-believe to actuality. The concept of 3D, mid-air, volumetric display already sampled in current sci-fi films, could soon be in our future world.

Another response to this question, as per the authors, is that "With media channels proliferating and specializing, common cultural references are becoming harder and harder to come by. Having common touchstones helps us remember design lessons and discuss ideas with each other. Sci-fi is a very popular genre, and the one in which speculative technology is seen most often. If you want to discuss an existing technology, you can reference a real-world interface. But to discuss future technologies, it's easier to reference a movie than to try to define it a priori." Ibid

Dunne and Raby's theories heavily support the application of my prototype process, (described in the later sections of the thesis). To be able to perceive what the future might hold when it concerns volumetric display, I closely examined sci-fi films that depict related futuristic technology.

Finally, Dunne and Raby propose that "Interface makers in the real world and in sci-fi are, essentially, doing the same thing—creating new interfaces. In this sense, all design is fiction—at least until it gets built or is made available to users and customers. When designers create anything that isn't the real, final product that ships, they're creating speculative interfaces—fictions. Each wireframe, scenario, pencil sketch, and screen mock-up says, *Here's how it might be,* or even *Here's how it ought to be.* Designers for each domain ask similar questions: Is this understandable? What's the right control for this action? What would be awesome? Although they ultimately work with different audiences, budgets, media options, goals, and constraints, the work is fundamentally similar. Each can learn something from the other." Ibid

This school of thought also applies to my prototype development. Multiple design iterations, have essentially looked at what volumetric display offers as a technology, what it might or could be, what might be achievable, and what is unique about it, all the while providing a bedrock for the possibilities of a constructive learning experience.

Further, when referring to visual interfaces, the authors propose that "Because television and film are such visual and auditory media, there is great opportunity to study particular visions of the technology of the future and that elements such as colour, shape, symbolism, and typography can create dramatically different screens than those we're used to seeing in real life. Simply put, cataloguing every visual element or style throughout sci-fi would take much more space and hence for the sake of brevity, elements are limited to the use of graphics and text to convey information and controls." (Shedroff, Noessel, Make it So, 2012, Chapter 3, Page 32)

Similar thoughts have propelled the creation of my prototype. Various graphical elements such as a plexus animation, objects that denote depth, have been utilized to convey the characteristic depth of volumetric display.

Among other interfaces, the authors reflect on *volumetric projection* – what it looks like, how they are used, and how it has been defined by sci-fi.

They state, "Volumetric projection is a mouthful. Why not just call it what everyone else calls it—a hologram? Part of the reason is that the term already belongs to another kind of image.

Remember those slightly 3D, multi-coloured shapes etched onto a silver substrate, as seen in the weird ending of Logan's Run? Or just look at a credit card—more likely than not there's a small hologram on it. This sophisticated printing technology has already laid claim to the term hologram, and these kinds of images are not like what we see projected in films." (Shedroff, Noessel, Make it So, 2012, Chapter 4, Page 76)

The authors speculate the usage of volumetric projection or 3D display technology (as also defined in the book) in movies such as *Star Wars* where moving 3D images (Princess Leia) are projected into space and seen from any direction without the aid of special viewing devices such as glasses. According to the author, although *Star Wars* was responsible for establishing the use of volumetric display as the de facto communication medium, it isn't the only example of it in sci-fi. In short, it is used as a mode of communication and navigation among others things. (Shedroff, Noessel, Make it So, 2012, Chapter 4, Page 77)

Given that volumetric projection or volumetric display as per Dunne and Raby overlap with the concept of holograms, for decades, holography has been the primary technology used to illustrate true 3D imagery and for this reason, I used holography in my initial experiments.

Nathan Shedroff and Christopher Noessel then emphasize, "Volumetric projection has been defined by sci-fi and has the main benefit of presenting information in a way that matches how humans sense most of the things in the world around them—in three dimensions. Our binocular vision, stereophonic hearing, and use of motion parallax are major inputs to understanding and interpreting the information that is contained in 3D space. Volumetric projection's promise to bring this capability to bear in our digital interfaces. But until volumetric displays in the real world become cheap and ubiquitous, most of us will design for and experience it in sci-fi. Perhaps its continued presence there will help push it forward in ways that will make its eventual adoption in the real world smooth and usable." (Shedroff, Noessel, Make it So, 2012, Chapter 4, Page 90)

The relevance of these theories, help predict the impact of future technologies. Although there is much potential for volumetric display and its uses in the real-world, the likelihood of it being a part of our everyday lives within the next decade is yet to be established.

Dunne and Raby contend that "If we speculate more—about everything—reality will become more malleable. The ideas freed by speculative design increase the odds of achieving desirable futures." (Dunne and Raby, Speculative Everything, 2013, Chapter 6, Page 100)

Diegetic Prototypes: Why we use film as a medium to imagine the future

Bruce Sterling defines the term diegetic prototypes as "an approach to design that speculates about new ideas through prototyping and storytelling." (Sterling, 2012)

The application of diegetic prototyping is an important aspect of this thesis because it helps to speculate a future technology, and is an approach to create a prototype that examines need, viability and benevolence.

Author David Kirby in *The Future is Now*, helps to position this expression, stating that he "introduces the term *diegetic prototypes* to account for the ways in which cinematic depictions of future technologies demonstrate to large public audiences a technology's need, viability and benevolence. Entertainment producers create diegetic prototypes by influencing dialogue, plot rationalizations, character interactions and narrative structure. These technologies only exist in the fictional world—what film scholars call the *diegesis*—but they exist as fully functioning objects in that world." (Kirby, 2016)

My final hi-fidelity design applies and integrates multiple components, from fictional scientific theories to pre-television antecedents, and also uses a diegetic prototyping process.

David Kirby gives an example from the virtual worlds used in film director, Brett Leonard's *The Lawnmower Man* (1992). Kirby helps to visualize the potential of computer-based technologies, specifically virtual reality (VR) and three-dimensional (3D) interactive technologies.

Based on Stephen King's short story, *The Lawnmower Man* (1992), according to Kirby, is "about a guy who telekinetically controls a lawnmower to rip a guy apart." As per Kirby, when director Brett Leonard was tackling his approach to the film, "the minimalist nature of the source material presented him with an opportunity to create a film based around the VR technologies he had been discussing with digital pioneers such as Jaron Lanier." Ibid

Kirby further discusses Leonard's goal for *The Lawnmower Man* (1992) which was "to create a modern *technological mythology* featuring interactive technologies" through the "film's computer-generated visual effects that served a dual purpose for Leonard. First, the state-of-the-art computer graphics would be the film's major selling point. Second, the VR world inhabited by the film's central character, Jobe, would illustrate for the audience VR technology's potential applications in the real world. For Leonard, VR represented an extreme example of the types of interactive technologies he was publicly promoting. 'If you go back and read the profiles of that

time, I was crying for a revolution. I saw an end of passive media and the beginning of interactive media.' Ibid

Kirby's examples in this article not only demonstrate the importance of a technology's need, viability, and benevolence, in diegetic prototyping, but also uses this design method to analyze why we use film as a medium to imagine futures.

This thought process is carried out in the study of my prototype as well. Director Leonard emphasizes that visuals are an important vehicle in promoting the potential of a technology. Similarly, the visuals explored in my design iterations as a result of utilizing a speculative design method, science fiction theories in films such as *Blade Runner 2049* (as seen in the subsequent section), audience feedback, as well as a diegetic prototyping process, are all vehicles implemented to propel my hi-fidelity prototype. These approaches help in reducing the gap between imaginary and real objects.

'Blade Runner 2049' (Denis Villeneuve, 2017)

As we already know, science fiction theories tend to be obsessed with the future, not just from an ethnographic point of view but from a profound technological perspective.

In sci-fi films such as *Star Wars* (1977) and *Minority Report* (2002), as well as *Blade Runner 2049* (2017) and *Black Mirror* series (2017), technological trends tend to recur and advance. The need for sci-fi film writers to become more imaginative is increasing because technological advancements and scientific development are becoming reality.

Since this study focuses on films that explore the future of technology and examines current trends that anticipate the future (demonstrated in the earlier sections), I will unravel the world of a recent film, *Blade Runner 2049* (2017).

The critically acclaimed sequel by Québécois Director Denis Villeneuve, which builds on the original story of *Blade Runner* (1982), centers around a dystopian future. Created with a budget of $150 million, it is a major breakthrough in terms of futuristic technology, specifically within the realm of volumetric display.

Blade Runner 2049's toxic and chaotic world utilizes a diverse array of technologies. Primarily these are AI and holography, along with digitized wearables and augmented reality. Maks Fus Mickiewicz, a senior journalist in *Is The Technology Of Blade Runner 2049 Already Here?* asks, "How does the fiction measure up against *The Future Laboratory's* trend forecast?" (Mickiewicz, 2017)

Mickiewicz scrutinizes *Blade Runner 2049* (2017), from the point of view of its flying vehicles, prescient prediction of future cities, replicants and functioning androids. Mickiewicz first looks at

the character *Joi*, a holographic artificial intelligence (AI) system, who connects with smart home devices as well as to the romantically connecting to the protagonist, Officer K. Mickiewicz states, "There is an emerging market for humanoid love" while indicating that this technology is very much in existence already. Ibid

I agree with Mickiewicz. Current world scenarios, have an influx of AI-based platforms such as Google Home, Amazon Echo, Siri and the Alexa that basically aim to provide assistance to our everyday living, which is exactly what is happening in *Blade Runner 2049* (2017).

Fig. 7. "Is The Technology Of Blade Runner 2049 Already Here?" Maks Fus Mickiewicz

The fact that the focus in this film is primarily on holographic technology that represents AI, in this case, *Joi*, who is a holographic assistant, leads me to believe that a technology like volumetric display is closer to our reality than we think. These types of sci-fi perceptions have not only proved to be accurate predictions they've also made sci-fi technology commercially available. Countless prescient visions have in fact come to our reality within a short duration.

The humanoid-based concepts in *Blade Runner 2049* (2017) have greatly inspired my thinking and the application of content such as the futuristic *talking-head* news reporter appears in my final prototype. As seen in the film, mid-air display holography, a form of volumetric display, is not only common, but is produced using 2D materials and visual effects. This parallels the construction of my final prototype.

C. PROTOTYPE DEVELOPMENT

Introduction

My prototype development, utilizes speculative design within the spectrum of design fiction methodology. The prototype's form and content is informed and inspired by the technical antecedents of volumetric display: pre-televisions ethereal occurrences such as phantasmagoria, magic lanterns, and Kristian Birkeland's cathode-ray immersive environments. The content of the prototype specifically references the launch of broadcast television in North America whose only content, at the time, was news. In each prototype iteration, I use 2D technology to create a 3D visualization.

Since my research revolves around a technology that doesn't exist yet, the purpose of my prototype is primarily illustrative. The goal is to give my viewer an insight into future possibilities. The challenges and probabilities of creating future technology with the limitation of current materials are explored in this section, while my research culminates in a high-fidelity design fiction experience.

The creative and technical process used in each of the prototypes is elaborated below.

Experimental Design Prototype 1 - Mixed Reality (Holography + Projection Mapping)

My first prototype was created in collaboration with holographic expert Professor Michael Page (The Phase Lab, OCADU) and his talented team, for an *in-class* critique.

This nascent prototype was a mixed reality (MR) based experiment that utilized holography and projection mapping technology. The arrangement consisted of a transmission hologram with the image of a 3D vase along with a motion graphic based plexus animation.

The prototype was deliberately setup in the dark due to the nature of the technology being used. Transmission holograms require a light source to shine through them to be able to view the depth of field and the three dimensionality of the image clearly. Hence, here the projector (that was used to project animation over the hologram), acted as the main light source.

Since I was attempting to mimic the extraordinary mid-air qualities of volumetric display, my initial intent was to suspend the hologram from the ceiling, however, that wasn't feasible. Due to time constraints, I utilized a hologram that belonged to the Phase Lab but it was too precarious to dangle an expensive glass art object in the middle of a dark room, and so I secured the hologram to an iPad holder. A short throw projector was used to illuminate the hologram surface with animated plexus graphics. However, the projection bled beyond the surface of the hologram onto the wall, which wasn't the intention. (Fig. 8, Fig. 9)

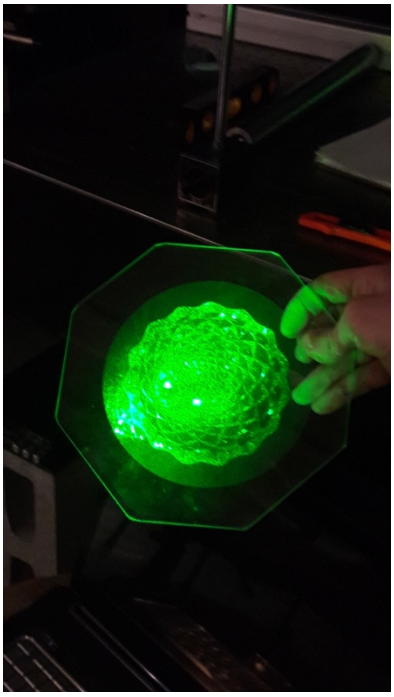


Fig. 8. Photo of Prototype 1 (Transmission Hologram) by Natasha Mody

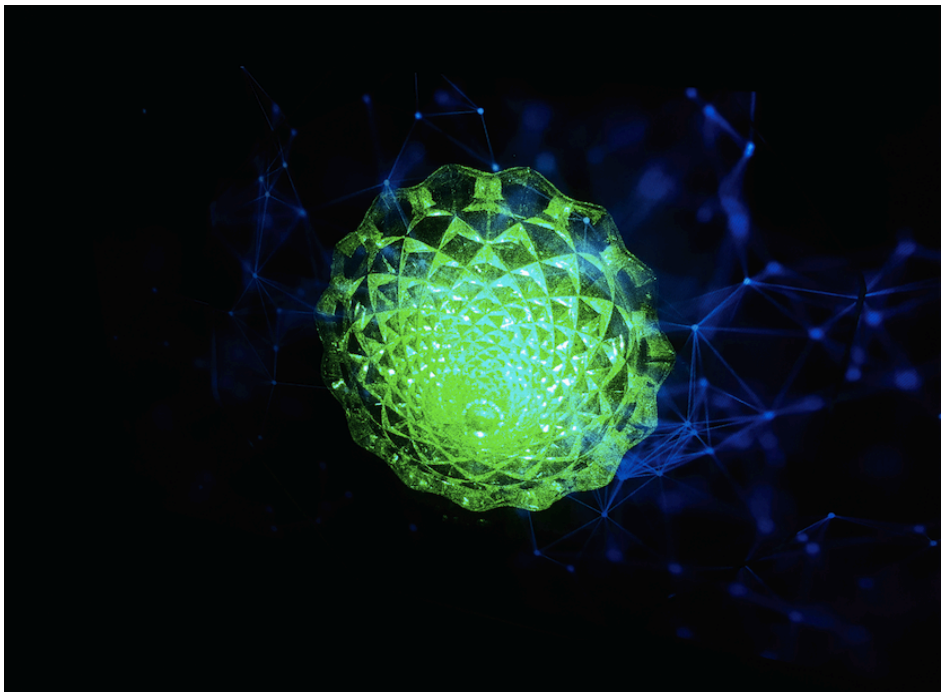


Fig. 9. Photo of Prototype 1 (Hologram + Projection Mapping) by Natasha Mody https://vimeo.com/260729689

The feedback received from my advisors and peers was that, even though they could see that I was trying hard to explore what this technology has to offer, this direction wasn't necessarily the most effective. In general, criticism pertained to both the scale of the projection and the content of the projection. The audience felt the scale was too small and that in order to create an immersive experience, the scale needed to be much larger. As far as the content goes, the audience couldn't relate to it. They suggested something with realistic intent, a human face, or a talking head telling a story. My peers wanted more depth and they wanted that depth to change over time, quite like how a person walking towards a camera gets larger the closer they are to the lens. My peers also suggested I conduct multiple, small experiments. The most vital criticism that I received, was also the idea that I was most frustrated with—that this prototype still relied on screens; it was still flat.

The aim of this experiment was multifaceted. It uses existing 2D technology to produce the illusion of volumetric display and show depth within a dynamic space. The interaction between the transmission hologram and the projection created a hybrid, mixed reality (MR) design that merged in the same space and attempted to create an illuminated three-dimensional autostereoscopic experience which needed no head gear!

This first prototype was preliminary but it was plausible, it was firmly situated within the realm of design fiction, and it offered a glimpse of how the technology might work.

Experimental Design Prototype 2 - Mixed Reality (Holography + Motion Graphics)
Taking into account all the prior feedback from the class critique, I tried a few small experiments.

One experiment was the pepper's ghost; whose glass reflection trickery gives the illusion of a 3D form.

Given that I was asked to *explore* different techniques with existing technologies, I created another mixed-reality hi-fidelity prototype. The little experiments led me to the larger, more detailed second attempt that was explored in the main gallery space for our final thesis show at the end of our 2017 Fall term.

The setup here again was in a dark space; this time around, it was a lot more advanced and sophisticated. It consisted of an original, self-built transmission hologram created in collaboration with the Phase Lab experts. A motion graphics animation piece was also created.

The hologram was meant to be suspended in mid-air and placed in front of a *disguised* screen that played the motion graphics. This took place in the black box of 49 McCaul gallery space. The goal was to blend still and dynamic elements to evoke a significant depth and three-dimensional illusion.

The physical creation of a living room came about as a result of my initial reference and prior interest to domesticity based on social arrangements within western cultures, specifically North America. Shared viewing experiences originated in the early 1930s with the invention of the television in North America, and this helped to contextualize it.

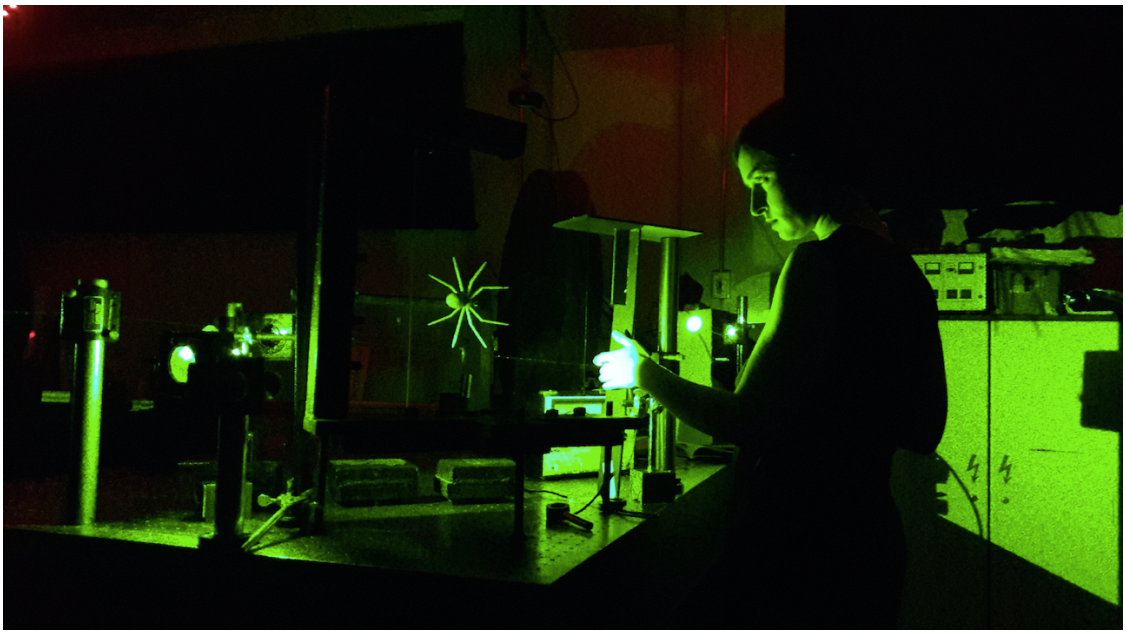
The content of the hologram posed many challenges but was a result of a lot of ideation, and was meant to represent pragmatism as well as reference the content of early television. The choice of content, a spider and its web, related to early BBC programming that focused on the natural world.

A 3D printed spider was created and then placed in the middle of an abstract web, crafted with fishing wire and hot glue, and threaded through black foam board. Multiple small tests were done before the final hologram (with the main subject matter i.e. spider and web) was recorded in the Phase Lab with the support of Professor Michael Page and his research assistants.

The arrangement included a physical living room space with a couch and a small coffee table. The hologram was hand-held in front of a disguised iMac screen that played a motion graphic animation of multiple little spiders. The laser was angled at 45 degrees so that the depth of the transmission hologram was seen clearly in the dark.

The hologram that was to be suspended unfortunately didn't happen for various logistical reasons, so it was hand held for the presentation. This was one of the setbacks. Another setback was that a part of the hologram broke while trying to create holes in the corner of the glass to suspend it. Since that didn't work out, we applied a strip of acrylic to the glass that needed to

bind overnight which delayed the process further. Other logistics became bigger issues as well, but it was a great learning experience overall and it felt great to explore yet another prototype. Some thought I went overboard with this presentation, but my aim eventually was to present something unique at this exhibit.



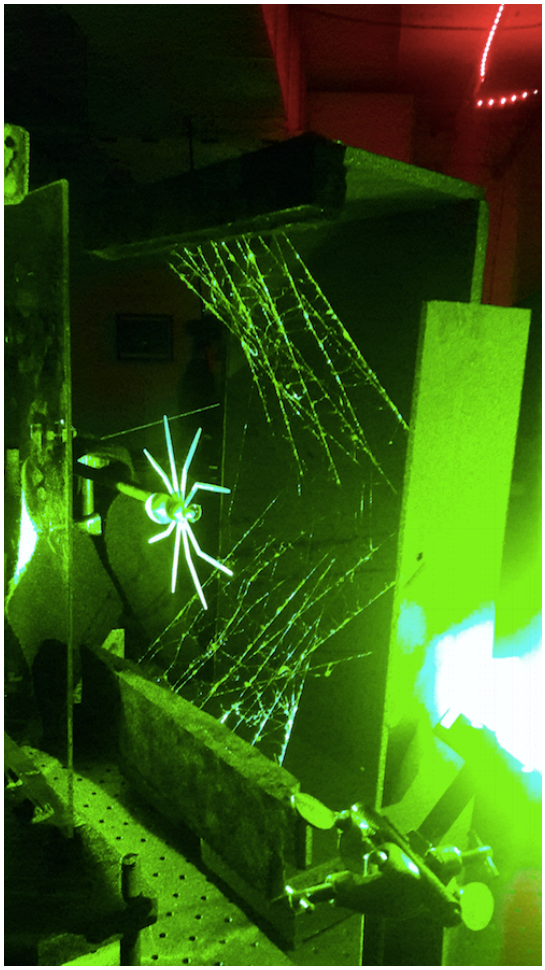


Fig. 10 (top), 11 (left), 12 (right). Photos of Prototype 2 by Natasha Mody

The audience was excited and I received mixed views. While some gave wonderful reviews, others gave constructive feedback. The efforts, time, energy, and resources that went into this experiment was appreciated and valued, which was most encouraging.

However, as per the feedback, this experiment wasn't entirely effective. One reason was that the background imagery and the hologram didn't work in terms of color comparison. The existence of two colors caused people to view two separate elements, when my goal was to have my audience only see one thing. I also needed to figure out how the animation worked with the hologram, because I needed to have the little spiders coming out of the black space, in z depth, from behind the hologram so that it made it more believable. The static holographic image and the animation behind it, didn't work well with each other. Some felt that I had done enough experimentation with the holographic film and that maybe I should try using other materials and technologies. Perhaps by having both layers moving, rather than one dynamic and one static, would make a difference.

The main objective of this speculative experiment once again was to achieve a sense of volume and depth. Although this prototype tried to somewhat do that, it wasn't entirely effective. It failed to convey complete three dimensionalities through a sense of depth, but as an experience, it was admired by many.

While I learned a lot about holography (working closely with the Phase Lab and through a workshop series) and mixed reality technologies, these design iterations helped me realize that these mediums weren't necessarily the best direction for the upcoming, final design prototype and defence exhibit.

Final Design Prototype – Mixed Reality (Holographic Display Fan + Projection Mapping)
The final prototype attempts to create a unique experience that assimilates the trials, errors, and successes of the earlier experiments. It focuses on and relates back to my primary research question, *"How might one create a 3D representation of volumetric display, which is essentially a technology that doesn't yet exist, using current technologies? What are the conceptual possibilities and technical challenges of prototyping a future, speculative, technology with current available materials?*

To address these aspects, the technology, content and the overall experience, relate to the sections detailed in this thesis, and subsequently referred to in this section.

Given that the prior two experiments weren't entirely technologically effective, especially the choice of technology that was used to support the experience, the final prototype required a new approach.

I extensively researched the following techniques: the use of fog, holograms, pepper's ghost, volumetric film, as well as Voxon's top-of-the-line volumetric display technology.

What proved most applicable and compelling were the distinct characteristics of the *holographic display fan*. Produced primarily in China, the holographic display fan has been used within advertising and at global expos. The fan consists of LED (light-emitting diode) handles that rotate when turned on. The fan rests on a fixed base that is wall-mounted. Accompanying software converts the file output and the content (images and animations) can be stored on a 4GB SD card.

The fan gives the audience an optical illusion of 3D volume by creating images seeming in mid-air. Technically, this is possible due to the vibrations and oscillations of the LED handles.

The fan as a device is very effective for the purpose of this prototype, and what's even better, is that it's compact, convenient and easy to use. The other mediums that were researched or then tested, didn't seem to provide the same visual impact as this display fan.

The content for this hi-fidelity prototype is a talking head—a futuristic reporter. The choice was based on many factors relating back to earlier sections of this thesis, particularly the ethereal and phantasmagoric imagery of pre-television eras as well as the launch of NBC's original news content on television that was first broadcast in North America. I also considered and incorporated the importance of human connection to AI (artificial intelligence) such as *Ava* in the film, *Ex Machina* (2015).

The prototype's concept falls into in a retro-future, cyberpunk genre.

The content was created in collaboration with Siddharth Gautam Singh, the Co-Founder and Creative Director, of 3 10 Studio, Barcelona. The creative process commenced with the finalization of a well thought out script that worked as a base for the visualization process that was further developed.

For the talking head, a series of time-consuming shoots with a suitable and talented model, Sanjana Kumar, was executed in collaboration with OCAD peers, Katie Micak and Dave Foster. The shots were then edited in post production and treated in Cinema 4D and After Effects. Many design iterations were produced to test the look and feel on the display fan, while keeping the objective of 3D volume and depth of field in mind.

To produce an immersive and captivating experience, galactic-like motion graphics from NASA's official archive were utilized. The idea was to create an awe-inspiring experience while contextualizing the primary subject matter further i.e. the talking head.

The setup consists of two elements; the primary element comprising of the holographic display fan that plays the talking head, the futuristic news reporter, in the foreground (mounted to a fake black wall), and the secondary element consisting of the galactic NASA-based motion graphics projected onto a fake black wall, in the background. The projection mapping utilizes a masking technique to ensure there is no overlap of imagery on the display fan.

For multiple reasons, the set up needs to be in a dark room. Being in a dark space, enhances the impact of the visuals given the use of LED lights emitted by the fan, it also helps create a sense of intrigue and emphasizes the mysterious origins of the imagery. Another reason is that it relates to pre-television era and Kristian Birkeland's immersive experiments. More importantly, with reference to Andrew Garcia's (interviewee) thought process, volumetric display, in all likelihood will first occur in theatres due to the impact of its scale, affordability, and our current desire to watch a film in the dark, especially when in theaters.

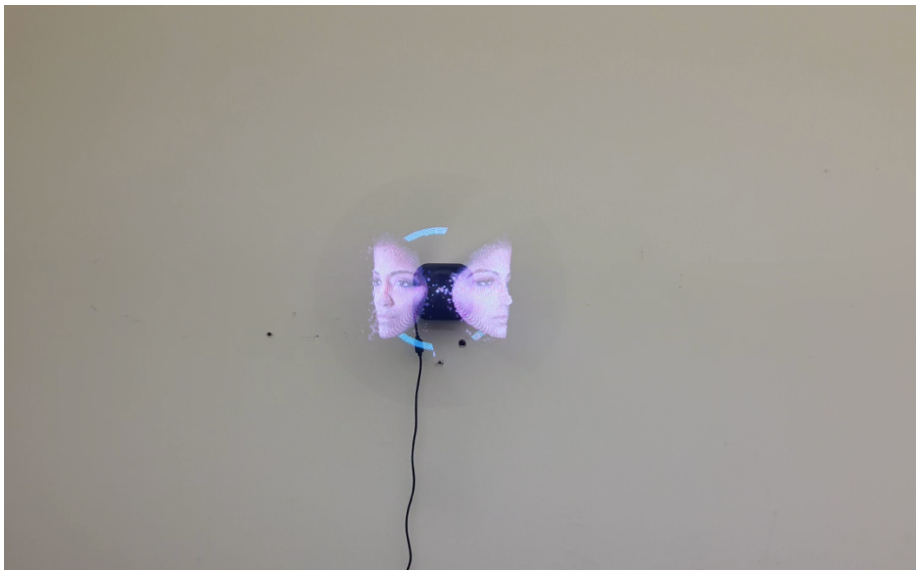


Fig. 13 (top), 14 (bottom). Photos of Final Prototype by Natasha Mody

Some of the prototypes' challenges relate to the limitations and drawbacks of the fan. File resolution is fairly low (445x445 pixels) and this affects the visual quality. Such low resolution doesn't allow for exacting details and special effects. Solid shapes, bold colors, and images created in 3D, work best as they illustrate depth of field and volume.

The biggest hindrance, is the fan's lack of audio capacity. This made the use of a talking head concept very challenging because there is no way to lip-sync audio to video. The use of external speakers was considered, but it would produce a lag between audio and video, making it quite ineffective. To solve this, a different plan involving a 3D animation of the talking head in the shape of three rotating masks that simply blinked, with no lip movement, was generated so that there was no need to lip sync the fan's content to the audio. Instead, the audio output was produced by the content that was projected onto the background element (the fake wall). The outcome was bizarre and futuristic, but one of the only possibilities to solve for the lack of audio synchronization.

The final step of this process utilized a user experience test and feedback. The feedback assisted in conceptualizing future possibilities of volumetric display as well as evaluating the conceptual possibilities and technical challenges of prototyping a future, speculative, technology with currently available materials.

The user experience test employed a *think aloud* approach and was conducted with five graduate students (peers) from OCAD University's Digital Futures program, who are predominantly millennials. Millennials were intentionally chosen primarily because they grew up immersed in technology and are very adept at adopting and using emerging technologies.

There were some challenges that were posed the day prior to the user test as the file that was being tested became corrupt and resulted in distorted imagery. After troubleshooting with the vendors in China, the issue was resolved. The participants experienced the visualization of the content on the holographic display fan while I introduced my thesis topic and reiterated my primary research question:

> *"How might one create a 3D representation of volumetric display, which is essentially a technology that doesn't yet exist, using current technologies? What are the conceptual possibilities and technical challenges of prototyping a future, speculative, technology with currently available materials?"*

When asked if the prototype gives the optical illusion of 3D volumetric display they responded that it definitely does that and the visualization really works.

They got the impression of 3D objects floating in the air and a sense of depth. They suggested that although the visuals of the circles are hypnotic, that they should fade when they float towards

the edge of the fan. They commented that the wide viewing angle, along with the fact that the content rotates, was especially successful. Overall, the respondents felt the effect was powerful.

When asked what type of spaces they could imagine encountering this technology, one viewer, who comes from a gaming design background, suggested it could be used as an instructional video in some sort of public facility, like train stations and airports, where AI-based virtual intelligence could speak to the public. Another viewer proposed that it could be an informational video for educational purposes because it looks very good. The medical field, for plastic surgery was another response as the face seemed broken. They also said it was very futuristic and super sci-fi.

When referring to the overall scale of the prototype, one of the participants thought the holographic fan was too small especially given the increasing sizes of televisions. The fact that it was almost at eye-level made it too personal and perhaps mounting the prototype higher would produce a more God-like and immersive experience. Even so, the respondent enjoyed the immense depth that was created.

When it came to their first impressions, they responded that it was very visual because it lights up in the dark. They were very intrigued by the overall effect, so much so, that they wanted to get closer to touch it and figure out how it worked.

With reference to how they would enhance the experience, viewers mention that if the audio had been synced, that might have enriched their overall experience.

When probed about this technology becoming a reality in the near future, one viewer said "Absolutely! It's already a prototype, right?" Another said, "Reality, yes, but *widely-used*, less so." One viewer added that this concept is being used globally through different mediums that try to achieve this sort of 3D volumetric display. Some also thought that projection mapping on buildings is similar to this prototyping experience, except it's 8K resolution!

Another important point that made was that when looking at the future of television, everyone in the market is eagerly trying to achieve a hi-res 3D output. Sky TV tried to do this at one point and it didn't work and emerging technologies such as VR attempt a 3D experience but haven't been too successful because a viewer has to wear headgear and people don't want to do that. They also proposed that television as long as we've known it, has been flat and that this holographic display fan has similarities in it being flat which may give it an advantage over other potential technologies.

In terms of how they envisioned exciting content and applications for a future version of 3D volumetric display, some responded saying it would be primarily entertainment (movies), and that they won't necessary infiltrate homes but compared it to going to an IMAX theater. They don't

see this as a technology that will be promoted in arcades in the way VR is. Another response mentioned, highway advertisements. One of the most interesting responses was that sci-fi already promotes this technology and that it could even be a mode of shopping through cell phones because it could realistically show scale. Others suggested that early versions of content could be more like television and news-based.

The active participation of my OCAD peers was really appreciated and their feedback was very useful in identifying key factors that impact the objective of my thesis.

Their feedback confirmed that the final prototype version, which combined the talking head with the holographic display fan, produced a sense of 3D volume while simulating a plausible volumetric display technology. Similar to Kristian Birkeland who created a lot with very little, I created a hi-fidelity 3D prototype with current 2D technologies.

While viewers appreciated the immersive effects of viewing the prototype in a dark space the display fan spins at a very high speed, which could be hazardous for viewers. To help resolve this, I will be mounting the fan higher, as well as cordoning off the space and adding signage. This change in height will also address one of the participant's concerns about wanting a more dominant, God-like experience.

In past experiments, scale was problematic, so it was imperative to receive pertinent feedback about it in this final prototype. The participants felt that the fan was too small, but I clarified that the final design for defense and the thesis exhibit in April 2018, will have the fan mounted on a large 6x8 feet fake black wall with motion graphics projected onto it. This would obviously increase the overall scale and depth significantly, making the experience more immersive and awe-inspiring.

The likelihood of this technology becoming a reality in the near future seems quite probable based on my research and the user test I conducted. The participants echoed some of the responses I received from Andrew Garcia's interview, which suggested that although emerging technologies like VR have snuck into our lives and attempted to create a magnificent 3D experience, they have not been very successful. A main benefit of volumetric display is the fact that it is autostereoscopic and even though it hasn't reached the masses yet, there is an immense probability within the near future that it will be commonplace in theatres. Perhaps later, this technology will be in domestic spaces as a mixed reality (artificial intelligence and volumetric display) device.

My peers imagined seeing this technology used within medical and educational industries, as well as advertising, shopping malls and expos. As observed within the horizon scan of this thesis, multiple competitors in the global market are already exploring these options. This technology is already, albeit gradually, creeping into our everyday and this helps form a foundation for a

tremendous and wide-spread future use.

This mixed-reality, hi-fidelity, prototype demonstrates that a futuristic technology can be created using current day materials. I achieved my primary objective quite successfully.

The prototype represents a scene out of a sci-fi film intentionally because volumetric display is futuristic in nature and entrenched in speculative design and sci-fi theories that define our tomorrow. As discussed in earlier sections, future trends in narrative entertainment illustrate that audiences want a compelling story told through an awe-inspiring experience. I believe my prototype gave my audiences a sneak peak into the future of what will eventually be a common entertainment and domestic technology.

D. CONCLUSION

This thesis explored the future potential of 3D volumetric display by analyzing its unexpected and unpredicted past. By studying the technological antecedents of volumetric display, I discovered that future technology has and can be imagined, and subsequently constructed, with decidedly low-tech materials.

This ethos, along with a horizon scan technique, and a strong theoretical approach grounded in sci-fi genre theory informed the conceptualization and development of my prototype. Creating multiple prototypes and incorporating participant feedback helped me unravel and explore speculative territory.

By speculating about design, I simultaneously speculated through design, and that speculation produced a hi-fidelity prototype that delivered a 3D volumetric display using only 2D technologies.

Through user experience feedback and an interview with an industry professional, I determined that the likelihood of volumetric display technology becoming a reality in the near future seems not only probable, but also nearly certain. The technology will most likely first occur in theatres and then eventually will be commonplace in domestic spaces.

Emerging technologies like virtual reality have already crept into our lives and while they attempt to create a magnificent 3D experience, they have not been very successful. The desire for immersive storytelling is clearly demonstrated in the current entertainment industry and because volumetric display technology is autostereoscopic, it will certainly have a leading role in filling this gap. As part of a mixed reality technology, volumetric display would provide the most immersive experience for viewers and consumers.

E. FUTURE DIRECTIONS

Based on conducted research, observations, and the outcome of the prototyping process, the future possibilities of volumetric display technology seem both enormous and multivalent.

In the context of this thesis, I would like to outline three possible and future applications within the realms of public space, domestic space, and entertainment.

Within these spaces, my imagined, albeit based on research, scenarios are greatly inspired by the historic pre-television spectacles discussed earlier in this thesis. I'm especially indebted to Norwegian scientist, Kristian Birkeland's immersive phantasmagoria, which presciently established a trend coming to fruition, many years later. These pre-television technologies not only provide historical and technical antecedents but they also help establish a trajectory from screen-free, low-tech, smoke and mirrors experiences to the advent of screen-bound television, to the future of images which oddly enough, seems to loop back and nod to the history of screen-less media.

Although volumetric display technology will most likely appear in theaters and public spaces before becoming common in the domestic space, I'd like to commence discussing future possibilities within the domestic space for several reasons.

The origin of television broadcasting was news coverage, first launched by NBC in North America in the early 1900s. I purposefully incorporated this fact in my prototype by having a talking head deliver a pseudo newscast with the aim to create a future technology that alluded to the cultural and technical importance of the first television broadcast.

My personal opinion is that volumetric display technology will eventually become a common fixture in most homes—just as having a television, slowly but surely, became common in the living room.

Throughout this thesis I've not only dealt with the technological elements of volumetric display technology, but also how this technology impacts the way stories are told. While not fictional, news coverage *is* storytelling and for this reason, it's imperative to look at how volumetric display technology would impact the delivery and the content of news within a domestic sphere.

Home Space:
When referring to the *home space* or the *domestic space*, as has been referenced earlier in this thesis, it is important to note that the television rooted itself in the *living rooms* of North America. Not only did this ingenious device bring families together, making shared viewing a bonding experience, but it also brought news from far away, into the comfort of people's homes.

Consider this futuristic scenario. If news about the chaos in Syria is broadcast and that broadcast could take you to the *live* scene, effectively making you *a part* of the news, it could shift how news impacts social justice and political awareness. If viewers feel like they are in a space, perhaps it would make the problems of that space harder to ignore.

In this sense, viewing not only becomes immersive, but also experiential.

Volumetric display can be envisioned as the future of the screen, it surpasses television within domestic space because volumetric display technology can immerse and transport viewers into an unknown world, all from the comfort and familiarity of their couch.

Another relatable instance looks at families that are spread across geographic locations and who already utilize Skype and Facetime to stay in touch. But, imagine being able to connect and communicate with family and friends in 3D and mid-air, imagine being able to easily transport to your favorite street or café. It's perhaps a logical and improved extension of Google street view.

Such immersive and space-travelling experiences have existing and historic science fiction references. So of course, a fictional plot device like the *holodeck*, from the television series, *Star Trek* by Gene Roddenberry (1966), that imbued stories and storytelling, could be considered the living room of the future.

Star Trek first aired in 1966 and 52 years later, in 2018, we are still hungry for this immersive technology. Hence, it doesn't seem unfathomable to dig deeper into the way in which these technologies help to re-imagine and redefine space, especially when it comes to a technology like volumetric display that brings qualities of volume and mass data with it.

Of course, it's prudent to also consider the potential disadvantages of volumetric display technology within domestic space.

Throughout this thesis I have expressed the immersive limitations of screens because of their inherent two-dimensionality, but their flatness also provides a degree of discretion, privacy, and independence. What would the drawbacks be though of multiple and conflicting streams of entertainment, floating in mid-air, within a domestic space?

One potential drawback is the distraction that could be caused when household members are trying to engage in different mediums in the same space. For instance, picture a scenario where household members are attempting a shared viewing experience, much like watching a television show, but with 3D images in mid-air, while others, are second screening trying to shop perhaps and are also viewing their products as hi-res 360 mid-air displays.

More so, we think of dystopia in terms of narrative, but a potential drawback could be that people

become more disconnected and a shared viewing experience, isn't one any longer. In fact, it affects human interactions within a domestic space.

In current situations, if multiple streaming causes a huge disconnect, with families sitting at the dinner table, ignoring each other and just staring at their phone, what will it be like when shoe shopping, tweeting and the news are all hovering over the dinner table? It would be quite chaotic.

Public Space:
Volumetric display technology could have many uses in the public space. A public space is generally a place that is open, accessible and is shared by people. Public spaces can include restaurants, cafés, museums, parks, beaches, trains, movie theaters etc.

For the sake of this discussion, let's focus on the use of this technology from the perspective of scale within a public space.

Scale significantly impacts consumer experiences in public spaces. Scale is also important for optimum experiences of volumetric display technology, much like the experience created by my final hi-fidelity prototype within the spectrum of this thesis.

However, if the scale of volumetric display technology could someday match the scale of particular public spaces, such as shopping malls or museums, the combined impact of technology and architecture could redefine how we deal with the parameters of public space. The potential for reimagining immersive, educational, or way-finding methodologies is significant.

Shopping malls and expos around the world are gradually utilizing the concept of holography to promote their products and brands. At this point, many are using the holographic display fan, the same technology incorporated in my final prototype. Tailored 3D imagery, floating in mid-air, is hard to resist. Such immersive and electrifying experiences would obviously compel consumers to purchase whatever product is being advertised.

Advertising thrives on novelty and what's more novel than a tailored, immersive experience? Not only is this a great way to capture consumer interest, it's also a great way to introduce consumers to an advanced piece of technology that they then might want to someday incorporate into their domestic space.

In this case, the scale of images produced by the fan doesn't affect the marketing of the brand but what makes the overall experience often impactful, is the placement, the number of fans used, and the type of imagery that's created.

This is evident in the recent Hypervsn solution, created by Kino-mo at the CES 2018 Expo that

took place in Las Vegas (Jan 7, 2018): Kino-mo Link Here. The technology was similar to the holographic display fan and consisted of an assemblage of multiple fans generating stunning 3D visuals. Viewers perceived the images as hi-resolution holograms floating in mid-air!

This type of large-scale visual attraction is powerful and disruptive, not an obstruction, given the space it is situated in. While this works well for places such as malls and expos, some thought to other public spaces like museums and theme parks or even music concerts and airports can be considered for a technology such as volumetric display.

This multiple fan approach works well for expos and malls so it's a logical conclusion to assume applications in even larger spaces such as airports, theme parks, museums or even concerts.

With reference to museums, applications of mid-air display devices used in the earlier film reference *Blade Runner 2049* (Villeneuve, 2017), comes to mind. The film portrays many instances of volumetric display technology, not just in the form of the character *Joi*, a holographic artificial intelligence (AI) system, but also from a navigational point of view. So, what if visitors at a museum were given a device that helped direct them? Upon activation, the volumetric display technology (scalable with gestures) would map visual cues, in mid-air, that directed visitors to the particular space within the museum they wanted to visit.

In essence, 3D projection enables a deeper exploration of scale in the viewing experience and that aspect is vital to keep in mind for any future direction taken within the realm of public spaces.

Of course, the larger the scale, the more potential the disruption, but because volumetric display technology has the potential to be variously scaled, this is not a limiting factor.

Entertainment:
Based on the conducted research and user feedback received, the next leap in entertainment experience is the incorporation of volumetric display technology in movie theatres. As a trend, virtual reality, augmented reality and 3D viewing was first tested industrially and then moved down the pipe into commercial venues. The same will probably be true of volumetric display technology.

While evaluating what the future of entertainment might hold when it comes to volumetric display, I envision this exquisite autostereoscopic experience coming to life, in two different ways-

The first would be hi-res floating images viewed in parallel to the screen, bringing the digital to the physical world, while the audience watches in the same direction, similar to our current viewing in movie theaters.

The second, is the creation of a 360° hi-res 3D imagery that allows the audience to view it from any angle, making the audience feel more immersed and integrated with the scene! Similar to gaming, where the player has the option of being a special character in the game, allowing for participation while making it more interactive.

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APPENDIX A: GLOSSARY

Volumetric Display (VD) – Definition 1

"A volumetric display device is a graphic display device that forms a visual representation of an object in three physical dimensions, as opposed to the planar image of traditional screens that simulate depth through a number of different visual effects."

Dictionary.com

Volumetric Display (VD) – Definition 2

"Volumetric display as those that create visual representations of objects in three dimensions, with an almost 360-degree spherical viewing angle in which the image changes as the viewer moves around. True volumetric displays fall into two categories: *swept volume displays* and *static volume displays*. *Swept volume displays* use the persistence of human vision to re-create volumetric images from rapidly projected 2D slices. *Static volume displays* use no major moving parts to display images, but rather rely on a 3D volume of active elements (Volumetric Picture Elements, or voxels) changing color (or transparency) to display a solid option."

Gartner's IT Glossary

Display Screen

"A surface area upon which text, graphics and video are temporarily made to appear for human viewing."

Dictionary.com

Screen

"A specially prepared, light-reflecting surface on which motion pictures, slides, etc., may be projected."

Dictionary.com

"a. a flat surface on which a picture or series of pictures is projected or reflected
b. the surface on which the image appears in an electronic display (as in a television set, radar receiver, or computer terminal); also the information displayed on a computer screen at one time."

Merriam-Webster.com

The screen is considered to be a type of *display*

In an online discussion *Difference between: screen, display, monitor, projector* on forum.wordreference.com, "A monitor is specifically a piece of computer equipment: it's a three-dimension object that sits on a desk or on a computer and is attached by wires. The front of the monitor has a screen, as does the front of a television set. The screen is the glass part of the monitor or television that displays pictures or information. Loosely, a monitor can be called a

screen, as no-one cares about the back of a monitor. The noun *display* refers to the part of a machine that displays information - the screen of a monitor, most commonly, but also oscilloscopes and other machines have displays of different sorts, perhaps displaying only a limited kind of information (such as spectrograms or digital numbers). A projector is a kind of machine for displaying pictures somewhere else - on a wall, for example."
forum.wordreference.com
slideshare.net

Display
"a. An electronic device for the visual presentation of data.
a 17-inch color display
b. The process or facility of presenting data on a computer screen or other device.
the processing and display of high volumes of information
c. The data shown on a computer screen or other device."
A display is not necessarily a *screen*
forum.wordreference.com
slideshare.net

Virtual Reality (VR)
"An artificial environment which is experienced through sensory stimuli (such as sights and sounds) provided by a computer and in which one's actions partially determine what happens in the environment; also : the technology used to create or access a virtual reality."
Merriam-Webster

Augmented Reality (AR)
"An enhanced version of reality created by the use of technology to overlay digital information on an image of something being viewed through a device (such as a smartphone camera); also : the technology used to create augmented reality."
Merriam-Webster

Mixed Reality (MR)
Mixed reality (MR), sometimes referred to as hybrid reality, is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. Mixed reality takes place not only in the physical world or the virtual world, but is a mix of reality and virtual reality, encompassing both augmented reality and augmented virtuality via immersive technology.
Dictionary.com

High-Fidelity Prototype
"An interactive prototype that simulates the real system or site's functionality and design details.

Uses hi-fi technology and closer to a final product."
usability.gov

Holography

"Holography is the science and practice of making holograms. Typically, a hologram is a photographic recording of a light field, rather than of an image formed by a lens, and it is used to display a fully three-dimensional image of the holographed subject, which is seen without the aid of special glasses or other intermediate optics."
Dictionary.com

Transmission Hologram

"A transmission hologram is one where the object and reference beams are incident on the recording medium from the same side. In practice, several more mirrors may be used to direct the beams in the required directions.

Normally, transmission holograms can only be reconstructed using a laser or a quasi-monochromatic source, but a particular type of transmission hologram, known as a rainbow hologram, can be viewed with white light."
Dictionary.com

Reflection Hologram

"In a reflection hologram, the object and reference beams are incident on the plate from opposite sides of the plate. The reconstructed object is then viewed from the same side of the plate as that at which the re-constructing beam is incident.

Only volume holograms can be used to make reflection holograms, as only a very low intensity diffracted beam would be reflected by a thin hologram."
Dictionary.com

Design Fiction Methodology

"Design Fiction is the construction of a narrative—a movie, animation, written story, presentation or installation—to immerse an audience in an experience that provokes emotional and intellectual responses. It is the generation of ideas that are not yet possible, to provoke a dialogue about what could or should be possible."
designresearchtechniques.com

Speculative Design

"Design is a means of speculating about how things could be—to imagine possible futures."
Speculative Everything, Anthony Dunne and Fiona Raby

Horizon Scan

"The practice of horizon scanning has its origin in the discipline of Futures Studies or Futurology,

which is the systematic forecasting of the future from present trends in society. *Futures*, seeks to understand what is likely to continue and what could plausibly change. It postulates what is probable versus what is possible by researching and identifying current patterns. *Futures* differs from short-term predictions and strategic planning in that it addresses time horizons that extend beyond 10 years from now."

designresearchtechniques.com

Science Fiction

"Science fiction (often shortened to SF or sci-fi) is a genre of speculative fiction, typically dealing with imaginative concepts such as futuristic science and technology, space travel, time travel, faster than light travel, parallel universes, and extraterrestrial life. Science fiction often explores the potential consequences of scientific and other innovations, and has been called a "literature of ideas". It usually avoids the supernatural, and unlike the related genre of fantasy, historically, science-fiction stories were intended to have a grounding in science-based fact or theory at the time the story was created, but this connection is now limited to hard science fiction."

Dictionary.com

Three Dimensional Displays

"A new three-dimensional (3D) display concept is described that employs a random accessed flying spot in a transparent volume of material viewable from any position outside the volume. Arbitrary, true 3D figures may be presented ranging from line to full surface drawings and including alphanumerics. The display has a multicolor capability, continuously variable intensity, and can exhibit fixed or moving objects with good resolution. Display volumes of several cubic feet with high information capacity seem feasible."

IEEE Xplore's Digital Library

<u>Types of Three Dimensional Display Technologies:</u>

1. Volumetric Display

"Volumetric display are those create visual representations of objects in three dimensions, with an almost 360-degree spherical viewing angle in which the image changes as the viewer moves around. True volumetric displays fall into two categories: *swept volume displays* and *static volume displays*. *Swept volume displays* use the persistence of human vision to re-create volumetric images from rapidly projected 2D slices. *Static volume displays* use no major moving parts to display images, but rather rely on a 3D volume of active elements (Volumetric Picture Elements, or voxels) changing color (or transparency) to display a solid option."

Gartner's IT Glossary

2. Holographic Display

"A holographic display as a display that uses coherent light, such as that created by laser, to create a three-dimensional (3D) image in space."

"True holographic displays create images that conform to the six depth cues by which we recognize 3D views in the real world:

- Perspective: Objects farther away appear smaller.
- Occlusion: A closer object may obscure objects in the distance.
- Stereoscopic vision: Two viewpoints get a different view of an image, as human eyes do.
- Motion Parallax: Perspective changes as a viewpoint moves.
- Convergence: Two points cross on viewing closer objects, as human eyes do.
- Accommodation: Lenses change focus depending on an object's distance within the image."

Whatis.com

3. Integral Imaging

"An autostereoscopic or multiscopic 3D display, meaning that it displays a 3D image without the use of special glasses on the part of the viewer. It achieves this by placing an array of micro lenses (similar to a lenticular lens) in front of the image, where each lens looks different depending on viewing angle. Thus rather than displaying a 2D image that looks the same from every direction, it reproduces a 4D light field, creating stereo images that exhibit parallax when the viewer moves."

Dictionary.com

4. Compressive Light Fields Display

"A new display technology called Compressive Light Field is being developed. These prototype displays use layered LCD panels and compression algorithms at the time of display. Designs include dual and multilayer devices that are driven by algorithms such as computed tomography and Non-negative matrix factorization and non-negative tensor factorization.

The light field is a vector function that describes the amount of light flowing in every direction through every point in space. The direction of each ray is given by the 5D plenoptic function, and the magnitude of each ray is given by the radiance. Michael Faraday was the first to propose (in an 1846 lecture entitled "Thoughts on Ray Vibrations") that light should be interpreted as a field, much like the magnetic fields on which he had been working for several years. The phrase *light field* was coined by Andrey Gershun in a classic paper on the radiometric properties of light in three-dimensional space (1936)."

Dictionary.com

<u>Viewing Methods:</u>

1. Stereoscopic

"Stereoscopy, sometimes called stereoscopic imaging, is a technique used to enable a three-dimensional effect, adding an illusion of depth to a flat image. Stereopsis, commonly (if imprecisely) known as depth perception, is the visual perception of differential distances among

objects in one's line of sight. There are a number of visual cues that help us to see things that way. If one object partially hides another, for example, we understand the one in front to be closer. Objects and patterns grow smaller as they recede and vertical lines converge; objects in the distance are hazier and less deeply colored, with a shift towards the blue end of the spectrum.

The perspective difference between objects seen through the left and right eyes (binocular disparity) and our accommodation through focusing completes stereopsis for normal viewing. 3-D TV (and movies as well) typically work by presenting two separate images – one for the right eye and one for the left – that are incorporated through the use of specialized glasses."
Whatis.com

2. Autostereoscopic

"Another technology, known as autostereoscopic imaging (auto 3-D), is screen-based and does not require viewers to wear special glasses. There are two classes of autostereoscopic displays. One type tracks the viewer's head position to ensure that each eye is presented with a different view. The other type of display uses multiple perspectives of each frame presented simultaneously so that, within a given range, a viewer will see separate perspectives with each eye."
Whatis.com

3. Multiscopic

"Unlike conventional 3D stereoscopy, which simulates a 3D scene by displaying only two different views of it, each visible to only one of the viewer's eyes, 3D multiscopy displays more than two images, representing the subject as viewed from a series of locations, and allows each image to be visible only from a range of eye locations narrower than the average human interocular distance of 63 mm. As a result, not only does each eye see a different image, but different pairs of images are seen from different viewing locations.

This allows the observer to view the 3D subject from different angles as they move their head, simulating the real-world depth cue of shifting parallax. It also reduces or eliminates the complication of pseudoscopic viewing zones typical of "no glasses" 3D displays that use only two images, making it possible for several randomly located observers to all see the subject in correct 3D at the same time."
Dictionary.com