INTERACTIVE HOLOGRAPHIC CINEMA

A Thesis

by

CHRISTOPHER ALBERT PORTALES

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2012

Major Subject: Visualization

Interactive Holographic Cinema

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Approved by:

Chair of Committee,	Carol LaFayette
Committee Members,	Karen Hillier-Woodfin Salih Yurttas John Keyser
Head of Department,	Tim McLaughlin

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ABSTRACT

Interactive Holographic Cinema. (May 2012)

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Chair of Advisory Committee: Prof. Carol LaFayette

In mainstream media and entertainment, holography is often misrepresented as single perspective non-stereoscopic imagery suggesting three-dimensionality. Traditional holographic artists, however, utilize a laser setup to record and reconstruct wavefronts to describe a scene in multi-perspective natural parallax vision ("auto-stereoscopic"). Although these approaches are mutually exclusive in practice, they share a similar goal of staging three-dimensional (3D) imagery for a window-like viewing experience. This thesis presents a non-waveform digital computer approach for recording, reconstructing, and experiencing holographic visualizations in a cinematic context. By recording 3D information from a scene using the structured light method, a custom computer program performs stereoscopic reconstruction in real-time during presentation. Artists and computer users could then use a hardware device, such as the Microsoft Kinect, to explore the holographic cinematic form interactively.

DEDICATION

This thesis is dedicated to my family.

ACKNOWLEDGEMENTS

Thank you to my committee chair, Carol LaFayette, and my committee members, Karen Hillier, Dr. Salih Yurttas, and Dr. John Keyser, for your help and expertise during this research. I would like to thank Sally Weber for being my mentor and introducing me to the holographic art form, as well as her husband Craig Newswanger. Thank you to Amanda Aultman for your love and patience. Finally, thank you Mother and Father for your love, care, and support.

NOMENCLATURE

2D	Two Dimensional
3D	Three Dimensional
CGH	Computer Generated Hologram
CPU	Computer Processing Unit
CUDA	Compute Unified Device Architecture
FPS	Frames per Second
GPU	Graphics Processing Unit
GUI	Graphical User Interface
HLSL	High Level Shading Language
IDH	Interactive Digital Holography
IHC	Interactive Holographic Cinema
LIDAR	Light Detection and Ranging
MFC	Microsoft Foundation Class
RGB	Red, Green, Blue
RGBD	Red, Green, Blue, Depth
SDK	Software Development Kit

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CHAPTER I

INTRODUCTION: THE PHANTASMAGORIC INFLUENCE

> *"'All right,' said the Cat; and this time it vanished quite slowly, beginning with the end of the tail, and ending with the grin, which remained some time after the rest of it had gone."*
>
> Lewis Carrol

Before cinema, projections of ghosts onto smoke and semi-transparent screens were part of a live show entertainment experience. Between 1790-1793, Paul de Philipsthal created and exhibited ghost-show entertainment, complete with orchestra, known as the Phantasmagoria. Coined in 1792 by Philipsthal meaning an 'assembly of ghosts,' the basis of Phantasmagoria included five distinguishing elements:

1) the use of back projection
2) the use of a special apparatus to produce growing and diminishing figures
3) the use of lantern images in which the figures emanate from painted black backgrounds
4) the projection of opaque (solid) objects
5) the blend of additional performance elements such as mirrors, smoke, black or white shadows, masks, and actors

Heard [1]

This inspired scientists and showmen to develop new approaches to create art.

This thesis follows the style and format of *Leonardo*.

In 1862, ‘Pepper’s Ghost’ debuted at the London Royal Polyntechnic Institution’s Christmas performance of Charles Dicken’s *Haunted Man* [2]. Named after John Henry Pepper, ‘Pepper’s Ghost’ was developed with Henry Dircks as a practical approach to the ‘Dircksian phantasmagoria,’ which required a custom built auditorium. The ‘Pepper’s Ghost’ technique required a reflective pane of glass to be set on-stage at a downward facing forty-five degree angle [1]. A light, when cued, would illuminate an off-stage subject, who would appear to the audience as if out of thin air with a translucent quality [3]. This had a defining effect on cinema and visualization itself, as an art and science. “A century after the first phantasmagoria shows, the cinema adopted many of the same themes, continuing the tradition to this day” [1].

The most widely recognized ‘hologram’ is the Princess Leia projection from the 1977 movie *Star Wars: Episode IV – A New Hope* [4]. In the movie, Princess Leia records a visual and audio message using a droid named R2-D2. The droid later presents the message as what is perceived to be a 360 degree 3D video projection of Princess Leia (Figure 1). The technology suggested was created for the film using computer graphics and does not currently exist. This visual effect represents what people understand and what is expected of holographic imaging.

Fig. 1. The Princess Leia ‘hologram’ from *Star Wars Episode IV: A New Hope*

CHAPTER II

RELATED WORK

A. Theater and Cinema

The gap between cinema and the stage can only be closed so much without changing the form. In modern times, non-stereoscopic and stereoscopic cinema is presented as a uniform, single seat, limited perspective visualization. Much like the Princess Leia ‘hologram,’ 3D movies do not offer true three-dimensionality, only the illusion of it.

Operatic theatrical events sell perspective valued viewing zones, limiting each audience member to a single vantage point. There is an assumption that the event itself will be best experienced in particular seats, although presented for all audience viewpoints. What can more safely be assumed is that the experience of an event one night will always differ when compared to any other given night. More so, the event itself, and all unique perspectives offered by it, have value.

Subtle changes prevent any physical performance from being duplicated perfectly. Before seeing the digital video presentation of *Le Nozze di Figaro* [5], it was obvious my perspective would be limited and non-unique. After viewing, I wondered how much different the performance would be with Mozart as the conductor and with the singers of the late 1780s. The cinematic aspects documented the operatic event. Comparatively, the cinematic aspects of *Baz Luhrmann’s Red Curtain Trilogy* [6] harnessed theater’s visual, musical and lyrical style in terms of rhythm and performance.

The ‘world’s first 3D hologram performance’ at the 2005 MTV Awards by the Gorillaz [7] gave a convincingly strong impression that the computer generated band members existed three-dimensionally on stage (Figure 2). In reality, the ‘holographic’ projection was the ‘Pepper’s Ghost’ effect, created using video projection, mirrors, and semi-transparent screens [8]. Nonetheless, 2D cinema as a live stage performance narrows the gap between live theater and film. Since the performance itself was pre-rendered and exists as data, it is portable and digitally transmittable (Figure 3).

Fig. 2. Gorillaz’s ‘holographic’ projection at the 2005 MTV Awards

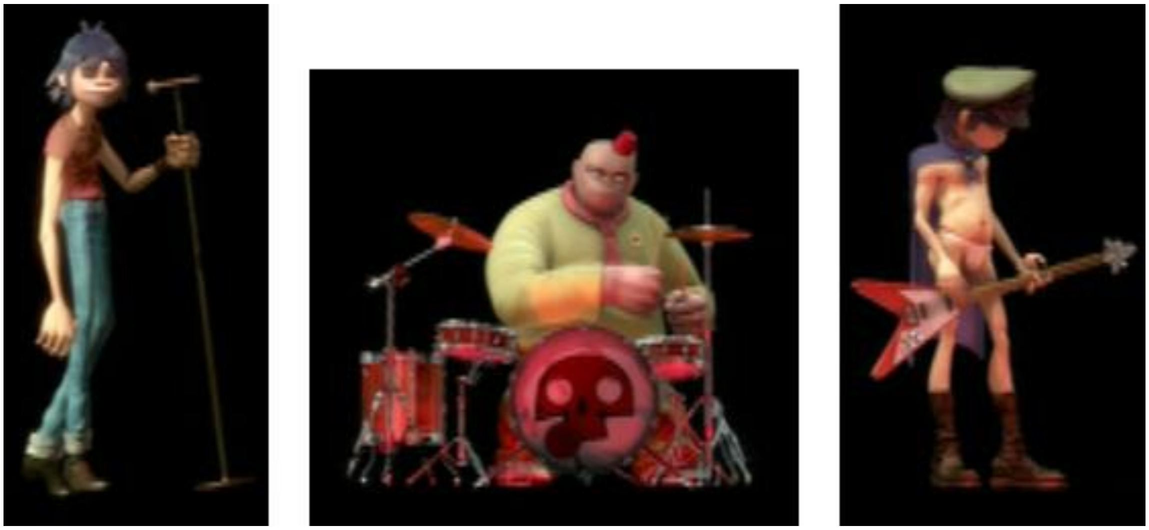


Fig. 3. Gorillaz's picture stills from pre-rendered stage performance video

B. Interactive Digital Media

Typically, event-based art installations are available for a limited period of time in an intentionally localized context. In *77 Million Paintings* [9], a computer program uses a screen to display a slowly changing light painting as visual music. This set was also created from the idea of making the art available as an installation event. Typically, for an installation exhibition in a controlled space, an audience member would have little input. In this case, by distributing and, therefore, decentralizing the installation, the audience member has comparatively more control over his or her experience. This allows for unique events to occur through the dynamics of the program, within a user-defined presentation environment. As a result 'every viewer's experience will be somewhat different' [9].

In 2008, the music video *House of Cards* [10] was made available for digital download not only as cinematic content, but also as the 3D data used to create it (Figure 4). Recorded using a light detection and ranging (LIDAR) scanner, this data allows for viewing and interactivity of the animation in real-time using the Processing software application. Although not intended to be labeled a 'hologram,' the data would be considered adequate for a computer generated hologram.

Fig. 4. Stereoscopic (red-cyan) rendering from the 'House of Cards' dataset

Interactive music video content continues to be explored. In 2012, the music video *Look Around* [11] was filmed using four 2D cameras, each one dedicated as a fixed static perspective to a single room scene. Instead of allowing control over depth data, the user can navigate between cameras, allowing for many combinations of interactive music video viewing. Additionally, a digital zoom feature is included, as well as interactive web links associated to scene objects. Figure 5 shows each scene, of a single room, from each of the four cameras. A video’s time length from any given camera is 3 minutes and 36 seconds, totaling 14 minutes and 24 seconds of footage for the 3 minute and 28 second song.

Fig. 5. The four scenes and camera views from the ‘Look Around’ music video

C. Holography

Derived from the Greek *holos* and *graphos* meaning ‘whole’ and ‘message,’ holography was discovered in 1947 by Dennis Gabor as a two-beam recording solution for electron microscope imaging. Its 3D imaging potential was not considered until the 1960s when engineers Emmett Leith and Juris Upatnieks rediscovered Gabor’s concepts, calling it ‘wavefront reconstruction photography.’ Holography has the unique ability to record and reconstruct light rays, colors, and intensities from a 3D scene; enabling it to provide auto-stereoscopic multi-perspective information.

When wavelengths of light are recorded using traditional holography, the photographic emulsion defines and, therefore, limits resolution from an infinite information source. For digital holography, this limitation exists as well. In addition, since light is defined in terms of bits, the frequency and bandwidth information can be generated, communicated, and received finitely [12].

When creating a traditional holographic image, one interacts with an object as one interacts with anything physical. A hologram can be created such that images can appear, referred to in holographic terminology as a virtual image and a real image. This is similar to looking through a window while maintaining a view of the content behind and in front of the viewing plane, with respect to the viewer, where the image behind is the virtual image and the image appearing as if it exists in front is the real image [13].

Traditionally, the process to create one record of a 3D scene is expensive in terms of laboratory costs, patience, precision, and formal training. As a result, holography lacks ubiquity and the comparatively easier learning curve of photography.

Despite this fact, the science is advancing and is considered ‘an inevitable step in the evolution of visual communication’ [14].

Specialized hardware systems such as the Mark III at MIT are close to achieving cinematic frame rates, but have demonstrated waveform based holographic video viewing [14]. Such a system has limited accessibility to the general public and is therefore out of the scope of this thesis. Instead, I focus on allowing artists, including those in traditional holography and cinema, to record and reconstruct holographic cinema with the intention that it can be viewed on a home computer as well as on more advanced systems.

CHAPTER III

METHODOLOGY

This method’s process aligns its goals with holography to record and reconstruct a 3D scene for cinematic holographic exploration as a director and audience member. Real and virtual imagery properties in holography are achieved using a digital computer for multi-perspective stereoscopic presentation. Waveform patterns, required to record and to reconstruct traditional holograms, are excluded from the recording process due primarily to the limitations they cause for holographic cinema to be explored more freely. Instead the focus is placed on cinematic aspects within a non-waveform digital computer, and uniquely available within a holographic environment.

A. Holographic Presentation Considerations

For realistic holographic presentation, these properties must be visualized on a physical surface such as hogels (a waveform holographic element [14] arranged in a matrix-like fashion to comprise an image) or pixels. The ideal holographic presentation form would be a non-physical, multi-perspective, auto-stereoscopic, spherical (360 degree vertical and horizontal) wavefront reconstruction – that is, the technology that the Princess Leia hologram suggests. Although there is no known technology with the capacity to produce such images non-physically, the visual content of this project is intended for all holographic unique properties. Regardless, technologies do exist to simulate and emulate the phenomenon on a physical surface.

Flat screens are more popular, ubiquitous, and allow for a maximum 180 degree viewing range. Hogel based flat screens are in development but are not currently available to the public for holographic presentation. Auto-stereoscopic screens provide a glassless free viewing experience, where the image is perceived stereoscopically as a 3D object, allowing for unique perspective viewing zones. However, these auto-stereoscopic screens do introduce undesired anomalies such as incorrect image overlap in some cases. Non-auto-stereoscopic digital flat screens are most ubiquitous, but would require software based implementations for holographic presentation.

Pepper's Ghost is typically projected non-stereoscopically onto a flat translucent surface. Modification to include stereoscopic viewing could allow for holographic presentation. This approach introduces translucency to holographic viewing. When a traditional hologram is made, a special translucent holographic film is used to properly record and reconstruct a 3D scene. When transparency is desirable as an artistic choice, for example overlaying two images, Pepper's Ghost can be used to present a hologram against a transparent surface.

B. Recording for Reconstruction

The essential problem of recording a 3D scene is how to discretely sample a continuous and infinite information source. A laser-based waveform approach to holographic recording has the capacity of producing resolutions higher than current digital systems. However, this approach presents problems in terms of cost, practicality, and ease of distribution. Most concerning is the requisite that holographic film must be immediately processed after a single frame exposure. The complicated nature of the laser setup, precision involved, and the necessity to avoid vibrations of any kind add to the painstaking and meticulous process of recording a single static image. For example, a plane flying overhead could cause enough noise and vibrations to ruin a hologram during exposure. A digital process to avoid such problems, while maintaining the capacity to recording dynamic information for holographic scenes, is most desirable.

The structured light methodology was chosen for its ability to record depth and color information of a scene as well as its cost effectiveness. This methodology accomplishes this task through triangulation and projected Gray codes as in figure 6 [15]. These codes are projected as an animated stripe pattern onto an object, and can be recorded with an analog or digital camera. The image recorded is then processed digitally to estimate the depth of the recorded object in space.

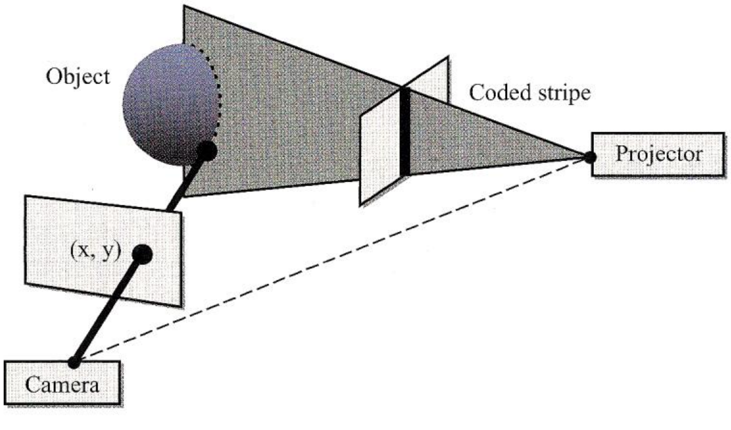


Fig. 6. Structured light setup

A significant drawback to the structured light approach, in terms of scene lighting, is the introduction of undesired light. This results from projected and animated Gray codes which cause alternating light and dark stripes onto a scene. That is, the Gray codes used for structured light acquisition (in a non-infrared context) are only desired for depth acquisition calculations, not artistic lighting. Fortunately, the Microsoft Kinect device resolves this issue by using infrared projection. The maximum amount of information that can be recorded from a scene using the Microsoft Kinect are red, green, and blue (RGB) color information channels as well as non-transparent depth information (RGBD). The depth information streamed from the Microsoft Kinect requires 16-bits (compressible to 12-bits using bit shifting), whereas each color channel requires 8-bits (24-bits RGB). I wrote a custom binary file format with an .ihc extension to store frames of scene data from the Microsoft Kinect.

Another drawback of using a structured light approach is the inaccurate recording of objects with reflective and refractive properties. The projected patterns used for recording estimate depth information based on the surfaces the patterns are projected onto. In the case of an object with reflective and refractive properties, these patterns can easily become distorted, rendering the information unusable. To include objects with these properties 3D compositing for multi-perspective presentation would be necessary. A solution for presenting reflections and refractions of objects in multiple perspectives as a real-time visualization within a cinematic context was non-trivial. Ray tracing, although computationally demanding, could be performed in real-time using the graphics processing unit (GPU). Alleviating this limited resource of these computations and allocating it for image processing was more desirable for this project.

C. Reconstruction Software

A waveform based holographic reconstruction system could generate the fringe patterns (overlapping waveforms) necessary from point based scene data. The degree of viewer interaction could be the multi-perspective auto-stereoscopic visualization that occurs from the arrangement of fringe patterns, as well as any additional pre-defined interaction depending on the capabilities of the system. For a digitally based non-waveform system, maintaining real and virtual imaging is most desirable.

1. Interactive Digital Holography

Emulation of the real and virtual image as stereoscopic multi-perspective viewing is the goal of achieving Interactive Digital Holography (IDH). Since fringe patterns are not being generated, the quality of imagery is naturally dependent on the viewing system available. In general, auto-stereoscopic 3D screens would not require a viewer to wear additional viewing glasses. For 2D non-auto-stereoscopic screens, producing polarized or anaglyph imagery would be necessary for stereoscopic viewing, and to simulate the real and virtual imagery. In addition, the viewer would be required to wear glasses for proper viewing. Preference is given to such screens for this project due to cost and serves as a solution to maximize ubiquity.

An IDH approach allows one to experience holographic visualization without the use of waveforms. A waveform based IDH would produce real and virtual auto-stereoscopic multi-perspective viewing. Since software does not exist specifically for these holographic requisites, design of such a program was necessary with the aforementioned capabilities.

2. Vantage Point Real-Time Rendering

The reconstruction software is based on a custom .ihc file format. The program loads red, green, and blue color information along with depth information as xyz coordinate points. Once loaded into memory, the data set, or scene, can be viewed interactively in real time. Since the data set is a sampling of a scene, negative space between sampled points will be noticeably visible without further processing.

The software was designed to achieve the most reproducible holographic ideals and holographic attributes. This includes multi-perspective viewing, forwards and backwards playability, variable frame rate adjustment, and zero parallax image manipulation. This is what allows for unique cinematic experiences to occur within a holographic context. For any given scene, multiple cinematic angles present new visual evaluation of the scene.

This software was designed for use with anaglyphic stereo glasses. These technical issues serve as the platform to approach the artistic issue of holographic cinematic exploration.

CHAPTER IV

EXPLORING HOLOGRAPHIC CINEMA: IMPLEMENTATION

A. History

During the summer of 2009, I worked with M.I.T. graduate and light artist Sally Weber in creating a static computer generated hologram. It became obvious during the process that the necessary level of interactivity required of holography was absent for adequate digital pre-visualization. This motivated the approach of using a stereoscopic viewport with head tracking to simulate holographic interactivity for the project. This approach was trivial. What was uncertain was how this model could be printed accurately since the model depended on the use of reflections and refractions.

Initially two commercial companies specializing in digital holography printing (RabbitHoles, and Zebra Imaging) were considered. RabbitHoles used an Autodesk Maya camera setup to generate printable horizontal parallax holograms. Zebra Imaging used Google Sketch-Up for their vertical and horizontal parallax holograms. Although we did not print at either company, it was interesting to learn that the primary interests were oriented towards static scene image printing. Presently neither has demonstrated publicly a holographic cinema capable approach.

I concluded that a digital holographic screen would be ideal for viewing holographic cinema because of its cost effectiveness and usability. Although the methodology was nontrivial, it made sense to create a simulation based on wavefront holographic properties with emphasis on real and virtual imagery.

B. Software Testing

Before the Microsoft Kinect was released, a structured light approach was sought. However, the biggest draw-back for this approach was that a large projector with non-infrared light would have to be used. In addition, this would not be ideal for recording a cinematic scene with actors, as the light itself would cause too much of a distraction, and possibly damage one's eyes.

In the meantime Max/MSP/Jitter 5 was explored using Radiohead's House of Cards dataset as preliminary data for reconstruction. It was concluded custom software would be ideal, particularly for GPU memory management.

NVIDIA's programming language, CUDA C, and GPU architecture was explored before the Kinect Beta SDK was released. The GPU multi-core processing was a major advantage, even for low-end graphics cards, such as NVIDIA's GeForce 8400 GS. For the purposes of this thesis it was determined unnecessary to continue using CUDA C, due to the NVIDIA graphics card limitation and desire to find a more manageable multi-graphics cards programming approach.

Once the Microsoft Kinect was released in November 2010, there was no official software development kit (SDK) to utilize the device. Nonetheless it was still ideal for recording for its low cost, ubiquity, and infrared light usage. To keep costs at their minimum it was decided that only one Kinect would be used, since this could still allow for multiple perspectives of the same scene to be generated. The DirectX 10 SDK, in combination with High-Level Shading Language (HLSL) 4.0 and the Media Foundation

Class (MFC) Windows 7 SDK, became the final choice to use in conjunction the Kinect SDK once released.

C. File Format

The .ihc file format was created to maintain two distinct types of information – a frame based dataset, and a point based dataset. Each are distinguished by the arrangement of the numbers 56 and 58 in the .ihc file header. If the first byte of the .ihc file header contains an unsigned char value of 56, and the second byte contains the unsigned char value 58, the following header information is a frame based dataset. If the first byte of the .ihc file header is 58, and the second byte is 56, the following header information is a point based dataset.

1. IHC Frame Based Dataset

Table 1 represents the case of a frame based dataset with 16-bit depth. The "IHC Specification" has been set to zero to represent the first version of .ihc.

Table 1 Example IHC File Header for a Frame Based Dataset with 16-bit Depth

Description	Example	Data Type	Size
IHC Validation A	56	unsigned char	8-bits (1 byte)
IHC Validation B	58	unsigned char	8-bits (1 byte)
IHC Specification	0	unsigned char	8-bits (1 byte)
Bit Depth	16	unsigned char	8-bits (1 byte)
2D Frame RGB width	640	unsigned short int	16-bits (2 bytes)
2D Frame RGB height	480	unsigned short int	16-bits (2 bytes)
2D Frame Depth width	632	unsigned short int	16-bits (2 bytes)
2D Frame Depth height	480	unsigned short int	16-bits (2 bytes)
3D Depth Data (min)	0	unsigned short int	16-bits (2 bytes)
3D Depth Data (max)	3975	unsigned short int	16-bits (2 bytes)

The proceeding data is organized as alternating frames of RGB and Depth data, where each RGB pixel is 3 bytes (unsigned char*3), and Depth (16-bit) is an unsigned short int. Although the number of frames is not stored in the header, this is easily calculated from the file size. Using the example data in table 1, an RGB frame of size will be 921,600 bytes (640x480x3 bytes), and the Depth frame will be 606,720 bytes (632x480x2 bytes), totaling 1,528,320 bytes. An .ihc file of size 1,375,488,016 bytes would have 900 frames of RGBD data (i.e. 30 seconds of footage at 30 fps).

Additionally, for a frame based dataset, the depth data can use bit-shifting from 16 to 12 bits for lossless compression. A 632x480 Depth frame will then be 455,050 bytes, and an RGBD frame 1,376,640 bytes total. Nine-hundred frames of RGBD data will be 1,238,976,016 bytes, saving 136,512,000 bytes. Figure 7 depicts a single 16-bit and 12-bit pixel.

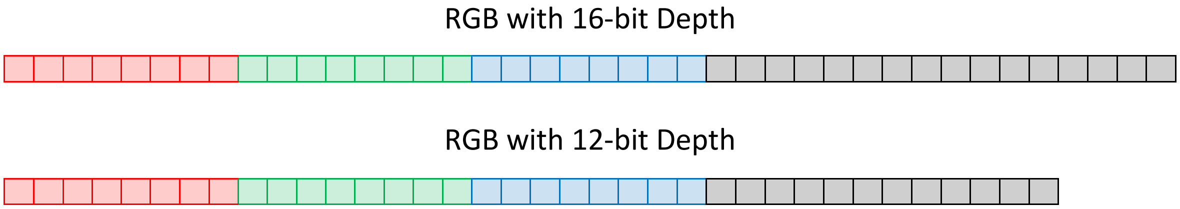


Fig. 7. 16-bit and 12-bit comparison of a pixel for frame based IHC dataset

The arrangement of RGB and depth data is frame based as well. That is, a full 640x480 RGB image is inserted into the .ihc file first, followed by the 16-bit or 12-bit

630x480 depth image. This is what allows for 12-bit bit shifting compression to be accomplished on the depth information for a frame based IHC dataset.

2. IHC Point Based Data Set

Table 2 represents the case of a point based dataset. Although no additional information about the dataset is stored in the header, for IHC Specification 0, the file should be organized as 3D data (xyz coordinates represented as three unique float values), and an intensity value (represented as an unsigned char).

Table 2 Example IHC File Header for a Point Based Dataset

Description	Example	Data Type	Size
IHC Validation A	58	unsigned char	8-bits (1 byte)
IHC Validation B	56	unsigned char	8-bits (1 byte)
IHC Specification	0	unsigned char	8-bits (1 byte)
Frames Per Second (FPS)	30	unsigned char	8-bits (1 byte)

Following the point based dataset file header is the point count value of the data frame, represented as an unsigned short int, which signifies the number of xyz and intensity values to read. Once this information has been processed, and until the end of file is reached, a point count value will be read preceding the available xyz and intensity value data set.

D. IHC Software

For the purpose of this thesis, customization was tailored to the Microsoft Kinect, since the structured light approach using a light projector was disregarded. Two software programs were created to achieve holographic cinematic exploration on a 2D screen: an IHC Recorder, and an IHC Reconstructor.

1. IHC Recorder Software

The IHC Recorder has several different viewers available (Figure 8). A primary viewer 680x680 pixels (left most), a secondary viewer 340x340 pixels which compliments the primary viewer (top-center), a depth statistics meter 340x50 pixels located under the secondary viewer, and two stacked 340x340 pixel windows to provide recorded information.

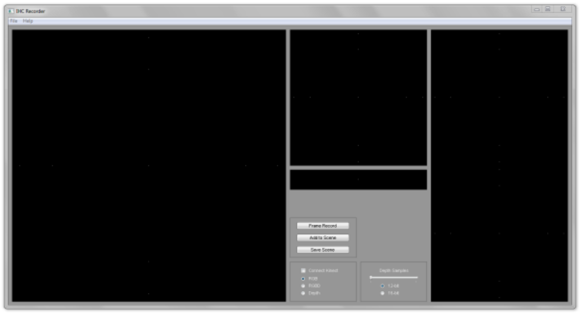
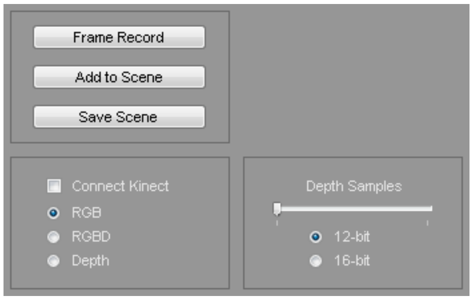


Fig. 8. IHC Recorder window

The default has the primary viewer set to RGB mode. Holding down left and right mouse buttons (while dragging) allows for interactive rotation of a scene in this viewer only. Additionally, the middle mouse wheel provides camera translation along the z-axis. The secondary viewer displays the depth information channel as a green and blue gradient, where green represents the foreground and blue represents the background. Red is used to indicate invalid values of depth. The two stacked windows display the last attempted recorded image as color (top) and depth (bottom) visualizations.



☐ Connect Kinect
● RGB
○ RGBD
○ Depth
● 12-bit
○ 16-bit

Fig. 9. IHC Recorder GUI

The IHC Recorder GUI is minimalistic (Figure 9). Starting from the top-left, “Frame Record,” “Add to Scene,” and “Save to Scene” buttons are available. The bottom-left has a “Connect Kinect” checkbox, which will only toggle if the Kinect initializes properly. Once data is streaming from the Kinect, RGB, RGBD, and Depth options are available for the primary viewer. Only when Depth is selected will the secondary viewer present RGB color information. The bottom-right section has a “Depth Samples” slider which allows the user to control the number of samples to be taken for each image (default value 1). The reason for this control is that for any given depth frame that is acquired by the Microsoft Kinect, there are depth values that will fall out of a computable range, and the information is invalid. By increasing the depth samples (maximum value 256), several depth frames can be evaluated, which are then compiled into a single depth frame image. This allows the user to decide if an adequate amount of information has been sampled properly. Hitting “Frame Record” will capture the color and depth information from the Kinect stream. Using “Add to Scene” would then store this frame to be saved. Once the desired scene has been recorded, selecting “Save to Scene” will save the .ihc file to a hard drive (default 12-bit depth).

2. IHC Reconstructor Software

The Reconstructor only has one 680x680 viewer (Figure 10). Although an RGBD Kinect scene is 640x480 for color, and 632x480 for depth, the viewer is larger to handle image offset for stereoscopic viewing. The highly variable nature associated with LIDAR information was also taken into consideration.

Fig. 10. IHC Reconstructor window

Since the software was written using the Windows 7 SDK, .ihc files can be loaded using the drag-and-drop feature, or by selecting each desired file through the menu bar. As with the IHC Recorder, a scene loaded within the IHC Reconstructor can be rotated interactively using the left and right mouse buttons. The middle mouse wheel provides camera translation along the z-axis as well.

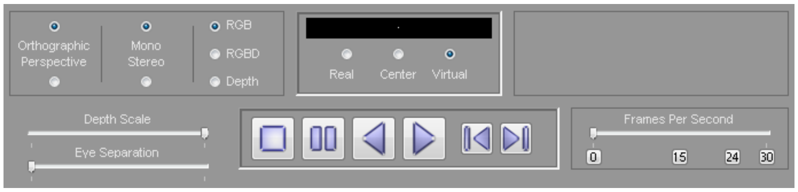


Fig. 11. IHC Reconstructor GUI

The IHC Reconstructor GUI has several options available (Figure 11). Starting at the top-left of the interface, this section has orthographic or perspective camera options, along with monoscopic or stereoscopic viewing choices. Additionally RGB, RGBD, or Depth information selections are available as well. It is important to note, that when stereoscopic button is clicked, the viewer will also switch to perspective and RGBD mode. Stereoscopic mode is limited to these options. The top-center allows for real and virtual imagery selection. A center option is available as well for both real and virtual imagery to occur simultaneously. The bottom-left section has both depth scale and eye separation sliders. The bottom-center contains the standard video controls stop, pause, reverse viewing, play forwards, and last/next frame buttons for idle scenes. Finally there is an interactive frame rate slider ranging from 0 fps to 30 fps. Preset buttons of 0, 15, 24, and 30 are provided just below the slider. It was important to include these presets for slider numerical estimation, and for familiar frame rates used in animation, cinematic standards, and television. Selecting 0 fps would be the same as hitting the pause button.

E. Holographic Cinematic Exploration Results

The exploration of holographic cinema is only limited to the most capable and available system. For the purposes of this thesis, the customized software met the necessities to begin the exploratory process.

Several scene files were recorded throughout the process of software creation. Figure 12 shows two example renderings from an .ihc scene file with an electronic piano keyboard. The same single frame is shown from two different perspectives as real images and is viewable with red-cyan anaglyph glasses.

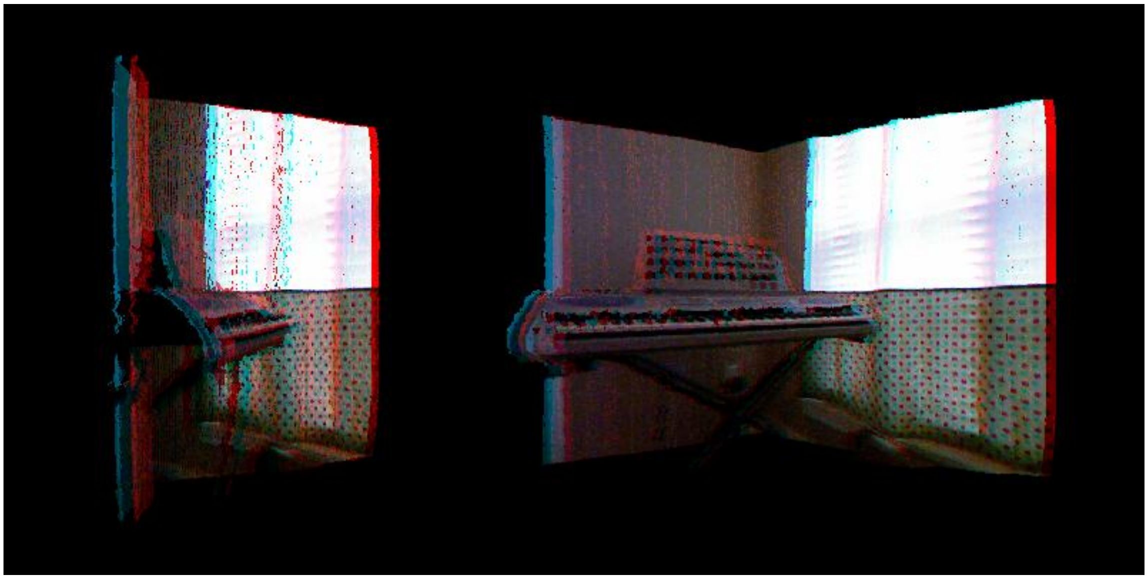


Fig. 12. Two .ihc stereoscopic (red-cyan) real images of the same frame

Currently, the reconstruction software has the ability to view only .ihc files, which must be opened in desired viewing sequence. In short, the software acts as both scene-queue editing (for holographic cinema) and a static single frame visualizer.

Available .ihc files from any artist can either be arranged in one particular order, with the high possibility that the same order may not be viewed. More so, with interaction from the viewer, the holographic cinematic presentation will always been seen differently.

In terms of recording, a holographic scene should have limited minimum reflections and refractions. Ideally a matte scene with no transparent surfaces will result in a more accurate recording. Furthermore, the Kinect cannot record depth information when the sun is too bright, as the structured light information becomes heavily distorted and miscalculated.

For demonstrative purposes, figure 13 is a rendering of the *House of Cards* [10] LIDAR information from an .ihc file. This single frame is viewable as a real image using for stereoscopic red-cyan glasses.

Fig. 13. An .ihc Radiohead 'House of Cards' stereoscopic (red-cyan) real image

The current set of recorded .ihc scene files comprise a short film of variable length, depending on which scene files are selected at time of viewing. The short film is intentionally untitled for viewer interpretation. The abilities and limitations of the software thus far have yielded interactive holographic cinematic as a promising art form.

CHAPTER V

CONCLUSIONS

A. Future Implications

Modern cinema evolved from new technologies and was heavily, if not wholly, inspired by theatrical stage performance. From one perspective, holographic cinema can be thought of in terms of a hybrid approach between theater and cinema. That is, the live essence and multiple view points of the stage coupled with the magic of movie-making begin to describe its potential and new possibilities. From another perspective, holographic cinema would not be mutually exclusive. Instead it can be seen as an integrated part of theater and cinema. For example, it can be treated as a way to pre-visualize visual effects for live stage performance as well as providing the cinematic documentation of such an event. The new approach to the holographic cinematic art form developed in this thesis will allow for accelerated exploration without the limitations associated with its waveform origins. Digital artists and directors will also have to think and create for multi-perspective vantage point presentations.

In traditional cinema, a multiple camera setup is used in capturing various angles to assist during the film editing process. In this approach, resolution is limited to the footage of the camera selected during editing. This results in loss of scene information from all but one camera. Within an interactive holographic cinema context, a multiple camera setup would combine color and depth information from all cameras, allowing for a more complete scene. However, the depth resolution of such a scene would be precision based by a methodology such as structured light. Furthermore, resolution will be dependent on the number of cameras available during scene capture.

Even elements, such as lighting, staging, and storyline will have to be considered for this new context. Interactive holographic scenes will have the benefit of varied lighting. That is, for any given scene, the lighting can be manipulated and seen differently during subsequent and repeated viewings. Likewise, staging will be thought of as the addition or subtraction of scene elements in conjunction with storylines. In traditional cinema, any given character is always followed at a particular point in time. In interactive holographic cinema, one character can be followed throughout one viewing. On second viewing, another character, or characters, can be followed instead. Collectively, these approaches will be challenged within the form by the dynamics and amount of complexity allowed by any director.

Interactive holographic cinema fits into the lineage of the evolved cinematic art form. Theatrical performances are confined physically to a particular space, the stage. Traditional cinema offered more flexibility in terms of location, allowing for more stages. The number of stages within the new form has again increased dramatically through vantage point and interactive manipulation in subsequent viewings. Continued application of new and available graphical approaches will refine and expand techniques for this new form.

B. Future Directions

The project was concluded using a 60 Hz monitor capable of producing a real-time anaglyphic image. To view a non-anaglyph stereoscopic image, 120 Hz monitors could be utilized with polarizing glasses, allowing for a more precise color correct image. Higher cost auto-stereoscopic screens are also available and could be used as well. Holographic displays are also in development.

Camera movement was limited to mouse functionality for real-time interaction. The addition of various traditional camera operations, such as camera roll, tilt, and pan, could be implemented to further enhance the holographic cinematic experience. Doing so will achieve a cinematic familiarity, as well as provide additional various vantage points.

Using point-based reflections and refractions to handle a CGH in conjunction with a 3D dataset can be categorized as 3D compositing. Further investigation for a practical solution to extract reflection and refraction information from a structured light, or similarly recorded, scene would be necessary to avoid the compositing approach.

The majority of traditional holograms currently available for viewing on the internet are non-stereoscopic and limited to a single perspective. An approach to creating a 3D CGH from the original source would allow for such holograms to be experienced as an interactive digital hologram.

Anyone interested in recording scene information for holographic reconstruction, with an emphasis on depth, would be able to do so using the approach outlined in this thesis. Particularly traditional holography and cinematic artists can explore the holographic cinematic form. This approach is not limited to those artists with previous experience, introducing a new wave of independent holographic filmmakers.

C. Summary

Digital holography is still in its infancy. An interactive digital holographic approach closes the gap between traditional and digitally created holograms, the theatrical stage and cinema, and is a readily available low cost pre-visualization. Furthermore, it allows for holographic cinematic exploration which would not otherwise be available due to the high cost and non-ubiquitous wavefront approach.

As cinema returns to its roots on stage in a new form, interactive digital holography offers viewers a unique perspective spatial exploration and experience of an event, live and preserved. Further development will allow for visualizations to occur in both holographic and non-holographic contexts and purposes.

As methodologies for capturing live 3D data advance, the visual effects of the pre-cinema theatrical experience will continue to evolve as multi-perspective form.

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