A REVIEW ON DIGITAL HOLOGRAPHIC THREE DIMENSIONAL VIDEO DISPLAYS

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ABSTRACT

Holography aims to record and regenerate volume filling light fields to reproduce ghost-like 3-D images that are optically indistinguishable from their physical 3-D originals. Digital holographic video displays are pixelated devices on which digital holograms can be written at video rates. Each point of the holographic screen emits light beams of different colour and intensity to the various directions, in a controlled manner. The light beams are generated through a light modulation system arranged in a specific geometry and the holographic screen makes the necessary optical transformation to compose these beams into a perfectly continuous 3D view. Many laboratories have reported working prototypes using different designs. Size and resolution of the SLMs are quite demanding for satisfactory 3-D reconstructions. Holograms are quite robust to noise and quantization. It is demonstrated that either laser or light-emitting diode (LED) illumination is feasible. Current research momentum is increasing with many exciting and encouraging results.

I. INTRODUCTION

In this short paper contribution, we briefly present a Three-dimensional video displays that can generate ghost like optical duplicates of 3-D objects and scenes have been depicted in science-fiction movies as futuristic means of visual media tools; such display devices always attracted public interest.. The display uses a specially arranged array of micro-displays and a holographic screen.

With proper software control, the light beams leaving the various pixels can be made to propagate in multiple directions, as if they were emitted from physical objects at fixed spatial locations. The display is driven by DVI streams generated by multiple consumer level graphics boards and decoded in real-time by image processing units that feed the optical modules at high refresh rates.Computer graphics is confined chiefly to flat images. Images may look three-dimensional (3-D), and sometimes create the illusion of 3-D when displayed, for example, on a stereoscopic display. Nevertheless, when viewing an image on most display systems, the human visual system (HVS) sees a flat plane of pixels. Volumetric displays can create a 3-D computer graphics image, but fail to provide many visual depth cues (e.g., shading, texture gradients) and cannot provide the powerful depth cue of overlap (occlusion). Discrete parallax displays (such as lenticular displays) promise to create 3-D imageswith all of the depth cues, but are limited by achievable resolution. Only a real-time electronic holographic ("holographic video") display can create a truly 3-D computer graphics image with all of the depth cues (motion parallax, ocular accommodation, occlusion, etc.) An electro holographic display generates a 3D holographic image from a 3D description of a scene. This process involves many steps, grouped into two main processes:

- Computational, in which the 3D description is converted into a holographic fringe.
- Optical, in which light is modulated by the fringe.

Fig: 1. The 3d Holographic Display Box

The difficulties in both fringe computation and optical modulation result from the enormous amount of information (or "bandwidth") required by holography. Instead of treating an image as a pixel array with a sample spacing of approximately 100 microns as is common in a two-dimensional (2-D) display, a holographic display must compute a holographic fringe with a sample spacing of approximately 0.5 micron to cause modulated light to diffract and form a 3-D image. A typical palm-sized full-parallax (light diffracts vertically as well as horizontally) hologram has a sample count (i.e., "space-bandwidth product" or simply "bandwidth") of over 100giga samples. Horizontal parallax-only (HPO) imaging eliminates vertical parallax resulting in a bandwidth savings of over 100 times without greatly compromising display performance. Holographic video is more difficult than 2-D displays by a factor of about 40,000, or about 400 for an HPO system. The first Holographic display created small (50 ml) images that required minutes of computation for each update. New approaches, such as holographic bandwidth compression and faster digital hardware, enable computation at interactive rates and promise to continue to increase the speed and complexity of displayed Holographic images.

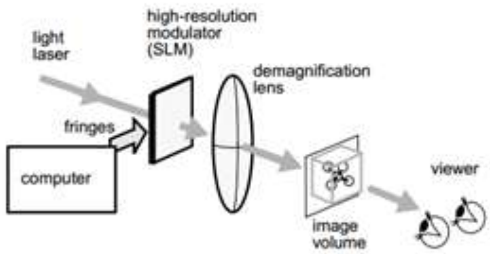

Fig:2 Holographic Bandwidth Compression

II. RELATED WORK

Developing a scalable holographic system targeting multiuser interactive computer graphics applications is a large engineering effort that requires advances in a number of technological areas. A full survey is beyond the scope of this short paper. In the following, we just provide a brief overview of competing 3D display technology for naked eye users.

Autostereoscopic displays implement left/right eye separation using various optical or lens rasters directly on top of LCD or plasma screens.

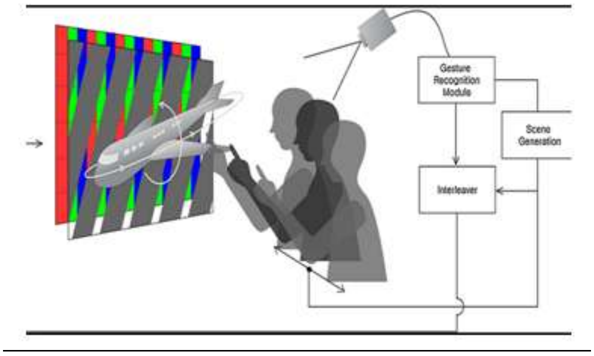

Fig: 3. Autostereoscopic Displays

This type of display imposes a single static viewing position. To overcome these limitations, manufacturers of stereoscopic displays are developing head/eye-tracking systems capable of following the viewer’s head/eye movement. However, such a solution cannot support multiple viewers and introduces latency.

Multi-view displays show multiple 2D images to multiple zones in space. They support multiple simultaneous viewers, restricting them, however, to be within a limited viewing angle. Multi-view displays are often based on an optical mask or a lenticular lens array. The Cambridge multi-view display is a classic design in this area.Lenticular state of the art displays typically use 8–10 images, i.e., directions, at the expense of resolution. A 3D stereo effect is obtained when left and right eyes see different but matching information. The small number of views produces however, cross-talks and discontinuities upon viewer’s motion. Our solution, instead, presents a continuous image to many viewers within a large workspace angle, due to the high number of view dependent on pixels that contribute to a single image.

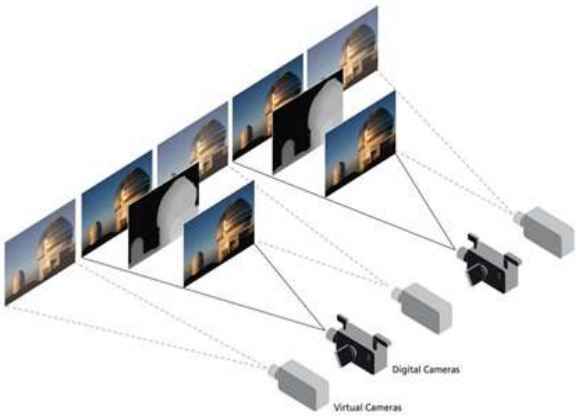

Fig: 4. Multi-View Displays

Volumetric displays project light beams on a semi-transparent or diffuse surface positioned or moved in spacethat scatters/reflects incoming light. By proper synchronization, it is possible to reconstruct 3D objects (fig:5Actuality, Felix, Deep Video Imaging). Portrayed objects appear however transparent, since the light spots addressed to points in space cannot be occluded by foreground voxels.

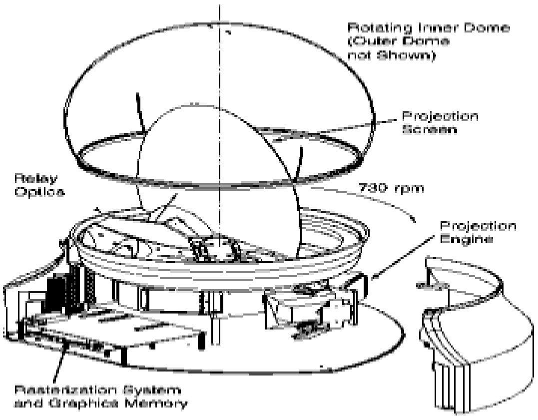

Fig: 5.Volumetric Displays

Pure holographic displays generate holographic patterns to reconstruct the light wave front originating from the displayed object, using acousto-optic materials, optically addressed spatial light modulators, or digital micro-mirror devices. Compared to stereoscopic and multi-view technologies, the main advantage of a hologram is in the quality of the 3D reconstruction. These systems are still confined to research laboratories, since the fundamental principle imposes limitations on realistically achievable image sizes, resolution, speckle, with consequent narrow fields of view, alongside enormous computing capacity required to reach acceptable refreshment rates for true interaction. In current prototypes, the display hardware is very large in relation to the size of the image (which is typically a few centimetres in each dimension).

III. DYNAMIC OF HOLOGRAPHIC DISPLAY

The first computer generated hologram was introduced by Lohmann and Paris in 1967. In the same year, Goodman and Lawrence brought forward the idea of the digital holography. Then, in 1980, the fundamental theory of digital holography was introduced by Yaroslavskii and Merzlyakov. We use the term B digital holography in a broader sense to include all sorts of digital techniques to compute wave propagation, diffraction, and interference, as well as digital capture and digital display of holograms. However,dynamic displays for holographic video are still far from providing satisfactory results. In electro holography, the resolution is significantly lower compared to thick holograms. Moreover, pixelated structures bring some additional problems. Pixel period determines the maximum frequency that can be represented when digital-to-analogy conversion is conducted in the Shannon sense, and this in turn determines the maximum diffraction angle.

Since liquid crystal spatial light modulators (SLMs) are currently the primary choice for digital holographic displays, it is quite relevant to briefly mention current capabilities of such devices.Since liquid crystal spatial light modulators (SLMs) are currently the primary choice for digital holographic displays, it is quite relevant to briefly mention current capabilities of such devices.There are various SLMs such as liquid-crystal-based devices (liquid crystal devices and liquid crystal on silicon devices), mirror based devices (digital micro-mirror devices) and solid crystal devices (acousto–optical devices). The acousto–optical modulators (AOMs) are mostly used in 1-D applications.There are various SLMs such as liquid-crystal-based devices (liquid crystal devices and liquid crystal on silicon devices), mirror based devices (digital micro-mirror devices) and solid crystal devices (acousto–optical devices). The acousto–optical modulators (AOMs) are mostly used in 1-D applications. Ohmura et al. proposed a method to increase the viewing angle using such SLMs. In their proposed system, they used a single SLM that was driven by a mirror module. As a consequence of this method the resolution along the horizontal direction increases.Liquid-crystal-based SLMs are classified into various types such as complex amplitude, amplitude-only, phase only, trans missive and reflective-type SLMs, and so on.

The discussions corresponding to the bandwidth restriction and the pixel period given in Section III are valid for all such types of pixelated SLMs. Among them, the fully complex amplitude-type SLM may be the ultimate solution for the accurate reproduction from the hologram corresponding to a 3-D object. Ability to support complex functions at the display is highly desirable since diffraction fields are represented as complex valued fields where both the amplitude and the phase are needed. An ideal SLM pixel should modulate both the amplitude and the phase of the incident light.However, it is difficult to manufacture the complex amplitude-type SLMs based on current technology. Phase-only SLMs may be the next best solutions for electro-holography because they have several advantages over amplitude-only SLMs such as suppressed zeroth-order and high-diffraction efficiency, which can theoretically reach 100%. Amplitude-only SLMs can also be used for electro holography. However, problems associated with strong undesired diffraction orders are more severe compared to the phase-only case. A research group from Barcelona University, Barcelona, Spain, combined two SLMs to display full complex Fresnel holograms. They used one SLM for the amplitude and the other one for the phase. They also investigated the quality of the reconstructions using real-only, imaginary-only, amplitude-only, and phase-only holograms.Schwerdtner et al. reported a novel hologram technology, which they called tracked viewing window (TVW). By this approach they only calculate a small portion of a hologram, which then reconstructs a narrow angle light that falls onto the tracked pupils of the observer. They demonstrated that thin film transistor (TFT) monitors can then be used as SLMs to build holographic displays.Another electro-holographic display technique was presented by Hahn et al. In their research, they used curved array of SLMs to increase the field of view.

Spatial Imaging Group at the Massachusetts Institute of Technology (MIT, Cambridge, MA) developed a series of holographic display systems named Mark-I, Mark-II, and Mark-III. Mark-I and Mark-II use acousto–optical modulators, whereas Mark-III uses guided-wave optical scanners. All three can render 3-D objects at video rates. A company developed another holographic display system. The system uses active tiling where an electrically addressed SLM (EASLM) projects tiles of a big hologram onto an optically addressed SLM (OASLM).

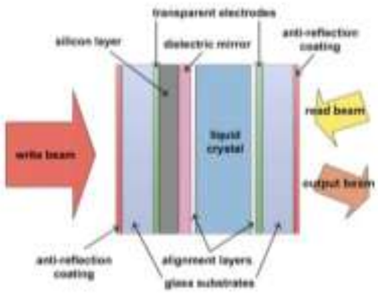

Fig:6. Optically Addressed Slm

IV. RECENT RESULTS FROM BILKENT UNIVERSITY

Holographic displays have been investigated at Bilkent University, Ankara, Turkey, since early 1990s. Recently, they used SLMs for such purposes and demonstrated single and multiple SLM holographic displays. They mostly use phase-only SLMs. For example, in a study involving only one phase-only SLM, in-line phase holograms, which were calculated by Gerchberg–Saxton algorithm, were used to show that reconstructions that are larger than the SLM size are feasible. In another system, three SLMs were used to generate colour holographic reconstructions.. Again the Gerchberg–Saxton algorithm was used to generate the in-line phase holograms that were written on the SLMs. Three phase holograms were calculated separately (for red, green, and blue channel) and loaded to the SLMs. Color light-emitting diodes (LEDs) were used as light sources; all three reconstructions were combined to obtain a color reconstruction. Yet another system generates and displays holograms in real time. The phase-only holograms for the display were computed using a fast, approximation-based algorithm called accurate compensated phase-added stereogram (ACPAS), which was implemented on graphics processing units (GPUs) to render the holograms at video rates. LEDs were used as light sources for reconstructions that can be observed by naked eye.

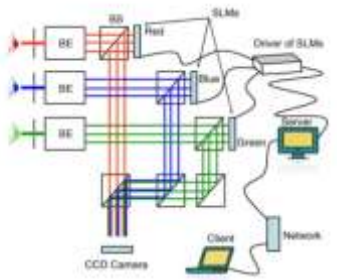

Fig:7. The Overall Setup

Fig. 7 shows the overall setup for the real-time colour holographic display system and Fig. 8(a)–(b)shows the original color 3-D model, the computer reconstruction from the phase-only hologram, and the optical reconstruction from the same hologram written on the SLM, respectively. They also compared the quality of optical reconstructions obtained by using a laser and a LED as the light source. Eventhough LEDs have broader spectra than lasers, they conclude that reconstructions using LEDs can be still satisfactory in quality. In a recent prototype, a curved array of six phase-only SLMs was used to increase the field of view. As a consequence of the achieved large field of view, the observer can look at the optical reconstruction binocularly and see a real 3-D image floating in the space. Reconstruction can also be observed from different angles without any discontinuity and with a larger horizontal parallax.

Fig.7 shows the optical reconstructions of a pyramid recorded from different angles. The ghost-like 3-D image (a real optical image) was positioned next to a similar physical object located at the same depth, and the recording camera was focused to that plane; such a setup shows the depth location of the reconstruction, as well as its quality of parallax and sharpness by providing a similarphysical object for comparison. The actual size of the base of the pyramid is about 1 cm X 1 cm, and its height is about 2 cm. The reconstruction (real image) is about 50 cm in front of the SLMs.

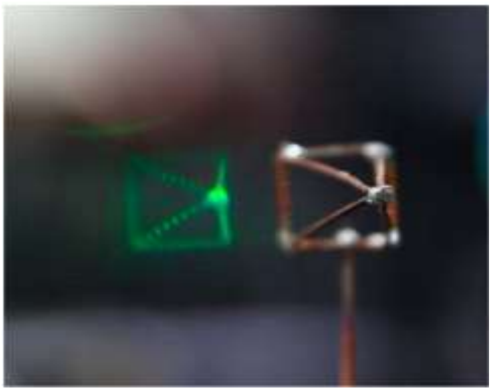

Fig. 8(A) Original Colour 3-D Model

This brief overview of current state of the art indicates that dynamic holographic displays do have the potential for highly satisfactory futuristic 3DTV displays; however, they do not yet provide such satisfactory results to the consumer who expects the counterpart of crisp clear conventional 2DTV displays. Further research is certainly needed.

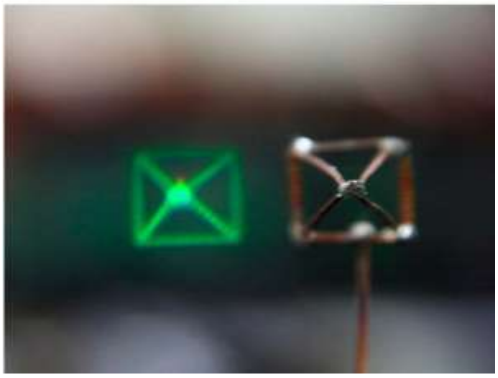

Fig:8 (b). The optical reconstructions.

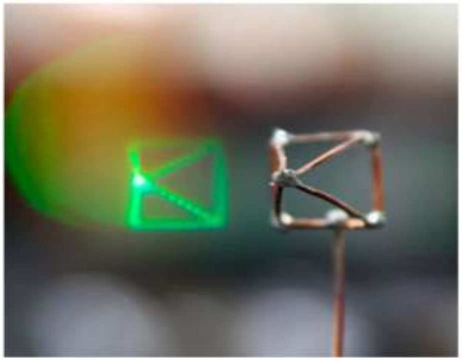

Fig. 8: (c) The optical reconstructions.

4.1 A Specification of Dynamic Holographic Display

The design and implementation of electronically controllable dynamic displays to support holographic video are thekey issues for the success of such true 3-D displays. Currently available devices have quite limited capabilities, and thus, do not yield satisfactory performance, yet. We expect that such products will be significantly improved I in the future. One of the tasks related to digital holographic video displays is to find the specifications associated with various physical parameters of a digital holographic display system to achieve satisfactory quality 3-D reconstructions. Candidate devices are different variants of pixelated SLMs for digital operation. Here in this section we present such specifications, for a few different cases, based on associated analysis and experiments. The analysis is based on related human visual system properties, which are then reflected to the parameters of satisfactory 3-D reconstructions; subsequent association of these reconstructed image features to the SLM parameters completes the analysis.Various physical parameters of a digital holographic display system to achieve satisfactory quality 3-D reconstructions. Candidate devices are different variants of pixelated SLMs for digital operation. Here in this section we present such specifications, for a few different cases, based on associated analysis and experiments. The analysis is based on related human visual system properties, which are then reflected to the parameters of satisfactory 3-D reconstructions; subsequent association of these reconstructed image features to the SLM parameters completes the analysis.

V. NOISE AND QUANTIZATION.

Theoretically, diffraction distributes the information due to a compact object to the entire space. As a consequence of that, reconstructions from even harshly quantized holograms may give reasonable results. Although holograms are quite immune to noise and quantization, it is still good to know the noise sources in digital holography. In commonly used pixelated electro–optical devices, fringe patterns are usually quantized to 256 levels. For example, in available phase-only SLMs, it is typical to have the phase quantized to 256 levels between 0 and 2 radians. Mills and Yamaguchi reported some quantization effects in phase-shifting holography. After numerical and experimental results they concluded that even 4-b quantization is enough, and, the difference when the quantization level is increased to 6-b or 8-b quantization is unnoticeable. Another source of error is the finite precision arithmetic used during the computation of holographic patterns. The physical setup itself that consists of optical elements is another source of distortion due to imperfections and imprecise alignments. Many optical elements have colour aberration problem, which means they act differently for each wavelength.Another type of noise in digital holography is the speckle noise. When coherent light passes through or reflectsback from randomly diffused media, randomized phase regions are generated and the superposition of such random phase components creates the speckle noise. There are many methods to eliminate this undesirable effect. LEDs have both time and space coherence to some extent. Narrow spectrum of LEDs brings some time coherence and using a pinhole in front of them increases the spatial coherence. However, since LEDs do not generate a perfectly coherent light, there is no observable speckle noise. LEDs are not harmful to the eyes as lasers if they are not too bright. Therefore, reconstructed images can be observed by the naked eye under the LED illumination. Other advantages of LEDs are ease of operation and their low cost. However, due to low coherence characteristics reconstructions might be somewhat blurred.

Based on the discussions above we can conclude that higher than 4-b quantization gives satisfactory results for a human observer especially when the number of hologram pixels is high. Since commercially available SLMs generally use 8-b quantization, it is more than needed. Moreover, since LEDs are not fully coherent, decrease in the speckle noise is significant and holographic reconstructions by using LEDs are promising. Therefore, LEDs can be effectively used in holographic display systems.

VI. CONCLUSIONS AND FUTURE WORK

We have presented a design and prototype implementation of a scalable holographic system design that targets multiuser interactive computer graphics applications. The current display prototype is already sufficient for developing compelling prototype 3D applications that exploit its truly multiuser aspects. We are currently working on two demonstrators: one for the medical market (CT data analysis), and one for the CAD market (design review).

Reasonable sizes and resolutions seem to be sufficient for a stationary observer with no lateral or rotational motion. However, the needed SLM size and pixel density quickly increase beyond the capabilities of today's electronic technology when such motion is allowed as in a natural viewing environment. An alternative is to arrangeplanar SLMs on a curved mount to relieve the requirement of small and high-density pixels.

It will be a large-scale 3D system with screen diagonal size of 1.8 meters, and a pixel reduced by 15% relative to the current models, to enable displaying high resolution 3D images.

REFERENCES

[1]. DODGSON N. A., MOORE J. R., LANG S. R., MARTIN G., CANEPA P.:Time-sequential multi-projector autostereoscopic 3D display. J. Soc. for InformationDisplay 8, 2 (2000), 169–176.

[2]. TakanoriOkoshi, Three-Dimensional Imaging Techniques. New York: Academic Press, 1976.

[3]. Michael McKenna and David Zeltzer. Three dimensional visual display systems for virtual environments. Presence: Teleoperators and Virtual Environments. Vol. 1 #4, pp. 421-458, 1992.

[4]. David F. McAllister, ed. Stereo Computer Graphics and Other True 3D Technologies. Princeton University Press, Princeton, N.J., 1993.

[5]. Mark Lucente and Tinsley A. Galyean, Rendering interactive holographic images. Proceedings of SIGGRAPH '95 (Los Angeles, California, August 6-11, 1995). In Computer Graphics Proceedings.