The Ever Evolving Holographic Technology

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Abstract: ***If a 2D picture is worth a thousand words, then a 3D image is worth a million. Holography is the recording and reconstruction of light field information. Although holography is a concept invented over 70 years ago, recent developments aim to create 3D displays in thin air that are perceivable without the use of any glasses.***

Keywords: Biophotonics, Autostereoscopic, 3-D holographic televisions, electro-holography, IR Holography

1. Introduction

Three-dimensional displays that can generate optical duplicates of 3-D objects have been depicted in science-fiction movies since decades. The question is whether such a display is possible in real world. Noting that seeing is a purely optical interaction, and what we (including living organisms and machines) see is due to the light that enters through our pupils, if we are able to record the volume in a time-varying light field in a 3-D scene, having all the required physical properties, and then regenerate this light field, maybe at another time, the observer will not be able to distinguish the original scene from its duplicate since the received light will be the same. Holography is derived from the Greek which means "whole drawing". Hologram, invented in 1947 by Dennis Gabor, in the most basic sense, is the recording and then reconstruction of light field information. It is such that when it is viewed, the observer cannot distinguish between the original scenario and the hologram because the hologram 'gives' the observer all the original light information.

2. Methodology

The process for holography is carried out in two phases: Recording and Reconstruction. Basic tools used in making a hologram include lasers, lenses, beam splitter, mirrors and holographic film. Holograms are recorded in dark environment to avoid the noise interference caused by other light sources. The recording stage of a hologram works on the interference phenomenon. It uses a laser source, a plane mirror or beam splitter and a photographic plate. The laser beam is incident on a plane mirror or beam splitter which splits the laser beam. One part of spitted beam, called the reference beam, after reflection from the splitter, strikes on the photographic plate. While other part of beam, is called the object beam strikes on the photographic plate after undergoing reflection from the various points of the object.This object beam interferes with the reference beam atthe photographic plate. Their superposition produces an interference pattern (in the form of dark and bright fringes) and this pattern is recorded over the photographic plate. This photographic plate with the recorded interference pattern on it is called as hologram. It is also known as Gabor zone plate after Denis Gabor. Each and every part of the hologram receives light information from various points of the object. Therefore, even a small part of the hologram is capable of reproducing the whole object.

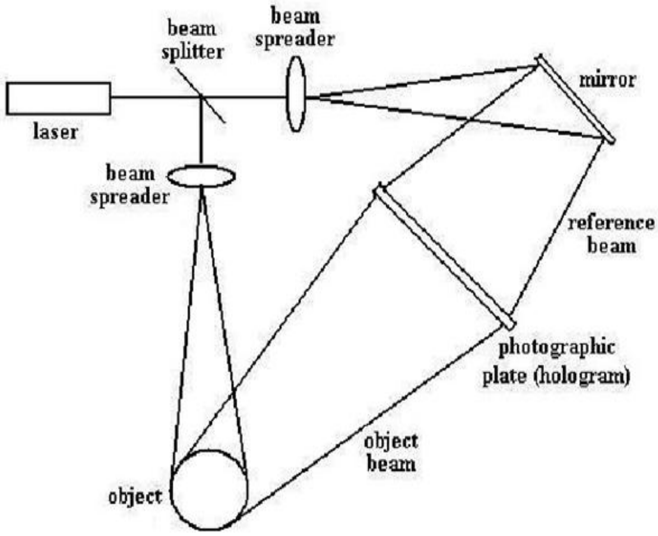

Figure 1: Construction of a Hologram

There are two kinds of holograms: Reflection holograms and Transmission holograms.

Reflection Holograms:
Reflection holograms form images by reflecting a beam of light off the surface of the hologram. They produce very high quality images but are very expensive to create.

Transmission Hologram
Transmission holograms form images by transmitting a beam of light through the hologram. These holograms are more common since they are inexpensive to mass-produce. Embossed holograms, like those on credit cards, are transmission holograms having mirrored backing.

3. Advancements in Holography

Since its inception in 1947 by Dennis Gabor, holography has come a long way. New and better techniques for recording and reconstructing a 3-D image have been devised ever since based on Gabor's initial works. The first mass-distributed hologram appeared inthe 1967 edition of the World Book Encyclopedia Science Yearbook. It depicted a 4"x3" transmission view of chess pieces on a board. In the year 1968, the first holographic art exhibition was organized at the Cranbrook Academy of Art in Michigan. Holograms entered application in commercial businesses by the year 1983 when MasterCard International, Inc. became the first company to use hologram technology for security in bank cards. And the application of holography in the world has been on the rise ever since.

Today, holography finds its use in many of the day-to-day and essential fields. Examples include, supermarket scanners that read the bar codes on their products for the store's computer by using a holographic lens system to direct laser light onto the product labels. Holography is used to depict the shock wave made by air foils to identify the areas of high stress. These holograms are used to improve the design of aircraft wings and turbine blades. A holographic lens is used in an aircraft "heads-up display" to allow a fighter pilot to see critical cockpit instruments while looking straight ahead through the windscreen. Holography is ideal for archival recording of valuables and fragile museum artifacts. Facial surgery and forensic science are benefiting from a portable holography system that can capture the shape and texture of faces in an instant. Holograms can also be used as storage material for data.

New methods have been devised to produce better recordings. One such technique is employing a long Infrared wavelength that allows for the hologram recording of large size objects, and makes the acquisition of the interference pattern less sensitive to vibrations [1]. IR holography can be adopted to visualize moving subjects through smoke and flames, demonstrating the possibility to record human-size holograms on a digital support [2].

Another breakthrough in holography was with the Lab-on-chips biophotonics. A new technology called hybrid optoelectronic manipulation in microfluidics combines a laser with electric fields and promises a new lab-on-a-chip designed to manipulate DNA, bacteria and viruses for a variety of fundamental science applications. The technology works by first using a red laser to position a droplet on a platform created at Purdue. Then, a highly focused infrared laser heats the droplet, and electric fields cause the heated liquid to circulate in a microfluidic vortex, used to isolate specific types of particles in the circulating liquid. Particle concentrations replicate the size, shape and location of the infrared laser pattern. The process takes less than a second.
With Digital Holographic (DH) microscopy, quantitative 3D reconstructions can be achieved thus solving the problem of biovolume estimation and 3D rendering of motile cells[3]. In particular, multiple-hologram reconstructions can be processed to recover the phase information of cells flowing behind a scattering layer in a microfluidic channel [16]. Moreover with DH, it is possible to see through a true blood flow [4].

4. Future of Holography

The future promises at developing 3-D display devices with which three-dimensional images can be perceived without the use of eye gears, such as 3-D glasses, Microsoft's Hololens, etc. Such a display will provide a truly immersive 3D experience, just like a hologram that changes perspectives as the observer's movements around it.

Today's 3D technology works by using two different images that are displayed by the TV the observer is looking at. One image is polarized vertically and the other horizontally. The lenses of the glasses are designed such that a different image passes through each eye, which creates the illusion of 3D. After all, the depth perception we experience in real life results from each eye seeing what is in front of us from a different perspective. Today's 3D technology falls short in a number of ways. The most obvious being the need for special viewing glasses that may be uncomfortable to wear and sometimes darken the on-screen imagery.

The ultimate three-dimensional television viewing experience will be autostereoscopic (meaning, it will not require any glasses), provide smooth parallax rather than just two views, and support other real-world perceptual cues to depth such as visual accommodation (focusing) [5].

Glassless 3D displays are the newest in the market and work on the present 3D technology. They have a barrier that directs different light into each of the two eyes when the 3D feature is enabled. When the 3D feature is disabled, the barrier gets disabled and the same light reaches both the eyes, which gives the 2D look. With 3D enabled, bits of the light are blocked from reaching either eye. Each eye sees a different image, creating the 3D look and the illusion of depth in our brain. There are a few different ways in which these displays work. In Parallax barrier displays, some light is blocked by each eye, so they each one sees a different image. They are used to block pixels from the front of the screen. They also block light from the backlight, which makes the device very energy-efficient and the picture brighter. Lenticular arrays use lenses to focus each eye on a different portion of the image. Both of these types rely on proper positioning of the viewer. Change in the position of the observer may not bring out the same desired 3D effect.

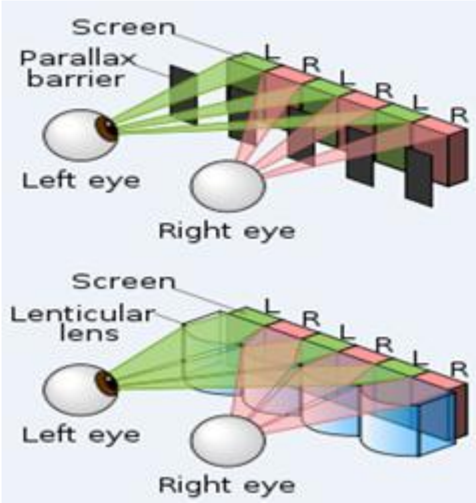

Figure 2: Present 3D technology using 'barriers' to direct different light into each of the eyes.

A breakthrough in rewritable and erasable holographic systems has paved the way for three-dimensional holographic televisions to become a reality. To create television sets the images would need to be changing multiple times and refresh each second. This has been shown possible with recent developments. There are some really interesting technologies that belong to the 3D holographic alcove. One among them is the electro-holographic display which uses electro-holography to record 3D objects and reconstruct them. This display is different from other 3D displays. For example, during the reconstruction of 3D images, it also captures the parallax. Another technology is called the touchable hologram that runs a software which relies on ultrasonic waves. The user who is touching the projected hologram can feel a pressure on their hand.

5. Conclusion

Holography finds various applications in different fields of business and science. Due to the improvements in the output and efficiency of light sources, optical elements, holographic plates, and the other holographic recording media, the quality of holographic images has improved significantly. Holographic Technology and Spectral Imagining have endless applications, as far as the human mind can imagine. Holography being the closest display technology to our real environment may just be the right substitute when reality fails. In future, holographic displays will be replacing all present displays in all sizes, from small phone screen to large projectors.

References

[1] Alexeenko, J.-F. Vandenrijt, G. Pedrini, C. Thizy, B. Vollheim, W. Osten, and M. P. Georges, BNondestructive testing by using long-wave infrared interferometric techniques with CO2 lasers and microbolometer arrays, Appl. Opt., vol. 52, no. 1, pp. A56–A67, Jan. 2013.

[2] M. Locatelli, E. Pugliese, M. Paturzo, V. Bianco, A. Finizio, A. Pelagotti, P. Poggi, L. Miccio, R. Meucci, and P. Ferraro, BImaging live humans through smoke and flames using far-infrared digital holography,[Opt. Exp., vol. 21, no. 5, pp. 5379–5390, Mar. 2013.

[3] F. Merola, L. Miccio, P. Memmolo, G. Di Caprio, A. Galli, R. Puglisi, D. Balduzzi, G. Coppola, P. Netti, and P. Ferraro, BDigital holography as a method for 3D imaging and estimating biovolume of motile cells,[Lab Chip, vol. 13, no. 23, pp. 4512–4516, Dec. 2013.

[4] V. Bianco, M. Paturzo, A. Finizio, A. Calabuig, B. Javidi, and P. Ferraro, BClear microfluidics imaging through flowing blood by digital holography,[IEEE J. Sel. Topics Quantum Electron., vol. 20, no. 3, p. 6 801 507, 2013.

[5] V. M. Bove, J. Barabas, S. Jolly, and D. Smalley, “How to build a holographic television system,” in Proceedings of the 3DTV-Conference: The True Vision-Capture, Transmission and Display of 3D Video (3DTV-CON '13), pp. 1–4, IEEE, 2013.

[6] Reichelt, S.; Haussler, R.; Leister, N.; Futterer, G.; Schwerdtner, A., "Large holographic 3D displays for tomorrow’s TV and monitors - solutions, challenges, and prospects," IEEE Lasers and Electro-Optics Society, 2008. LEOS 2008. 21st Annual Meeting of the , vol., no., pp.194,195, 9-13 Nov. 2008

[7] Yu-Cheng Fan; Chun-Chang Lu; Di-Wei Syu; Sin-Hong Chen; Yun-Ting Shie, "3-D Holographic Data Storage Circuit Design," Magnetics, IEEE Transactions on , vol.50, no.7, pp.1,5, July 2014

[8] [8] Memmolo, P.; Bianco, V.; Merola, F.; Miccio, L.; Paturzo, M.; Ferraro, P., "Breakthroughs in Photonics 2013: Holographic Imaging," Photonics Journal, IEEE , vol.6, no.2, pp.1,6, April 2014.