Holographic television: status and future

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1 Introduction

Recent history of visual multimedia is given by a rapid development of three-dimensional imaging, visualization and display. This includes stereoscopic and autostereoscopic systems, head mounted displays, integral photography and digital holography [1,2,3]. Although almost all currently available 3D displays used in 3D TV are stereoscopic, a viewer still suffers a certain discomfort due to physical duplication of 2D light distribution which reaches his eyes. The technology which could potentially offer more comfortable and realistic 3D capture and display is holography. It has been recognized by Lieth and Upatnieks already in 1962 [4], however due to several limitations connected with an analog versus digital data capture and limited bandwidth of hologram transmission systems the real implementation of optical holography in television had not been realized. The dormancy of the research works on the holographic television lasted until 1990 when high resolution CCD cameras, fast image processing computers and spatial light modulators become available [5]. The advances in these electro-optics products speed up works at both electro-holographic video and displays as well as the full concept of 3D holographic television. Below we report on history, present works, limitations and prediction for future development of the research on these topics.

3 Review

The first electro-holographic video, called Mark-I was developed at MIT Media Lab in 1989. It used multi acousto-optical (AO) modulators and in the most recent versions (Mark-III) surface acoustic waves [6]. This approach has strong advantages such as wide diffraction angle, high diffraction efficiency and high spatial frequency, however AO devices are rarely used as they modulate the light in one dimension and require scanning. Liquid crystal SLMs are more suitable for electro-holography and they were applied in such systems as SeeReal (a wide viewing zone, but for a single observer) [7], QinetiQ (active tiling system allowing to extend it to obtain pixel count in the order of 10^9) [8]. However these systems used as a data source computer generated holograms, only. The full path of 3D capture and display was demonstrated in 2009 by Japan's National Institute of Information and Communication Technologies [9]. The acqusition system uses an integral photography camera, computer to generate a digital hologram and three LCSLMs to reconstruct full colour image in real-time. There are also several other approaches including coherent stereogram, hybrid holographic techniques (capturing 3D data by structured light techniques and recalculating a cloud of points (x,y,z) into computer generated hologram), holo-video using image hologram approach and many other [3,5]. However they do not provide a complete realistic solution for 3D holographic television due to several technological limitations connected with available detectors and SLMs (pixel and aperture size, speed).

3 Full digital holography approach

The full implementation of digital holography into television system requires providing solutions at three main stages of : capture, data transmission and display (Fig.1). Digital holographic data require also extended processing and manipulation [10] in order to decouple the capture and display system and provide the phase data for final reconstruction at multiple phase-only LC SLMs display [11]. The holograms captured are most often on-line Fresnel holograms, in which the zero order and twin image reduction is performed by phase shifting (static scenes) or numerical procedures of unwanted terms removal (dynamic scenes) [5].

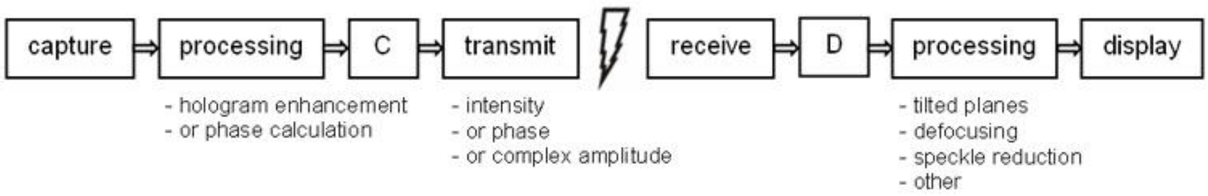

Fig. 1. The digital holographic signal processing chain required in holographic television of real scenes C – compression, D - decompression

The systems which will make the best use of a spatio-temporal bandwidth of the matrix detectors and SLMs and provide good conditions for binocular vision have circular configurations as shown in Fig.2 [10]. The main problem in this configuration is to provide the best fill factor FF (FF - the ratio of angular dimension of an active CCD/SLM area to angular separation of CCDs/SLMs) for the captured and displayed wavefield which in consequence allow to reconstruct continuous object wavefield and its comfortable viewing by an observer.

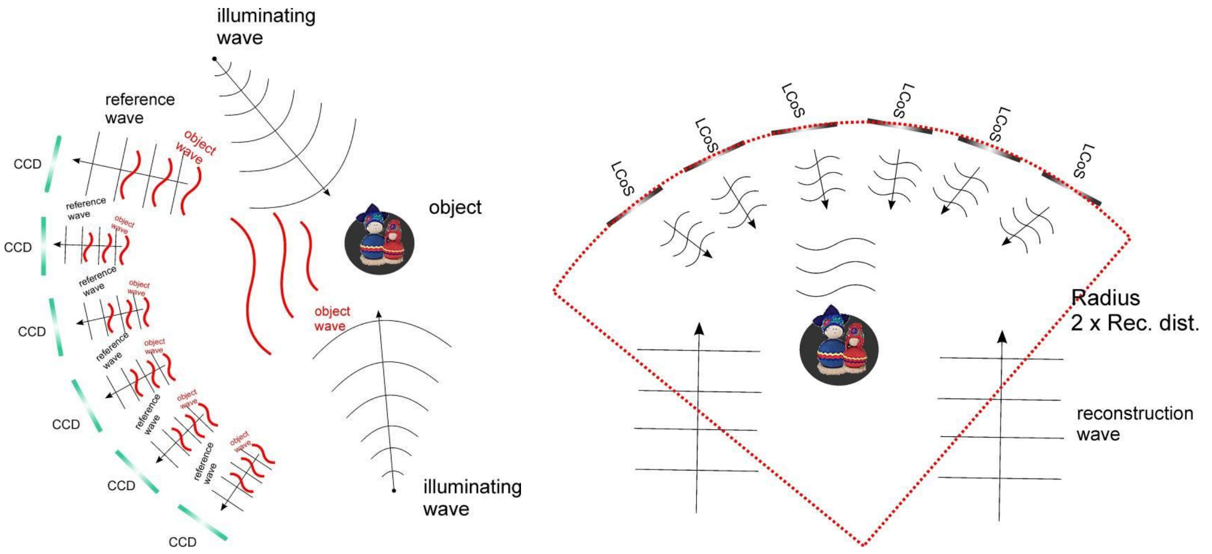

Fig. 2. The schemes of data capture (a) and display (b) by multiple CCDs and LC SLMS in the circular configuration

4 Conclusions and outlook

The ideal 3D holographic television would produce moving images in real time that exhibits all characteristics of an original scene. However we are still far with the capture and display technology to achieve this goal and allow comfortable visual perception of a holographic scene. The main efforts should be focused on:

- increasing aperture (0.5m^2) and decreasing the size of pixel for both detector and display (ap.1μm),
- provide CMOS and SLM (OLED) at a flexible substrate,
- provide novel smart method to reduce the spatial bandwidth of a scene (efficient use of spatio-temporal bandwith of both detector and display),
- increase the quality (reduce coherent noise) of reconstruction and flexibility of an observer position versus holographic display.

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6 References

1. B. Javidi, F. Okano (Eds) (2002) Three dimensional Television, Video and Display Technology, Springer, Berlin, Germany
2. B. Javidi, F. Okano, J-Y. Son (Eds.) (2009) Three-Dimensional Imaging, Visualization and Display, Springer, Berlin, Germany
3. H. M. Ozaktas, L. Onural (Eds.) (2008) Three-Dimensional Television, Springer, Berlin, Germany
4. E. N. Leith, J. Upatnieks, B.P. Hildenbrand, K. Haines (1965) Requirements for the wavefront reconstruction Television Facsimile System, J. SMPTE 74: 893-896
5. T-Ch. Poon (Ed.), (2006), Digital Holography and Three-Dimensional Display, Springer, Berlin, Germany
6. P.S. Hilarie, S.A. Benton, M. Lucente, P.M. Hubel (1992) Color images with the MIT holographic video display Proc. SPIE 1667:73-84
7. R. Haussler, A. Schwerdtner, N. Leister (2008) Large holographic display as an alternattive to stereoscopic displays Proc. SPIE 6803:68030M
8. M. Stanley et al. (2004) 3D electronic holography system using a 100mega-pixel spatial light modulator Proc. SPIE 5249:297-308
9. http://www.television broadcast.com/article/79134
10. D. P. Kelly et al.(2010) Digital holographic capture and optoelectronic reconstruction for 3D displays, Int. J. Digital Multimedia Broadcasting, 2010: ID759329
11. G. Finke, T. Kozacki, M. Kujawinska (2010) Wide viewing angle holographic display with multi spatial light modulator array, Proc. SPIE 7723, 772330A