TYPE Editorial
PUBLISHED 21 November 2022
DOI 10.3389/fphot.2022.1073297



OPEN ACCESS

EDITED AND REVIEWED BY
Pascal Picart,
Le Mans Université, France

*CORRESPONDENCE
P. W. M. Tsang,
eewmtsan@cityu.edu.hk

SPECIALTY SECTION
This article was submitted to Optical Information Processing and Holography, a section of the journal Frontiers in Photonics

RECEIVED 18 October 2022
ACCEPTED 09 November 2022
PUBLISHED 21 November 2022

CITATION
Tsang PWM, Poon T-C, Zhang Y and Ferraro P (2022), Editorial: Digital holography: Applications and emerging technologies.
*Front. Photonics* 3:1073297.
doi: 10.3389/fphot.2022.1073297



# Editorial: Digital holography: Applications and emerging technologies

P. W. M. Tsang[1]*, Ting-Chung Poon[2], Yaping Zhang[3] and Pietro Ferraro[4]

[1]City University of Hong Kong, Kowloon, Hong Kong SAR, China, [2]Bradley Department of Electrical and Computer Engineering, Virginia Tech, Blacksburg, VA, United States, [3]Yunnan Provincial Key Laboratory of Modern Information Optics, Kunming University of Science and Technology, Kunming, Yunnan, China, [4]National Research Council (CNR), Roma, Italy

KEYWORDS

**acoustic field imaging, chemiluminescence tomography, deep neural network, digital holography, fourier ptychographic reconstruction, fringe printer, noise suppression, visual cryptography**

Editorial on the Research Topic
Digital holography: Applications and emerging technologies

A lot of researchers in optics have mentioned that holography, pioneered by Gabor in the late 40s could be a major, and possibly the ultimate solution towards three-dimensional (3-D) display. This may not be an overstatement, for as early as 1962, Yuri Denisyuk and his peers have realized optical holograms for recording 3-D images of real-world objects. When lit with a coherent light source, a hologram reconstructs a realistic visual image of the 3-D objects it records. Being different from another effective and widely adopted 3-D technology based on the lenticular lens, observing a hologram does not lead to accommodation-vergence conflict, which could induce visual fatigue or headaches to some people. Despite all its advantages, optical holography does not gain equal acceptance in the consumers market as compared with traditional photography. The discrepancy is mainly due to the need of expensive and delicate optical setups, mounted in a practically vibration-free optical table in a dark room, in capturing a hologram. These kind of stringent requirements basically limit the production of holograms to a laboratory environment that is generally unavailable to consumers at large. Similar to photography, optical holograms records magnitude of light waves encapsulating both amplitude and phase information on photographic films, and the contents cannot be changed afterwards. To produce a hologram with animated content, multiple frames of object images are sequentially recorded onto a multiplexed hologram. In this approach, the optical waves of each object image is mixed with a unique off-axis reference beam, and exposed onto the photographic film. The number of frames is rather limited and only a short video clip can be recorded onto a multiplexed hologram. Insofar, what the holography technology can be provided to the community is perhaps the 3-D holograms that we can purchase from the specialty stores.

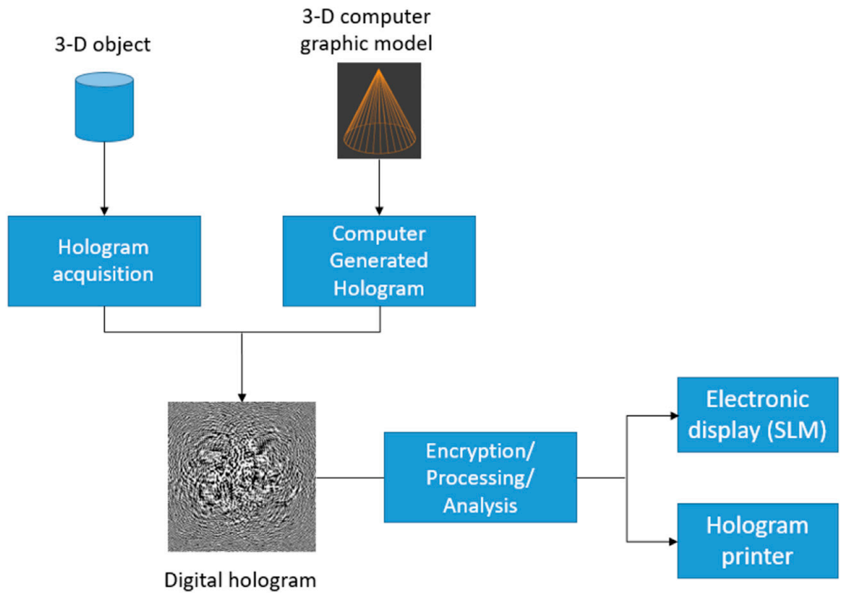


FIGURE 1
Typical infrastructure of digital holography.

However, the rapid advancement of optical, display, and computing technologies have casted light on a promising framework and future for holography, probably extending it to a realm that is comparable, if not exceeding the current digital photography. The new paradigm is realized with the integration of classical optical holography with the digital technology, an amalgamation that is generally referred to as 'digital holography'. For ease of explanation, let's refer to a typical infrastructure of digital holography in Figure 1.

From Figure 1, we observe that digital holography bears similar infrastructure as digital photography. A digital hologram can be captured from a physical object, or numerically generated from a computer graphic model. The digital hologram can be further processed and/or encrypted, and subsequently displayed with a high resolution device, or printed with a hologram printer. However, digital holography can be applied to capture, process, and display 3-D images, which is not possible with digital photography. These processes are more complicated to realize as holographic signals are complex-valued with both magnitude and phase information. Existing cameras and displays are only effective in recording and reconstructing the magnitude component of optical waves, which cannot be directly applied in handling complex-valued signals. Apart from recording and displaying 3-D images, digital holography can also be used in encryption. A digital hologram is comprised of high frequency fringe patterns that do not reveal much clue on the object image it represents. Hence if a digital hologram is encrypted, it is much more difficult to crack the decryption key through trial and error. However, this also makes a digital hologram more difficult to classify, as traditional image analysis techniques (such as contour tracing and corner detection) cannot be applied to extract a meaningful object shape from the hologram fringe patterns. In the past 3 decades, numerous research works have been conducted to develop various components in the digital holography framework. Despite the encouraging progress achieved to date, the art of digital holography keeps on evolving at a rapid pace as it involves sophisticated integration of both existing and emerging technologies. This Research Topic, comprising of 13 papers contributed by renowned scholars and experts in the field, aims to provide readers with a quick overall view on some of the latest and exciting development on digital holography. Hereafter, we shall briefly outline the main emphasis of each paper, so as to provide readers with a summary on the topics that are being covered. For those who have specific interested in selected areas, the succinct descriptions can also facilitate them to identify the relevant paper(s) to focus on.

Shen et al. in their paper, "*High-throughput artifact-free slightly off-axis holographic imaging based on Fourier ptychographic reconstruction*", describe a method for reconstructing the amplitude and phase images from a hologram that is acquired with slightly off-axis digital holographic microscopy. The authors point out that although this hologram capturing method improves the space-bandwidth product, and partially suppressing the background intensities, it is imposed with a spectral aliasing problem which cannot be discarded with filtering techniques. The phase information is jeopardized as a consequence. To overcome this issue, a non-linear optimization method based on Fourier ptychographic microscopy (FPM), is proposed to recover the object amplitude and phase information from the hologram. Experimental results reveal that the proposed method outweighs conventional off-axis method, as well as the Kramers–Kronig (KK) method in both amplitude and phase reconstruction.

Askari and Park in their paper, "*Augmentation of 3D holographic image graticule with conventional microscopy*", develop a method that projects a graticule image on test subjects. Producing a graticule pattern is often faced with the dilemma that while enlarged (extended) depth-of-field (DOF) is required for lateral measurement, a shallow DOF is needed for longitudinal measurement. The authors overcome this method by generating a hologram at minimum, and maximum angular spectrum range for extended, and shallow DOF, respectively. Experimental results, based on numerical simulation and optical reconstruction, reveal that a hologram generated with the proposed method can produce focused graticule patterns across a depth range of 80 mm. At the same time, it can also generate shallow DOF images that are only focused within a narrow depth range.

Hassad et al. in their paper, "*Multi-view acoustic field imaging with digital color holography*", apply digital holography for acoustic field imaging. Although sound signals can be measured with microphone array, the resolution and fidelity of the measurement are affected by the size and the presence of the sensors. These shortcomings could be avoided with optical imaging. The authors have proposed to use multicolor laser beams to capture three spatially multiplexed off-axis digital holograms of the acoustic field of a volume from three different directions. Experimental results reveal that the amplitude and phase components of the acoustic signal can be reconstructed from the digital holograms. A deviation between the integrated amplitude along the laser direction, and the true amplitude is noted, suggesting good research potential based on the proposed method.

Coherent noise is often a problem in digital holography as it affects the quality of measurement as well as for optical display. Li et al. in their paper, "*Speckle noise suppression algorithm of holographic display based on spatial light modulator (Invited),*" provide an overview on the speckle noise suppression of holographic display.

Past research has demonstrated that coherent noise can be reduced with deep neural network which is trained with a large dataset. The need of the large dataset is overcome in the paper by Tang et al., "*Coherent noise suppression of single-shot digital holographic phase via an untrained self-supervised network*". The authors propose to use a constant random uniform noise, and a single-phase noise as the input and ground truth for training the network.

Zhou et al. in their paper, "*Visual cryptography using binary amplitude-only holograms [Invited],*" investigate visual cryptography (VC). In VC, the useful information can be rendered without the usage of decryption algorithms. However, many VC schemes cannot withstand occlusion attacks. The authors propose the use of holography along with VC to verify their technique that is able to withstand occlusion attacks and noise contamination.

Coherent holographic imaging has a serious drawback as it is extremely susceptible to speckle noise. On the other hand, incoherent holography allows a higher signal-to-noise ratio as compared to its coherent counterpart. Tahara in his paper, "*Review of incoherent digital holography: applications to multidimensional incoherent digital holographic microscopy and palm-sized digital holographic recorder—Holosensor,*" provides a review on the advancement of modern incoherent digital holography.

Pixelated spatial light modulators (SLMs) introduce errors during holographic display. Chen et al. in their paper, "*Compact computational holographic display (invited article),*" use the use of phase shifting holography along with automatic differentiable (AD) optimization to improve the quality of holography reconstruction.

Yamaguchi and Yoshikawa in their paper, "*Development of a fringe printer with 0.35 um pixel pitch*," give a review of the development of a fringe printer that can achieve 0.35um pixel pitch computer-generated holograms and the specification of the printer has been verified experimentally.

Jin and Situ in their paper, "*A survey for 3D flame chemiluminescence tomography: theory, algorithms, and applications (invited),*" give an extensive review on the progress of chemiluminescence tomography (FCT), which is a 3D imaging technique of key physical parameters in the combustion process.

Liu at al. In their paper, "*Compressive interferenceless coded aperture correlation holography with high Imaging quality (Invited),*" use compressive sensing to improve the low signal-to-noise ratio inherent in one of the incoherent digital holographic techniques–interference coded aperture correlation holography (I-COACH). They have been able to suppress the background noise and improved the reconstruction quality of conventional I-COACH without sacrificing the imaging speed.

Zhou et al. in their paper, "*Elimination of quadratic phase aberration in digital holographic microscopy by using transport of intensity*," take advantages of the merits of transport and intensity (TIE) and digital holography (DH) to eliminate quadratic phase aberration introduced by the microscope objective in digital holographic microscopy. A regularization parameter is employed within the TIE method for phase retrieval.

Deep-leaning has been developing rapidly in recent years. Shimobaba et al. in their paper, "*Deep-learning computational holography: a review (invited)*," provide a comprehensive review on computational holography using deep leaning. The authors believe that the combination of deep leaning and physically-based calculations will lead to ground-breaking computational holography research.

## Author contributions

PT: Draft and review the manuscript. T-CP: Draft and review the manuscript. YZ: Review the manuscript and provide advice. PF: Review the manuscript and provide advice.

## Funding

National natural science foundation of China (Grant No. 61865007 and 62275113).

## Acknowledgments

Once again, we would like to express our deepest thanks to all the authors and co-authors for their valuable contributions to this Research Topics.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note