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Editorial

Computational imaging and its applications

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Sensing the world through indirect computational approaches, computational imaging provides new platforms to reconstruct target images using novel concepts of computational algorithms and imaging systems. Driven by breakthroughs in compressive sensing and machine learning, computational imaging has experienced rapid growth in recent years, opening new frontiers in imaging science. This Focus Issue consists of two topic reviews, one tutorial, and nine research papers, with a broad range of topics in computational imaging, including ghost imaging, single-pixel imaging, holographic imaging, metasurface imaging, thermal wave imaging, 3D imaging, AI-based imaging, and their relevant applications in LiDAR detection, optical encryption, object tracking, dynamic image displays, etc.

Ghost imaging is a typical computational imaging technique that reconstructs object images by calculating intensity correlations between object and reference beams. In the first review paper [1], Zhao *et al* summarized the probability theory for ghost imaging with thermal light, and employed it to analyze fractional-order ghost imaging, positive–negative correspondence ghost imaging, and photon-resolved ghost imaging. In a separate review paper [2], Gong and Han reviewed the basic principles and the key technical problems and advantages of narrow-pulsed and long-pulsed ghost imaging LiDARs via heterodyne detection, highlighting their promising potential in remote sensing and target tracking. Using only a single-pixel detector for signal collection, single-pixel imaging replaces the reference beam measurements of traditional ghost imaging with structured illumination patterns. Highly symmetrical and orthogonal patterns, such as Fourier patterns, are critical for improving imaging efficiency in single-pixel imaging. In the tutorial paper [3], Long *et al* provided a tutorial for Fourier single-pixel imaging, including its basic principles, technical details of Fourier pattern generation, an N-step phase-shifting approach, and Fourier basis pattern binarization, which facilitates a deeper understanding and practical implementation of Fourier single-pixel imaging for researchers. Applying a spatiotemporal multiplexing method, Liu *et al* demonstrated commercial DLP projector-based full-color single-pixel imaging to obtain a 128×128 pixel image in only 330 s, which provided an economical and efficient method for proof-of-principle experimental test and exhibition applications [4]. Zheng *et al* proposed and experimentally demonstrated a target positioning method for ultraviolet objects based on single-pixel detection [5]. Unlike single-pixel imaging, this method is an image-free paradigm and consists of four parallel branches, i.e. four photodetectors are required for efficient tracking, providing a practical and low-cost solution for real-time ultraviolet target positioning.

As a key branch of computational imaging, digital holography captures interference patterns electronically and numerically reconstructs the wavefront via computational algorithms to obtain both the amplitude and phase information of light waves with a digital sensor. Zhou *et al* proposed a modified Gerchberg–

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Saxton algorithm for digital holography to achieve subwavelength resolution reconstructions with reduced speckle noise, where an upgraded angular spectrum method, a narrow probability distribution, and double amplitude freedom are applied to compensate for high-frequency detail loss in inverse propagation and obtain an optimal initial phase [6]. Taghavi and Marengo developed a scattering-based framework, termed 'differential sensing', for holographic encryption, where the encryption process is done computationally with a cryptographic key as two complex and random media, and the decryption process is done analogically via physical imaging in the presence of the correct decryption media [7]. This method moves all computational burden to the encryption, and therefore enables real-time customer validation and secure communication. Using only a transmission-type retroreflector and a beam splitter, Kheibarihafshejani and Park proposed and demonstrated a method to extend the depth range of integral imaging systems for full-color 3D displays in both virtual–real and real–real configurations, largely enhancing the applicability of integral imaging systems in mixed-reality environments [8]. Metasurfaces with subwavelength nanostructures enable unprecedented control over light propagation, allowing compact and multifunctional imaging systems. Leveraging the tunable properties of Sb_2S_3 between the amorphous and crystalline states, Wang *et al* proposed a metasurface composed of Sb_2S_3 nanobricks for dynamic image displays in the visible range, enabled by active manipulation of the optical spectrum, amplitude, and phase, leading to threefold (e.g. structural-color image, and grayscale image and holographic image) dynamic exhibition functions [9]. This multifunctional phase-change metasurface may open the door to optical storage, encryption, and display applications.

The rapid development of artificial intelligence has revolutionized computational imaging by dramatically improving image quality, reconstruction speed, and analytical capabilities. Liu *et al* introduced a UNet-based network integrated with an adaptive encoder, named AdaptiveNet, to enhance the general classification and restoration of optical images [10]. The proposed AdaptiveNet can achieve optimal recovery image results across a range of image restoration tasks involving different experimental scenarios, including scattering, blurring, and defocusing. With the help of unsupervised machine learning, Buffarini *et al* proposed a method that uses the dynamic speckle technique, multiple-wavelength imaging, and tuneble algorithms for non-invasively examining hidden drawings of historically significant objects [11]. In addition, Sharma *et al* proposed an analytical modeling and numerical simulation strategy for demonstrating the Golay-coded thermal wave imaging technique's inclusion detection, characterization, and quantitative analysis capabilities in titanium alloy Ti-6Al-4V [12].

In summary, we hope that this focus issue offers valuable insights into computational imaging and its relevant applications. We sincerely thank all contributing authors for their exceptional work and extend our great gratitude to the editorial team of the Journal of Optics for their efforts in bringing this issue to fruition. We trust that readers will find this focus issue both enlightening and inspiring.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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