Computational optical imaging goes viral

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Due to the advent of digital technology, the last two decades have seen an explosion of computational optical imaging, as symbolized by super-resolved fluorescence microscopy that received the 2014 Nobel Prize in Chemistry. Computational techniques combined with optical imaging systems have enabled unique capabilities that cannot be achieved by optical imaging hardware alone. Notable examples of such capabilities are reflected in compressive imaging,[1] lensless microscopy,[2,3] ultrafast imaging,[4–6] coded aperture imaging,[7] ghost imaging,[8] quantitative phase imaging,[9,10] and super-resolution microscopy.[11,12] Furthermore, the rise of advanced machine learning techniques, in particular deep learning based on deep neural networks, has added an intense spice to the field of computational optical imaging.[13–15] This is indicated by the sharp rise in the number of related publications in Fig. 1.

Supported by the high waves of computational optical imaging, the objective of this Special Topic is to highlight basic principles, advanced techniques, light sources, and applications of computational optical imaging. Specifically, the Special Topic contains one perspective and seven original research articles as described below. It is important to note that the field of computational optical imaging is highly interdisciplinary by nature, covering a diverse range of research subjects such as manufacturing, environmental science, pharmaceutical science, pathology, and material science. Therefore, the field serves as a gold mine of ideas, discoveries, and innovations and is expected to grow in the next decade and beyond.

In this Special Topic, Zhou *et al.*[16] provide a timely perspective on advances in three-dimensional single-particle localization microscopy, which has been found effective in particle imaging velocimetry, single-molecule microscopy, three-dimensional tracking of vesicles in living cells, and *in vivo* blood-flow mapping. Specifically, they introduce the operational principles, recent technical innovations, and enabling applications of the method. The perspective also compares currently available techniques for three-dimensional localization microscopy in terms of attainable precision and practical utility and discusses the remaining challenges and possible future directions of the field. Consequently, the perspective provides an excellent overview of recent advances in the field for students and researchers who are interested in developing or using three-dimensional single-particle localization microscopy.

This Special Topic also comprises several original articles about computational optical imaging. Caravaca-Aguirre *et al.*[17] report an ultrathin hybrid photoacoustic-fluorescence endoscope with a 250 nm cross section based on an optical multi-mode fiber and an optical fiber hydrophone that is capable of providing both anatomical and functional image contrasts. Daloglu *et al.*[18] present a low-cost, portable, robust ultraviolet holographic microscope that is capable of high-contrast imaging of protein crystals and distinguishing them from salt crystals without the need for expensive and bulky optical components. Ren *et al.*[19] theoretically propose and experimentally demonstrate a computational method based on sparse

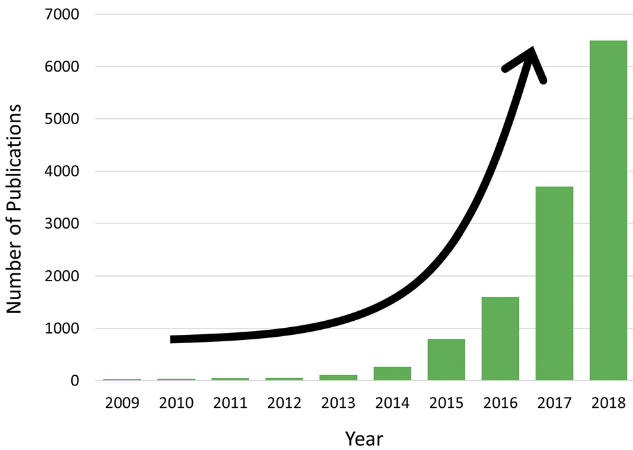

FIG. 1. Number of publications by year for the Web of Science search term: deep learning imaging. Note that this search term also includes non-optical medical imaging. Deep learning has become an essential part of imaging over the last few years.

optimization to automatically compensate for phase aberrations in digital holographic microscopy. Song *et al.*[20] report a full-field Fourier ptychography method that performs spatially varying pupil modeling for rapid field-dependent aberration metrology. Stockton *et al.*[21] introduce a method for Fourier computed tomographic imaging based on the collection of spatial frequency projections of an object in a lateral plane when the object is illuminated in a focused line, which enables enhanced spatial frequency support along a single spatial direction to be isotropic in the entire transverse spatial frequency domain. Yuan *et al.*[22] demonstrate terahertz heterodyne Fourier imaging based on active illumination with continuous-wave radiation at 300 GHz and a raster-scanned antenna-coupled field-effect transistor for phase-sensitive detection. Fan *et al.*[23] report a method for single-shot isotropic quantitative phase imaging based on color-multiplexed illumination to demonstrate high-resolution, accurate, robust phase retrieval with isotropic lateral resolution.

In conclusion, this Special Topic is intended to highlight the recent advances of computational optical imaging. It is our hope that the Special Topic will serve as a forum for students and young researchers to further extend the potential of computational optical imaging beyond what is achievable with conventional optical imaging. An upcoming Special Topic titled "Photonics & AI" is intended to cover papers on computational optical imaging assisted by artificial intelligence (AI). We are grateful to Editor-in-Chief Benjamin Eggleton, Journal Managers Benedetta Camarota, Diana Schlamadinger, and Erinn Brigham, and other associate editors for the technical assistance with publishing.

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