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Optical Computational Imaging

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The field of computational imaging explores a new imaging system design approach by jointly designing the optical hardware and computational algorithms. This approach allows one to optically encode the rich information in the optical field for optimal detection and information extraction by post-measurement algorithms. The computational imaging approach has been widely applied to a broad range of sensing and imaging tasks by using various encoding strategies, such as depth estimation and 3D representation, multi- and hyperspectral imaging, polarimetric analysis, and object detection and tracking. Guided by this overall philosophy, computational imagers trade between computing resources and hardware complexities to acquire multiplexed measurement, and then process and reconstruct multidimensional information about a scene more efficiently than conventional imaging systems. The collection of thirteen papers in this section highlights some of the state-of-the-art research in the field, and provides an overview of computational imaging architectures and algorithms for a variety of tasks and applications.

Two papers describe computational imaging techniques that process depth information for the purposes of imaging and display. In fact, the essence of computational imaging is exemplified by [Salahieh et al.](#), where a simple optics with fixed focus causes the image of objects at different depths to be blurred, but the knowledge of the point spread function (PSF) and its depth-variant nature is used along with a depth map to computationally correct this effect, resulting in an image that is focused at all depths. [Hong et al.](#) discuss using commercially available gaming devices for sensing depth information along with color imagery, and then displaying the resulting 3D information using integral imaging displays. Three papers deal with applications of computed tomography (which is a form of 3D computational imaging) for analyzing properties of materials and gases. [Sun et al.](#) discuss the role of regularization parameters in the reconstruction of 3D volumes in diffuse optical tomography. [Zhang et al.](#) compare microlaser and microultrasonic excitation thermography to x-ray tomography for the purpose of studying flaws in

polymer composites. [Wang et al.](#) discuss the use of flame chemiluminescence tomography (FCT) for instantaneous 3D diagnostics for analyzing flames with high spatial and temporal resolutions.

The application of computational imaging for analyzing spectral and polarization information is discussed in three papers. [Miyazaki et al.](#) describe a method for characterizing surface normal of black specular objects through polarization analysis of reflected light. [Mejia and Arguello](#) introduce a filtered gradient method for compressive spectral imaging that converges faster and produces better results than other existing iterative techniques. [Correa et al.](#) describe a multiple snapshot colored compressive spectral imager that improves on the performance of single snapshot spectral imager by rotating a dispersive element, so the dispersed spatio-spectral source is coded and integrated at different detector pixels in each rotation.

Four papers discuss how information sensing and task performance are integrally related in the framework of computational imaging. [Masoudi et al.](#) discuss methods for improving the shape-threat detection performance of x-ray computed tomography by optimizing adaptive measurements with single and multiple sources. [Shilling and Muise](#) discuss methods for target detection using optimum multiplexed measurements that do not require image reconstruction as an intermediate step. [Gedalin et al.](#) assess a compressive spectral imager for target detection, and report that this approach requires an order of magnitude less data than a conventional spectral imaging system, and is also considerably faster. [DuBosq and Preece](#) assess the use of a compressive imager by human operators for recognizing handheld objects. This paper is perhaps one of the first to characterize and model the performance of the compressive imager from a human perception standpoint.

Last but not least, the final paper by [Shah et al.](#) brings together different elements of computational imaging to describe an end-to-end multiplexed system for imaging and target detection. They describe the encoding strategy, the opto-electronic design, and some strategies for processing the information for either forming an image or for detecting

moving objects. This paper exemplifies the potential benefits of computational imaging from an overall sensor system standpoint.

We hope that this special section provides readers with a broad overview of the many possible applications of computational imaging, and the current research thrusts in the field. We would also like to take this opportunity to thank the contributing authors and the staff of *Optical Engineering* in helping to compile this special section on computational imaging.

Abhijit Mahalanobis is a senior fellow of the Lockheed Martin Corporation. His primary research areas are in systems for information processing, computational sensing and imaging, and video/image processing for information exploitation and automatic target recognition. He has over 150 journal and conference publications in this area. He also holds four patents, coauthored a book on pattern recognition, contributed several book chapters, and edited special issues of several journals. He completed his BS degree with honors at the University of California, Santa Barbara in 1984. He then joined the Carnegie Mellon University and received MS and PhD degrees in 1985 and 1987, respectively. Prior to joining Lockheed Martin, Abhijit worked at Raytheon in Tucson and was on faculty at the University of Arizona and the University of Maryland. He was elected Fellow of SPIE in 1997 and IEEE in 2015. He was recognized as the 2006 Scientist of the Year by Science Spectrum Magazine.

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Lei Tian is an assistant professor in the Electrical and Computer Engineering Department at Boston University, and a member of the Photonics Center. He received his MS in 2010 and PhD in 2013 from MIT. He was a postdoctoral associate in the EECS department at the University of California, Berkeley from 2013 -2016. His research focuses on computational imaging and sensing, high-throughput microscopy, phase retrieval, and imaging in scattering media. His awards include the 2014 Imaging Systems and Applications Best Paper Award and the 2011 Emil Wolf Outstanding Student Paper Prize, both from the OSA. He serves as a topical editor of Applied Optics, and conference chair and program committee member in multiple conferences of OSA, SPIE, and IEEE.