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Daniel LeMaster
Michael Hart
Andrew Lambert
Szymon Gładysz

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Daniel LeMaster
Air Force Research Lab
Wright Patterson Air Force Base, Ohio, United States
E-mail: daniel.lemaster@us.af.mil

Michael Hart
College of Optical Sciences
University of Arizona
Tucson, Arizona 85721, United States
E-mail: mhart@optics.arizona.edu

Andrew Lambert
School of Engineering and Information Technology
University of New South Wales Canberra
Canberra ACT 2600, Australia
E-mail: a.lambert@adfa.edu.au

Szymon Gładysz
Fraunhofer IOSB
Ettlingen, Germany
E-mail: szymon.gladysz@iosb.fraunhofer.de

We welcome readers to this special section on long-range imaging. The purpose is to explore technologies that operate at or beyond the boundaries of current range performance across land, sea, air, and space. Though possibilities for this special section were vast, it would appear that atmospheric turbulence and refractive bending effects are chief among concerns for long-range imaging researchers, comprising 8 of 10 papers in the special section. The guest editors had similar perceptions and recognized the lack thus far of a venue to publish works that address this interesting and challenging problem. We are therefore glad of the response to this call, grateful for the thoroughness of the reviewers, and hope that *Optical Engineering* becomes a regular home for this technology area.

Image degradation due to turbulence and bulk refractive effects are consequences of variations in the refractive index of air. Random variations on a time scale of a few milliseconds and on spatial scales ranging from a few millimeters to tens of meters gives rise to turbulence. The observable effect of turbulence near an imaging aperture is blur along with global apparent motion, while turbulence that occurs closer to the target degrades imagery though space-varying warping and distortions. Turbulence, which is driven primarily by temperature fluctuations, varies significantly with time of day, altitude, wind speed, and a host of other environmental factors along the imaging path. The refractive index of air also exhibits variations over much longer and larger temporal and spatial scales. Variations on these scales tend to displace and stretch imagery, the effect of which is commonly experienced as a mirage. Modeling, measuring, and mitigating these effects have been enduring research topics since the foundational work of V. I. Tatarski in the 1960s.[1]

Four of the papers in the special section deal with simulating the effects of turbulence and bulk refraction on imagery. Hardie et al. present an approach to simulating anisoplanatic imagery. This includes a new method for defining phase screen parameters and new validation techniques based on the statistics of apparent motion in the scene. The paper by Basu applies combined numerical weather mesoscale and ray-tracing models to explain a case of imaging the Milwaukee skyline from over three times the range set by the geometric horizon across Lake Michigan. Anzuola and Gladysz report on their new method to generate fast and accurate turbulent phase screens using a weighted sum of Karhunen–Loève polynomials that faithfully reproduce Kolmogorov spatial and temporal statistics. Lachinova et al. provide an extensive comparison of conventional Monte-Carlo wave optics turbulence simulations with their much more computationally efficient brightness function approach.

There are also four additional papers on measuring and/or mitigating turbulence effects on imagery. McCrae et al. discuss an approach for estimating the atmospheric coherence diameter from wavefront tilt variance due to turbulence using time-lapse imagery. Hardie et al. present an approach for restoration of imagery in the presence of anisoplanatic conditions that weights the aggressiveness of the restoration using image-based estimates of coherence diameter and confidence in distortion corrections. Kelmelis et al. draw on experience to survey the many considerations that must go into real-time turbulence restoration of imagery and, in a related paper, Kozacik et al. present a comparison of turbulence image restoration algorithms using the bispectrum speckle processing, lucky-region fusion, and blind deconvolution techniques.

The special section also includes two papers tackling other aspects of long range imaging. Hart et al. design and build a prototype multiaperture Fizeau interferometer for space-based infrared imaging. This prototype features carbon fiber reinforced polymer primary optics and a factor of three reduction in volume over equivalent conventional telescopes. Finally, the paper by Smith lays down a theoretical argument for substantially increasing the range of laser radars through the application of a quantum Bell state system.

This vast area has many unanswered or unrefined aspects, and we hope that beyond the works presented here, authors will consider publishing on the hot topics or imaging metrics that are applicable to turbulence-degraded imagery, how to handle the inherent lack of truth data in the imagery, novel imaging apparatus, and paradigms related to turbulence strength and imaging through turbid media, to name but a few. We look forward to reading future works in this journal addressing these and other facets of the problem that is long-range imaging.

References

1. V. I. Tatarski, *Wave Propagation in a Turbulent Medium*, translated by R. A. Silverman, Dover Publications, Inc., New York (1961).

Daniel A. LeMaster is the technical advisor for the EO Target Detection and Surveillance Branch in the Sensors Directorate of the Air Force Research Laboratory (AFRL). His purview includes the research of 20 engineers and scientists and numerous contracted efforts. He is the author or coauthor on over 30 conference and journal papers, 1 book chapter, and 1 patent (pending). He has also served as a conference chair and committee member for SPIE, is an associate editor for the journal *Optical Engineering*, and is a recent recipient of the SPIE DCS Rising Researcher Award. Some of his recent research activities have improved high-altitude reconnaissance imaging systems and provided new tools for treaty inspectors. His previous research interests included passive polarimetric imaging, among other things. Before deciding to become an engineer, he served in the U.S. Army.

Michael Hart is an associate professor in the College of Optical Sciences at the University of Arizona. He specializes in the implementation of advanced adaptive optics for large astronomical telescopes and other optical systems, including the 6.5 m MMT, and the twin 8.4 m Large Binocular Telescope. His current research tackles tomographic wavefront sensing and deformable mirror development for lightweight imaging systems and high-power beaming systems. Additional work focuses on the development of physically constrained image restoration and video-enhancement algorithms, automatic target recognition, object-independent wavefront sensing, and the recovery of 3-D object structure from blurred imagery.

Andrew Lambert is an associate professor in the School of Engineering and Information Technology at the University of New South Wales, Canberra, at the Australian Defence Force Academy. His interest in turbulence-degraded imagery was first published in a journal paper in 1999 (Fraser, Thorpe, Lambert, *JOSA A* v16 no.7), with a body of work spanning almost 3 decades exposing turbulence-induced super-resolution in imagery, turbulence characterization and mitigation using digital image restoration, real-time image processing, and adaptive optics. He has served on various SPIE conference program committees, such as the Image Reconstruction from Incomplete Data series, and related conferences. His research enables astronomical image processing, space situational awareness, space-based and ground-based surveillance imaging, and machine vision guidance of UAVs.

Szymon Gładysz is head of the Adaptive Optics Group at the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB. His research interests are in speckle statistics, atmospheric turbulence, adaptive optics, and image restoration. He has been awarded awards and grants from University of California, U.S. Air Force Office of Scientific Research, and the Office of Naval Research Global. He authored or coauthored over 80 publications in journals and conference proceedings and has served as conference chair, program chair, and committee member for conferences, and guest editor for *Optical Engineering* and the *Journal of Applied Remote Sensing*.