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Foreword to the Special Issue on Quality Improvements of Remote Sensing Data

REMOTE sensing data are often degraded by many issues that may include the failure of onboard hardware, signal downlink, atmospheric conditions, and overall quality/age of the sensors (for example, in terms of signal-noise ratio or sharpness). These factors reduce the quality of the acquired data, making it often difficult or impossible to extract relevant information.

In the past two decades, we have seen an increased interest by the research community in the development of restoration and enhancement techniques. Specifically, the theoretical, conceptual, and algorithmic advancements in the areas of data modeling, optimization, and statistical inference have opened new opportunities to improve the quality of remote sensing data. This special issue (SI) provides a venue to the most recently developed methods and techniques.

In early 2017, a Call for Papers for this SI was distributed to the community, seeking contributions to serve as references for the state of the art in quality improvement of remote sensing data. A total of 26 papers were submitted in response to the call, and, after a peer-review process, 11 were recommended for publication and are included in this issue. The 11 articles are organized into the following groups:

- 1) denoising of very high resolution (VHR) optical remote sensing images (one paper);
- 2) restoration of hyperspectral images (three papers);
- 3) quality improvement and/or evaluation of SAR images (four papers);
- 4) reconstruction of time-series remote sensing data (one paper);
- 5) resolution enhancement by fusing multisource data (paper papers).

The first paper of this SI elaborates on the problem of denoising optical VHR images [item 1] in the Appendix]. Masse *et al.* present several optimizations to mitigate the high-computational complexity of nonlocal Bayes based denoising methods, aiming at improving their efficiency while keeping good denoising performance.

The next three papers mainly focus on the restoration problem of hyperspectral images. Bai *et al.* transform the task of image denoising into a high-order tensor approximation problem, and propose a hierarchical least square based non-negative Tucker decomposition method to improve both efficiency and efficacy [item 2] in the Appendix]. He *et al.* model stripes, dead lines, and impulse noise as sparse noise, and formulate a model by combining local low-rank matrix recovery and spatial-spectral

total variation [item 3] in the Appendix]. Zhuang and Bioucas-Dias also make full use of the sparse and low-rank properties of hyperspectral images, and propose two fast and competitive algorithms for image denoising and inpainting, respectively [item 4] in the Appendix].

This SI also includes four papers that illustrate different approaches for improving the quality of synthetic aperture radar (SAR) data. Ma *et al.* make a broad review on recent developments of polarimetric SAR despeckling and give comparisons of several state-of-the-art methods [item 5] in the Appendix]. Abergel *et al.* present subpixellic methods for sidelobes suppression of single look complex SAR images, which can produce images with improved quality suitable both for visual inspection and further processing [item 6] in the Appendix]. Ali *et al.* evaluated three techniques for removing the Sentinel-1 “border noise” and concluded that the bidirectional all-samples are the best, which is very significant for real-time or near real-time services of Sentinel-1 data [item 7] in the Appendix]. Bueso-Bello *et al.* provide a performance evaluation of TanDEM-X quad-polarization products with the goal of validating the improvements obtained by the optimized parameters [item 8] in the Appendix].

Wang *et al.* illustrate a novel method for the processing of normalized difference vegetation index (NDVI) time-series [item 9] in the Appendix]. The approach reduces the noise caused by snow in the third-generation NDVI dataset from Global Inventory Modeling and Mapping Studies.

The last two papers aim at improving the spatial resolution of remote sensing images by data fusion. Liu *et al.* propose a trapezoid interpolation based thermal disaggregation model to generate fine resolution land surface temperature (LST) products from coarse resolution LST ones. The proposed model takes advantage of auxiliary data based on the fractional vegetation cover, the index-based built-up/bare land index, and other data [item 10] in the Appendix]. Song *et al.* present a spatio-temporal fusion method for Landsat and MODIS images aimed at high spatial and temporal superresolution. In this paper, deep learning is employed to improve the robustness of the inference [item 11] in the Appendix].

The papers in this SI represent a comprehensive review on the state of the art relative to quality improvements of remote sensing data. We believe that the new insights uncovered in these papers will open new perspectives and set a reference for future research in the field.

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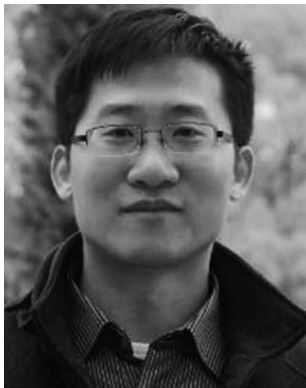
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APPENDIX
RELATED WORK

- 1) A. Masse, S. Lefèvre, R. Binet, S. Artigues, G. Blanchet, and S. Baillarin, “Denoising very high resolution optical remote sensing images: Application and optimization of nonlocal bayes method,” *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 11, no. 3, pp. 691–700, Mar. 2018.
- 2) X. Bai, F. Xu, L. Zhou, Y. Xing, L. Bai, and J. Zhou, “Nonlocal similarity based nonnegative tucker decomposition for hyperspectral image denoising,” *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 11, no. 3, pp. 701–712, Mar. 2018.
- 3) W. He, H. Zhang, H. Shen, and L. Zhang, “Hyperspectral image denoising using local low-rank matrix recovery and global spatial-spectral total variation,” *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 11, no. 3, pp. 713–729, Mar. 2018.
- 4) L. Zhuang and J. M. Bioucas-Dias, “Fast hyperspectral image denoising and inpainting based on low-rank and sparse representations,” *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 11, no. 3, pp. 730–742, Mar. 2018.
- 5) X. Ma, P. Wu, Y. Wu, and H. Shen, “A review on recent developments in fully polarimetric sar image despeckling,” *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 11, no. 3, pp. 743–758, Mar. 2018.
- 6) R. Abergel, L. Denis, S. Ladjal, and F. Tupin, “Subpixellic methods for sidelobes suppression and strong targets extraction in single look complex sar images,” *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 11, no. 3, pp. 759–776, Mar. 2018.
- 7) I. Ali, S. Cao, V. Naeimi, C. Paulik, and W. Wagner, “Methods to remove the border noise from Sentinel-1 synthetic aperture radar data: Implications and importance for time-series analysis,” *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 11, no. 3, pp. 777–786, Mar. 2018.
- 8) J.-L. Bueso-Bello, P. Prats-Iraola, M. Martone, J. Reimann, U. Steinbrecher, and P. Rizzoli, “Performance evaluation of TanDEM-X quad-polarization products in bistatic mode,” *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 11, no. 3, pp. 787–799, Mar. 2018.
- 9) C. Wang, J. Chen, Y. Tang, T. A. Black, and K. Zhu, “A novel method for removing snow melting-induced fluctuation in GIMMS NDVI3g data for vegetation phenology monitoring: a case study in deciduous forests of north america,” *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 11, no. 3, pp. 800–807, Mar. 2018.
- 10) K. Liu *et al.*, “A thermal disaggregation model based on trapezoid interpolation,” *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 11, no. 3, pp. 808–820, Mar. 2018.
- 11) H. Song, Q. Liu, G. Wang, R. Hang, and B. Huang, “Spatiotemporal satellite image fusion using deep convolutional neural networks,” *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 11, no. 3, pp. 821–829, Mar. 2018.



Huanfeng Shen (M'10–SM'13) received the B.S. degree in surveying and mapping engineering and the Ph.D. degree in photogrammetry and remote sensing from Wuhan University, Wuhan, China, in 2002 and 2007, respectively.

From 2006 to 2007, he was a Research Assistant with the Department of Mathematics, Hong Kong Baptist University. In July 2007, he joined the School of Resource and Environmental Sciences (SRES), Wuhan University, where he is currently a LuoJia Distinguished Professor and Deputy Dean of SERS. He has published more than 100 research papers in international journals. His research interests include image quality improvement, remote sensing mapping and application, data fusion and assimilation, regional and global environmental change.

Dr. Shen was or is the PI of five NSFC (National Natural Science Foundation of China) projects, and a project PI of National Key Research and Development Program of China. He has been supported by several China talent programs, such as The Youth Talent Support Program of China (2015), China National Science Fund for Excellent Young Scholars (2014), the New

Century Excellent Talents by the Ministry of Education of China (2011). He is a Council Member of the China Association of Remote Sensing Application. He is also currently a member of the Editorial Board for *Journal of Applied Remote Sensing*.



Xiuping Jia (M'93–SM'03) received the B. Eng. degree from the Beijing University of Posts and Telecommunications, Beijing, China, in 1982, and the Ph.D. degree in electrical engineering from the University of New South Wales, Australia, in 1996.

Since 1988, she has been with the School of Engineering and Information Technology, The University of New South Wales at Canberra, Campbell, ACT, Australia, where she is currently a Senior Lecturer. Her research interests include remote sensing, image processing, and spatial data analysis. He has authored or coauthored more than 200 referred papers, including more than 90 journal papers. She has co-authored the remote sensing textbook titled *Remote Sensing Digital Image Analysis* [Springer-Verlag, 3rd (1999) and 4th eds. (2006)].

Dr. Jia is a Subject Editor for the *Journal of Soils and Sediments* and an Associate Editor for the IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING.



José M. Bioucas-Dias (S'87–M'95–SM'15–F'17) received the E.E., M.Sc., Ph.D., and Habilitation degrees in electrical and computer engineering from Instituto Superior Técnico (IST), Universidade Técnica de Lisboa (now Universidade de Lisboa), Lisbon, Portugal, in 1985, 1991, 1995, and 2007, respectively.

Since 1995, he has been with the Department of Electrical and Computer Engineering, IST, where he is a Professor and teaches inverse problems in imaging and electric communications. He is also a Senior Researcher with the Pattern and Image Analysis Group, the Instituto de Telecomunicações, which is a private nonprofit research institution. His research interests include inverse problems, signal and image processing, pattern recognition, optimization, and remote sensing. He has introduced scientific contributions in the areas of imaging inverse problems, statistical image processing, optimization, phase estimation, phase unwrapping, and in various imaging applications, such as hyperspectral and radar imaging.

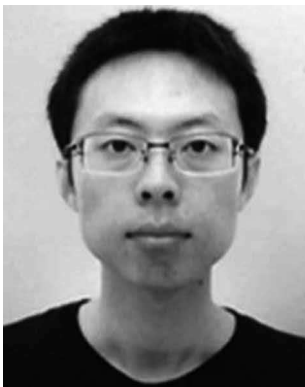
Dr. Bioucas-Dias was included in Thomson Reuters' Highly Cited Researchers 2015 list and was the recipient of the IEEE GRSS David Landgrebe Award for 2017.



Nicolas Dobigeon (S'05–M'08–SM'13) was born in Angoulême, France, in 1981. He received the Engineering degree in electrical engineering from ENSEEIHT, Toulouse, France, and the M.Sc. degree in signal processing from the INP Toulouse, Toulouse, France, both in 2004, and the Ph.D. degree and Habilitation à Diriger des Recherches in signal processing from INP Toulouse in 2007 and 2012, respectively.

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Prof. Dobigeon was the recipient of the Best Reviewer Award from the IEEE GEOSCIENCE REMOTE SENSING LETTERS (2011), an IEEE GRSS WHISPERS Best Paper Award (2013), an IEEE ICIP Top 10% Paper Award (2014), and was a finalist of the Student Paper Contests at IEEE ICASSP (2007 and 2017) and IEEE CAMSAP (2015). He was an Area Chair of European Signal Processing Conferences (EUSIPCO, 2015 and 2017). He is currently serving as an Associate Editor for *EURASIP Signal Processing* and as a member of the Signal Processing Theory and Method (SPTM) Technical Committee of the IEEE Signal Processing Society. Since 2017, he has been a Junior Member of the Institut Universitaire de France.



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Dr. Cui is an Associate Editor for the IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATION AND REMOTE SENSING. He has been recognized as a 2013 Best Reviewer of the IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING. He received the first-prize for the student paper competition at the 2010 Asia-Pacific Radio Science Conference (AP-RASC10), the Best Paper Award of the 2012 International Symposium on Antennas and Propagation, and the 2013 IEEE Geoscience and Remote Sensing Society Symposium Prize Paper Award.



Fabio Pacifici (S'03–M'10–SM'13) received the Ph.D. degree in geoinformation and the Laurea Specialistica (M.Sc.; *cum laude*) and Laurea (B.Sc.; *cum laude*) degrees in telecommunication engineering from Tor Vergata University, Rome, Italy, in 2010, 2006, and 2003, respectively.

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Dr. Pacifici is the current Director of Industry Relations for the IEEE Geoscience and Remote Sensing Society (GRSS), serves as an Associate Editor for the IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING (JSTARS), and is an elected member of the IEEE GRSS Administrative Committee. He was the Editor-in-Chief for the IEEE GRSS eNewsletter (2014–2017) and the Chair for the IEEE GRSS Data Fusion Technical Committee (2011–2013). He was the recipient of the Early Career Award from IEEE GRSS in recognition of the outstanding service for the benefit and advancement of the geoscience and remote sensing community, the WHISPERS Best Paper Award in 2014, the 2011 Best Reviewer Award from IEEE GRSS for his service to JSTARS, and the Best Student Paper award at the 2009 IEEE GRSS Joint Urban Remote Sensing Event, in Shanghai, China. He also won the 2007, 2008, and 2009–2010 IEEE GRSS Data Fusion Contest.