Foreword to the Special Issue on Advances in Pattern Recognition in Remote Sensing

THE technical committee for pattern recognition in remote sensing (PRRS) and mapping (TC7) of the international association for pattern recognition (IAPR) organizes a biennial workshop on PRRS. This workshop series has been a popular forum for experts of both communities, pattern recognition and remote sensing, and accordingly there is co-sponsoring from IAPR, IEEE-GRSS, and ISPRS. In particular, the intercommission working group for pattern analysis in remote sensing (ICWG II/III) of the ISPRS is closely cooperating. The latest workshops have been very successfully held in December 2016 in Cancun, Mexico, and in August 2018 in Beijing, China.

Additionally, TC7 compiles special issues on PRRS in journals such as IEEE-JSTARS or *Pattern Recognition Letters* [items 1)–6) in Related Works]. The issue at hand fits in this series. Contained are 29 papers, including some work of authors that have participated and published preceding work in the 2016 PRRS in Cancun. However, the issue was open to general participation on the topic.

Remote sensing as a scientific subject progresses with the platforms, i.e., the satellites and currently unmanned aerial vehicles, the sensor technology, improvements of the synthetic aperture radar antennas and processing, ever rising precision in satellite positioning and orbit control, rising resolution in spatial temporal, spectral domains in the optical sensing, and rising numbers of platforms bring more and more and ever improving data. Automation in the analysis of these is inevitable.

Eight papers of this issue work with standard panchromatic or color imagery of the visual domain plus adjacent near infrared [items 7) –14)]. Though most remotely sensed data still come in these forms, there is clear emphasis of this issue on hyperspectral data, which is the domain of ten papers [items 15)–24)]. Such spectra for each pixel are still an exception, so that most of these papers use the same three data sets: Indian pines, Salinas, and Pavia. It is a challenging field concerning recognition methods, and it may well be more important in the future.

Because of its all-weather capabilities the synthetic aperture RADAR (SAR) sensor gains importance, and accordingly the third large portion of the papers in the issue deals with such data namely eight [items 25)–32)]. The particular noise distribution and mapping geometry of these images makes them a hard challenge for interpretation and analysis, regardless whether automatic or by human observers. SAR data are available in large spatial and high temporal coverage today. In addition, the future will see a considerable growth in this type.

The remaining three papers [items 33)–35) use laser radar data (LIDAR), which does not come in a two-dimensional (2-D) image format. These data are given as 3-D point cloud. They give very detailed spatial information usually on a smaller scale than the standard remotely sensed data. Item 35) fuses such data with aerial imagery.

Pattern recognition as a scientific subject has seen a major change in recent years. A substantial improvement in recognition performance was achieved by use of multilayer perceptrons. In principle, these adaptive end-to-end learning methods adjusting many parameters of a nested system of nonlinear functions so as to minimize the empirical risk of misclassification on a training sample are known for many decades. The convolutional variant reducing the number of parameters on 1-D signals or 2-D images as inputs was long known as well. Using the term "neural network" for such perceptrons emphasizes the biological inspiration leading to their construction in the long gone days when people were dreaming of "electronic brains." Such terms can be a little deceiving. We would rather prefer the term connectionist architectures.

The remarkable improvement in pattern recognition performance as compared to established standard methods by 2010, such as feature space dimension reduction, nearest neighbor, SVM, adaptive boosting, decision trees, etc., was achieved by use of *massive* connectionist perceptrons, i.e., the impressing progress in computational hardware. The most successful models are *deep*. They feature many layers, and have many "neurons" in each layer. Out of the 29 papers in this special issue, seven use these modern deep learning convolutional networks, namely Li *et al.* [item 9)], Tan *et al.* [item 12)], Wu *et al.* [item 13)], Lin *et al.* [item 16)], Kong *et al.* [item 22)], Wang *et al.*[item 26)], and Schilling *et al.* [item 35)]. Moreover, Zhang *et al.* [item 23)] use a recurrent network, which is also a currently popular connectionist architecture, and Zou *et al.* [item 32)] use receptive fields for their logic inferences, which is similar to the connectionist understanding of convolution.

Preconnectionist standard methods are still in use, and set the state-of-the-art in many subsubjects of analysis of remotely sensed data. In this issue, we find *template matching* in Fu *et al.* [item 28)]; *nearest neighbor* variants in Taff *et al.* [item 7)], Tu *et al.* [item 15)], and Tu *et al.* [item 17)]; *principle component analysis* in Kang *et al.* [item 34)]; *support vector machines* in

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Perez-Suay *et al.* [item 11)] and Liu *et al.* [item 19)]; *clustering* in space-time in Liu *et al.* [item 10)]; hierarchical clustering in Wuttke *et al.* [item 14)]; and anomaly or *outlier detection* in Vafadar and Ghassemian [item 18)].

Super-pixel segmentation is used by Tu *et al.* in [item 15)] and [item 21)]; *Perceptual grouping* along Gestalt laws is used by Jing *et al.* [item 8)] and Xu *et al.* [item 33)]; *active learning* is used in Wuttke *et al.* [item 14)]; and *sparse representation* in Ghasrodashti *et al.* [item 20)], Zhang *et al.* [item 24)] (calling it distributed sampling), and Li *et al.* [item 30)].

Omati and Sahebi use a combination of diverse methods including Marcov random fields, watershed segmentation, and genetic optimization [item 25)]. In addition, the recently popular *nonnegative matrix factorization* is found in this issue, namely in Raeisi *et al.* [item 27)]. There is also one contribution using decision trees (rather forests)—Hariharan *et al.* [item 31)], and one using logical rule inference—Zou *et al.* [item 32)].

Together the well written papers collected in this issue constitute a quite representative sample of what is going on in the field today. We thank all authors for their contribution. Particularly, we appreciate the work of the anonymous reviewers giving their expertise and devotion. We are also grateful to Prof. J. Q. Du, Editor-in-Chief of IEEE JSTARS, making this special issue possible and contributing a lot of labor to it.

E. MICHAELSEN, *Guest Editor*
Department Object Recognition
Fraunhofer-IOSB
Ettlingen 76275, Germany
(e-mail: eckart.michaelsen@iosb.fraunhofer.de)

J. SHAN, *Guest Editor*
School of Environmental and Ecological Engineering
Lyles School of Civil Engineering
Purdue University
West Lafayette, IN 47907 USA
(e-mail: jshan@purdue.edu)

U. STILLA, *Guest Editor*
Department of Photogrammetry and Remote Sensing
Technical University of Munich
Munich 80333, Germany
(e-mail: stilla@tum.de)

W. LI, *Guest Editor*
College of Information Science and Technology
Beijing University of Chemical Technology, Beijing, China
(e-mail: liwei089@ieee.org)

RELATED WORK

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Eckart Michaelsen received the Diploma in mathematics from the University of Innsbruck, Innsbruck, Austria, in 1987, and the Dr. Ing. degree from the University of Erlangen, Erlangen, Germany, (chair for pattern recognition H. Niemann), working on syntactic methods of pattern recognition, in 1998.

He is currently with the Fraunhofer Institute IOSB, Ettlingen, Germany. He authored or coauthored about a hundred scientific papers mostly on knowledge-based analysis of remotely sensed images, Gestalt perception in machine vision, and automatic visual UAV navigation in peer reviewed journals and conferences.

Dr. Michaelsen was the Chair of IAPR Technical Committee TC7 (pattern recognition in remote sensing and mapping) between 2014 and 2018. He is an Associate Editor for the *Pattern Recognition Letters* and the *Pattern Recognition and Image Analysis* journals. He is a member of program committees for conferences, such as ICPR, IGARS, PRIA, and CAIP.

Jie Shan (SM'14) received the Ph.D. degree in photogrammetry and remote sensing from Wuhan University, Wuhan, China, in 1989.

He is currently a Professor with the Lyles School of Civil Engineering, Purdue University, West Lafayette, IN, USA. He has been a member of faculty with universities in China and Sweden, and a Research Fellow in Germany. He has authored/coauthored more than 200 scientific publications. In addition, he has been a Reviewer for more than 50 scientific journals, coordinated numerous scientific workshops, symposia, and conferences. His research interests include sensor geometry and positioning, object extraction and reconstruction from images and point clouds, urban remote sensing, automated digital mapping, and pattern recognition and data mining of spatial, temporal, and semantic data.

Dr. Shan is a recipient of multiple best paper awards, including the Talbert Abrams Grand Award and the Environmental Systems Research Institute Award. He is currently on the Editorial Boards or an Associate Editor for several journals, including, among others, the *International Journal of Remote Sensing*, IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, and *Remote Sensing*. He has been the Editor of highlight articles for *Photogrammetric Engineering and Remote Sensing*, a Guest Editor of multiple special issues for *Photogrammetric Engineering and Remote Sensing, Remote Sensing*, and IEEE JOURNAL OF SELECTED TOPICS IN APPLIES EARTH OBSERVATIONS AND REMOTE SENSING. He is an elected ASPRS Fellow.

Uwe Stilla was born in Cologne, Germany, in 1957. He received the Diploma (Dipl.-Ing.) degree in electrical engineering from the University of Paderborn, Germany, the Diploma (Dipl.-Ing.) degree in biomedical engineering, and the Ph.D. (Doctor of Engineering) degree in pattern recognition from the University of Karlsruhe, Germany, in 1980, 1987, and 1993, respectively.

From 1990 to 2004, he was with the Research Institute of Optronics and Pattern Recognition (FGAN-FOM), Ettlingen, Germany. Since 2004, he has been a Professor with the Technische Universitaet Muenchen, Munich, Germany, and the Head of the Department of Photogrammetry and Remote Sensing. He was the Vice Dean of the Faculty of Civil, Geo, and Environmental Engineering and is currently the Dean of Studies of the Bachelor's and Master's Programs "Geodesy and Geoinformation, "Earth Oriented Space Science and Technology (ESPACE)" and "Cartography." His research interests include image analysis in the field of photogrammetry and remote sensing.

The publication list of Uwe Stilla shows more than 450 entries.

Wei Li (S'11–M'13–SM'16) received the B.E. degree in telecommunications engineering from Xidian University, Xi'an, China, in 2007, the M.S. degree in information science and technology from Sun Yat-Sen University, Guangzhou, China, in 2009, and the Ph.D. degree in electrical and computer engineering from Mississippi State University, Starkville, MS, USA, in 2012.

Subsequently, he spent one year as a Post-Doctoral Researcher with the University of California at Davis, Davis, CA, USA. He is currently a Professor and the Vice Dean of the College of Information Science and Technology, Beijing University of Chemical Technology, Beijing, China. His research interests include hyperspectral image analysis, pattern recognition, and data compression.

Dr. Li is currently an Associate Editor for the IEEE SIGNAL PROCESSING LETTERS. He was a Guest Editor for special issue of the *Journal of Real-Time Image Processing*, *International Journal of Remote Sensing*, and the IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS IN REMOTE SENSING (JSTARS). He is an active reviewer for the IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, the IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, and the IEEE JSTARS. He was the recipient of the 2015 Best Reviewer Award from the IEEE Geoscience and Remote Sensing Society for his service for the IEEE JSTARS.