Editorial Foreword to the Special Issue on Artificial Intelligence for Hyper- and Multi-spectral Remote Sensing Image Processing

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I. Introduction

IN THE current age of widespread application of artificial intelligence (AI) across various facets of life, satellite remote sensing is no outlier. Thanks to the ongoing enhancements in the spatial and temporal resolutions of satellite images, they are emerging as invaluable assets in areas such as land-use analysis, meteorology, change detection, and beyond. Accurate analysis and classification at various levels of hyperspectral images (HSIs) and multispectral remote sensing images (RSIs) are essential for extracting valuable insights from these datasets.

As advancements in AI continue to evolve alongside the abundance of remote sensing imagery data, conventional image processing methods are complemented by sophisticated deep and machine learning techniques for the interpretation of RSIs. Nevertheless, their processing capacity is constrained by the accessibility of annotated training data. To solve the problem of limited annotated training data, generative adversarial networks (GANs) are employed by researchers to perform data augmentation in semisupervised and unsupervised learning, although there is still a long way to go on using GANs on RSIs.

Another limitation is the complexity of HSIs, as these images contain much more data as compared with multispectral images and makes it difficult to construct a deep learning model for classification. The high-dimensional and noisy spatial and spectral nature of data further adds to the challenge. This underscores the necessity for employing advanced computational methods to analyze and process such images effectively. Automatic change detection is also an important domain where multitemporal RSIs are used for an extensive range of applications, such as assessing disasters impact, monitoring the impact of human activities on the landscape, monitoring changes on the Earth's surface, etc. With the progress in the area of metaheuristic algorithms, researchers are also employing various metaheuristic algorithms for finding optimal values of image segmentation parameters as well as hyperparameter tuning of deep learning models for image segmentation and classification, in order to achieve better results.

The focus of this Special Issue was to explore novel practices, algorithms and architectures aimed at addressing the challenges encountered by researchers working on the analysis and classification of hyperspectral (HS) and multispectral RSIs. The primary objective was to encourage researchers in this field to submit high-quality manuscripts aimed at addressing the aforementioned challenges, thereby facilitating further progress in this domain.

This Special Issue of IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (JSTARS) contains 11 articles. Each manuscript within this thematic compilation has made a substantial contribution in pushing forward the efforts to tackle the challenges confronting researchers in the field of HS and multispectral RSIs. Nonetheless, there remains a substantial journey ahead. We are confident that the papers published in this special issue will offer valuable insights into some of the latest developments in the field of HS and multispectral RSIs. These papers focus on the following interesting and relevant topics in the HS and multispectral RSI processing.

1) *Image denoising:* Pan et al. [A1] proposed a multiscale adaptive fusion network (MAFNet) to investigate the denoising of HISs. It is capable of learning the nonlinear complex mapping between clean and noisy HISs. The performance of MAFNet is illustrated using synthetic as well as real HSI datasets.
2) *HS unmixing:* Chen et al. [A2], presented a spatial-spectral adaptive nonlinear unmixing network (SSANU-Net). The SSANU-Net's encoder comprises a two-stream network dedicated to learning spatial and spectral features of the images separately. Similarly, the decoder incorporates a two-stream network to separately model the linear and nonlinear components of interphoton interactions. An adaptive weighting strategy is used, enabling the network's application across various scenarios. Jin and Yang [A3] proposed a graph attention convolutional autoencoder architecture for HS unmixing. They also improve the decoder based on the postpolynomial nonlinear mixing model. Qu and Li [A4] presented a NewSpr-NMF algorithm to address the slow convergence efficiency of existing $l_{1/2}$ sparse nonnegative matrix factorization methods for HS unmixing.
3) *Pansharpening:* Fang et al. [A5] presented a novel single-branch, single-scale lightweight convolutional neural network (for pansharpening. A novel dense residual-connected structure and convolutional block are used to achieve an improved balance between accuracy and

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efficiency, and the model's performance is evaluated using four distinct datasets.

4) *Image segmentation:* Pang et al. [A6] presented a patch-to-region framework for the semantic segmentation of large format RSIs. It considers the local detail characteristics and global contextual information of the images to facilitate accurate semantic segmentation of high-resolution RSIs.
5) *Image classification:* Hamza et al. [A7] presented an automated model for land scene classification in satellite images, achieved through the inner fusion of two deep learning models. Hyperparameter tuning is conducted using Bayesian optimization, and the model is trained utilizing deep transfer learning. In addition, an enhanced poor and rich controlled entropy optimization technique is introduced for feature selection. Singh et al. [A8] proposed a postprocessing-based spectral-spatial classification method for HS images by integrating spectral and spatial information. Two feature selection techniques are also introduced to acquire a set of principal components for each class of HS images, which further improves the classification accuracy. Chhapariya et al. [A9] proposed a deep spectral-spatial residual attention network (DSSpRAN) for HSI classification. DSSpRAN integrates spectral and spatial features concurrently by incorporating a spectral residual attention network and a spatial residual attention network. The efficacy of the proposed model is assessed on five datasets. The effectiveness of DSSpRAN is evaluated on five datasets.
6) *Object detection:* Hong et al. [A10] presented a novel deep learning model, called SBT-FireNet, specifically designed for monitoring fire spots from Himawari-8 satellite images. The model comprises three modules aimed at extracting spatial, band, and temporal features of fire spots. It is tested in four fire-prone areas with high forest cover and has shown remarkable performance.
7) *Data generation:* Wei et al. [A11] proposed a method called Cam-PC, which serves as a bridge between the real and digital realms, facilitating the creation of point cloud adversarial samples capable of targeting both LiDAR and remote sensing radar data-based models. The method comprises two modules, R-D and D-R, which produce more covert adversarial point cloud samples by altering digital and physical attributes.

The success of this Special Issue is attributed to the dedication and contributions of numerous individuals in diverse roles. The guest editors wish to convey their sincere appreciation to all the authors for their invaluable inputs. We extend our heartfelt appreciation to the reviewers for offering irreplaceable and beneficial feedback to the authors. In addition, we wish to express our gratitude to JSTARS and its Editor-in-Chief, Prof. Jun Li, for her selfless guidance during the entirety of this Special Issue process. Her guidance and support were integral to the entire journey, without which this endeavor would not have been possible. Lastly, we sincerely hope that readers of this topical collection will find it beneficial, and that it will offer new insights and open up new research avenues for scholars in this domain.

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APPENDIX
RELATED ARTICLES

[A1] H. Pan, F. Gao, J. Dong, and Q. Du, "Multiscale adaptive fusion network for hyperspectral image denoising," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 16, pp. 3045–3059, 2023, doi: 10.1109/JSTARS.2023.3257051.

[A2] X. Chen, X. Zhang, M. Ren, B. Zhou, Z. Feng, and J. Cheng, "An improved hyperspectral unmixing approach based on a spatial–spectral adaptive nonlinear unmixing network," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 16, pp. 9680–9696, 2023, doi: 10.1109/JSTARS.2023.3323748.

[A3] D. Jin and B. Yang, "Graph attention convolutional autoencoder-based unsupervised nonlinear unmixing for hyperspectral images," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 16, pp. 7896–7906, 2023, doi: 10.1109/JSTARS.2023.3308037.

[A4] K. Qu and Z. Li, "A fast sparse NMF optimization algorithm for hyperspectral unmixing," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 17, pp. 1885–1902, 2024, doi: 10.1109/JSTARS.2023.3341583.

[A5] Y. Fang, Y. Cai, and L. Fan, "SDRCNN: A single-scale dense residual connected convolutional neural network for pansharpening," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 16, pp. 6325–6338, 2023, doi: 10.1109/JSTARS.2023.3292320.

[A6] S. Pang, Y. Shi, H. Hu, L. Ye, and J. Chen, "PTRSegNet: A patch-to-region bottom–up pyramid framework for the semantic segmentation of large-format remote sensing images," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 17, pp. 3664–3673, 2024, doi: 10.1109/JSTARS.2024.3352578.

[A7] A. Hamza et al., "An integrated parallel inner deep learning models information fusion with bayesian optimization for land scene classification in satellite images," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 16, pp. 9888–9903, 2023, doi: 10.1109/JSTARS.2023.3324494.

[A8] A. K. Singh, R. Sunkara, G. R. Kadambi, and V. Palade, "Spectral–spatial classification with naive bayes and adaptive FFT for improved classification accuracy of hyperspectral images," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 17, pp. 1100–1113, 2024, doi: 10.1109/JSTARS.2023.3327346.

[A9] K. Chhapariya, K. M. Buddhiraju, and A. Kumar, "A deep spectral–spatial residual attention network for hyperspectral image classification," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published, doi: 10.1109/JSTARS.2024.3355071.

[A10] Z. Hong et al., "Near real-time monitoring of fire spots using a novel SBT-FireNet based on Himawari-8 satellite images," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 17, pp. 1719–1733, 2024, doi: 10.1109/JSTARS.2023.3338448.

[A11] B. Wei et al., "Cam-PC: A novel method for camouflaging point clouds to counter adversarial deception in remote sensing," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 17, pp. 56–67, 2024, doi: 10.1109/JSTARS.2023.3324483.

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Dr. Palade is an Associate Editor for several journals, such as IEEE TRANSACTIONS ON NEURAL NETWORKS AND LEARNING SYSTEMS, *Knowledge and Information Systems*, *Neurocomputing* (2009–2019), *International Journal on Artificial Intelligence Tools*, and *International Journal of Hybrid Intelligent Systems* (and Cofounder of this journal). He has delivered keynote talks to international conferences on machine learning and applications. He is Member of the IEEE Computational Intelligence Society.

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