remote sensing

Editorial

Editorial to Special Issue "Remote Sensing Data Compression"

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Abstract: A huge amount of remote sensing data is acquired each day, which is transferred to image processing centers and/or to customers. Due to different limitations, compression has to be applied on-board and/or on-the-ground. This Special Issue collects 15 papers dealing with remote sensing data compression, introducing solutions for both lossless and lossy compression, analyzing the impact of compression on different processes, investigating the suitability of neural networks for compression, and researching on low complexity hardware and software approaches to deliver competitive coding performance.

Keywords: remote sensing data compression; lossless compression; lossy compression; compression impact; neural networks; computational complexity

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1. Overview of the Issue: Remote Sensing Data Compression

Announcing this Special Issue, the following was considered. First, a huge amount of data is acquired each day by different remote sensing systems and these data must be transferred to image processing centers, stored, and delivered to customers. Due to various restrictions, data compression is strongly desired or necessary. Second, there is a wide diversity of methods that can be used, requirements to compression and their priority, types, and properties of images to be processed, practical implementation aspects, etc. Our intention was to collect papers focused on advances in lossless and lossy compression, multi- and hyperspectral image compression, radar image compression, applications of remote sensing data compression; compression standards, practical implementation of image compression techniques, data compression hardware and software, impact of data compression on solving classification and identifications tasks.

As a result of our work as guest editors, 21 submissions have been received from which 6 have been rejected. The accepted publications cover a wide variety of questions.

Five papers relate to lossless and near lossless methods with application to multi- and hyperspectral data.

The paper "Analysis of Variable-Length Codes for Integer Encoding in Hyperspectral Data Compression with the k^2-Raster Compact Data Structure" by Chow, K., Tzamarias, D.E.O., Hernández-Cabronero, M., Blanes, I., Serra-Sagristà, J. [1], examines various variable-length encoders that provide integer encoding to hyperspectral scene data within a k^2-raster compact data structure. This structure leads to a compression ratio similar to that produced by some classical compression techniques while also providing direct access for query to its data elements without requiring any decompression. The selection of the integer encoder is critical for a competitive performance (compression ratio and access time). Different integer encoders, such as Rice, Simple9, Simple16, PForDelta codes, and DACs are investigated. Further, a method to determine an appropriate k value for building a competitive k^2-raster compact data structure is discussed.

The paper "Using Predictive and Differential Methods with K^2-Raster Compact Data Structure for Hyperspectral Image Lossless Compression" by Chow, K., Tzamarias, D.E.O., Blanes, I., Serra-Sagristà, J. [2] extends the previous paper by proposing a lossless coder for real-time processing and compression of hyperspectral images. After applying either a predictor or a differential encoder by exploiting the close similarity between neighboring bands, it uses the k^2-raster compact data structure to further reduce the bit rate. Experiments show that using k^2-raster alone already achieves much lower rates (up to 55% reduction), and with preprocessing, the rates are further reduced (up to 64%). Finally, experimental results show that prediction produces higher rates reduction than differential encoding.

The paper "Compression of Hyperspectral Scenes through Integer-to-Integer Spectral Graph Transforms" by Tzamarias, D.E.O., Chow, K., Blanes, I., Serra-Sagristà, J. [3] exploits the redundancies found between consecutive spectral components and within components themselves through the use of spectral graph filterbanks, such as the GraphBior transform. Such graph based filterbank transforms do not yield integer coefficients, making them appropriate only for lossy image compression schemes. In the paper, two integer-to-integer transforms are introduced for the purpose of the lossless compression, and its performance as a spatial transform is assessed.

The paper "Performance Impact of Parameter Tuning on the CCSDS-123.0-B-2 Low-Complexity Lossless and Near-Lossless Multispectral and Hyperspectral Image Compression Standard" by Blanes, I., Kiely, A., Hernández-Cabronero, M., Serra-Sagristà, J. [4] studies the performance impact related to different parameter choices for the new CCSDS-123.0-B-2 Low-Complexity Lossless and Near-Lossless Multispectral and Hyperspectral Image Compression standard. This standard supersedes CCSDS-123.0-B-1 and extends it by incorporating a new near-lossless compression capability, as well as other new features. Experimental results include data from 16 different instruments with varying detector types, image dimensions, number of spectral bands, bit depth, level of noise, level of calibration, and other image characteristics. Guidelines are provided on how to adjust the parameters in relation to their coding performance impact.

The paper "High-Performance Lossless Compression of Hyperspectral Remote Sensing Scenes Based on Spectral Decorrelation" by Hernández-Cabronero, M., Portell, J., Blanes, I., Serra-Sagristà, J. [5] investigates the most advantageous compression–complexity trade-off in hyperspectral image (HSI) compression. Compression performance and execution time results are obtained for a set of 47 HSI scenes produced by 14 different sensors in real remote sensing missions. Assuming only a limited amount of energy is available, obtained data suggest that the FAPEC algorithm yields the best trade-off. When compared to the CCSDS 123.0-B-2 standard, FAPEC is 5.0 times faster and its compressed data rates are on average within 16% of the CCSDS standard. In scenarios where energy constraints can be relaxed, CCSDS 123.0-B-2 yields the best average compression results.

There are three papers that deal with compression impact on classification and segmentation.

The paper "Lossy Compression of Multichannel Remote Sensing Images with Quality Control" by Lukin, V., Vasilyeva, I., Krivenko, S., Li F., Abramov, S., Rubel, O., Vozel, B., Chehdi, K., and Egiazarian, K. [6] studies a dependence between classification accuracy of maximum likelihood and neural network classifiers that have been applied to three-channel images and visual quality of compressed images. It is demonstrated that the classification accuracy starts to decrease faster when image quality due to increasing compression ratio reaches a distortion visibility threshold. In addition, classification accuracy depends essentially on the training methodology: training carried out for lossy compressed data seems preferable over training on undistorted data.

The paper "Lossy Compression of Multispectral Satellite Images with Application to Crop Thematic Mapping: A HEVC Comparative Study" by Miloš Radosavljević, Branko Brkljač, Predrag Lugonja, Vladimir Crnojević, Željen Trpovski, Zixiang Xiong, and Dejan Vukobratović [7] provides a comprehensive analysis of the HEVC still-image intra coding while applied to multispectral satellite images acquired by the Landsat-8′s OLI and Sentinel-2′s multispectral instrument. In the specific context of a crop classification application, HEVC's intra coding is shown to maintain approximately the same classification accuracy of a random forest pixel-based classifier for CR up to 150:1 while it is only up to 70:1 with JPEG 2000. It also achieves a better trade-off between compression gain and image quality, both visually and in terms of PSNR values, as compared to standard JPEG 2000.

The paper "Spectral Imagery Tensor Decomposition for Semantic Segmentation of Remote Sensing Data through Fully Convolutional Networks" by Josué López, Deni Torres, Stewart Santos, and Clement Atzberger [8] suggests a whole framework, called HOOI-FCN, to perform compression of an input RS-image followed by semantic classification. A Tucker decomposition-based mapping with preservation of the features of the classes of interest transforms the input third-order tensor into a core tensor with the same spatial resolution but a lower number of bands. This is done by means of the higher order orthogonal iteration (HOOI) algorithm. A fully convolutional network (FCN) is next considered to classify the core tensor at the pixel level. HOOI-FCN is shown to achieve high performance metrics competitive with some RS-multispectral images semantic segmentation state-of-the-art methods on Sentinel-2 images while significantly reducing computational complexity and processing time.

Lossy compression of data for unmanned aerial vehicle (UAV) is also attracting interest, as witnessed by two papers.

The paper "Real-Time Hyperspectral Data Transmission for UAV-Based Acquisition Platforms" by Melián, J.M., Jiménez, A., Díaz, M., Morales, A., Horstrand, P., Guerra, R., López, S., and López, J.F. [9] focuses on rapid compression of hyperspectral data prior to their transmission using two different NVIDIA boards—the Jetson Xavier NX and the Jetson Nano. The obtained results show the possibility of achieving real-time performance if the Jetson Xavier NX is used for all the configurations that could be applied in real missions.

The paper "FPGA-Based On-Board Hyperspectral Imaging Compression: Benchmarking Performance and Energy Efficiency against GPU Implementations" by Julián Caba, María Díaz, Jesús Barba, Raúl Guerra, Jose A. de la Torre, and Sebastián López [10] proposes a highly optimized implementation using integer arithmetic of the lossy compression algorithm for hyperspectral image systems. The purpose is to comply with the high-frame requirement imposed by a UAV-based sensing platform. The single-core version of the FPGA-based solution onto a heterogeneous Zynq-7000 SoC chip allows setting the baseline scenario of compressed hyperspectral image blocks at 200 FPS, using a small number of FPGA resources and low power consumption. Moreover, it is shown that a multi-core FPGA-based version can reach the same level of performance as the most efficient embedded GPU-based implementations.

Two papers concern neural network use in image compression.

The paper "Reduced-Complexity End-to-End Variational Autoencoder for on Board Satellite Image Compression" by de Oliveira, V.A., Chabert, M., Oberlin, T., Poulliat, C., Bruno, M., Latry, C., Carlavan, M., Henrot, S., Falzon, F., and Camarero, R. [11] concentrates on design of a complexity-reduced variational autoencoder with attempt to meet the constraints dealing with board satellite compression, time, and memory complexities. A simplified entropy model that preserves the adaptability to the input image is proposed. It is shown that the designed complexity-reduced autoencoder provides a better rate-distortion trade-off compared to the Consultative Committee for Space Data Systems standard CCSDS 122.0-B.

The paper "Spectral–Spatial Feature Partitioned Extraction Based on CNN for Multispectral Image Compression" by Kong, F., Hu, K., Li, Y., Li, D., and Zhao, S. [12] puts forward a multispectral image compression framework that is fully based on a convolutional neural network (CNN). The novelty concerns the feature extraction module, divided into spectral and spatial parallel parts. The testing is carried out for datasets acquired by Landsat-8 and WorldView-3 satellites. A better performance is shown in comparison to JPEG 2000, 3D-SPIHT and ResConv, another CNN-based algorithm.

Compression acceleration is also addressed in the paper "An FPGA Accelerator for Real-Time Lossy Compression of Hyperspectral Images" by Daniel Báscones, Carlos González, and Daniel Mozos [13], which derives a custom FPGA implementation of the costliest part (tier 1 coder within JPEG2000) of the JYPEC algorithm, a lossy hyperspectral compression algorithm that combines PCA and JPEG2000. The main goal is to accelerate it significantly to bring the full algorithm execution time down as much as possible and even below the real-time constraint. An average acceleration of 3.6 is verified when the FPGA accelerated algorithm is applied to six hyperspectral images, four from the Spectrir library and two from the CCSDS 123 dataset.

Finally, two papers are devoted to compressive sensing.

The paper "Compressive Underwater Sonar Imaging with Synthetic Aperture Processing" by Choi, H., Yang, H., and Seong, W. [14] deals with synthetic aperture sonars (SAS) in underwater imaging. SAS imaging algorithms that employ compressive sensing are considered and verified through simulation and experimental data. A better resolution compared to the ω-k algorithms with minimal performance degradation by side lobes are demonstrated in simulations. Experimental data show the method's robustness with respect to sensor loss.

The paper "A Task-Driven Invertible Projection Matrix Learning Algorithm for Hyperspectral Compressed Sensing" by Dai, S., Liu, W., Wang, Z., and Li, K. [15] proposes a hyperspectral compressed sensing algorithm with low complexity and strong real-time performance. It is based on a task-driven invertible projection matrix learning algorithm aiming at solving the problems of long time-consuming and low reconstruction accuracy of compressed sensing-based reconstruction algorithms. Experiments performed on Indian Pine AVIRIS hyperspectral dataset show that, compared with the traditional compressed sensing algorithm, the proposed compressed sensing algorithm has higher reconstruction accuracy and improved real-time performance by more than a hundred times, thus leading to great application prospects in the field of hyperspectral image compression.

2. Conclusions

From the fifteen papers published in this Special Issue, we can state that compression of remote sensing data is today an active research area with new direction appearing and attracting attention of scientists engaged in the design of methods to meet customers' expectations. We hope that the readers will enjoy this Special Issue.

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