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GUEST EDITORIAL

Special issue on architectures and techniques for real-time processing of remotely sensed images

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Advances in sensor technology are revolutionizing the way remotely sensed images are collected, managed and processed. The incorporation of latest generation sensors to airborne and satellite platforms is currently producing a nearly continual stream of high-dimensional image data [6], and this explosion in the amount of collected information has rapidly created new processing challenges [4]. In particular, many current and future applications of remote sensing in Earth science, space science, and soon in planetary exploration science, require real or near realtime processing capabilities. Relevant examples include monitoring of natural disasters, such as earthquakes and floods, military applications, tracking of man-induced hazards, such as wild land and forest fires, oil spills and other types of biological agents. Most of these applications require timely responses for swift decisions, which depend on real-time performance of algorithm analysis.

Owing to the diversity and large dimensionality of the image data sets provided by observation instruments in Earth and planetary applications, there are no commonly accepted real-time image processing architectures and techniques in the context of remote sensing missions. In future years, remote sensing imaging spectrometers [2] such as hyperspectral- and ultraspectral imagers [1] will continue increasing their spatial and spectral resolutions (imagers with thousands of narrow spectral bands are currently under development), thus producing a nearly continual stream of high-dimensional image data [5] and increasing the possibility of exploitation of the data with regards to multi-spectral imagers [3]. Such technological advances are not only expected in optical remote sensing instruments, but also in radar and other types of remote sensing systems. Such explosion in the amount, size and dimensionality of the information collected on a daily basis presents new challenges for real-time processing in certain remote sensing applications, which demand for quick response in practical exploitation.

This special issue on "Architectures and techniques for real-time processing of remotely sensed images" is intended to present the state of the art and the most recent developments in the incorporation of (near) real-time image processing techniques and specialized architectures in the context of remote sensing applications. This special issue covers different techniques and architectures for (near) real-time image processing in remote sensing. The techniques addressed in the special issue deal with relevant problems in Earth observation, such as damage mapping in case of earthquakes, flood monitoring, target and anomaly detection for military applications, cloud cover assessment or precision agriculture. The set of implementation strategies discussed in the special issue is also extensive, including parallel and distributed platforms, grid computing and multi-core environments, and specialized architectures for real-time on-board processing such as field programmable gate arrays (FPGAs) or commodity graphics processing units (GPUs). Combined these topics are expected to provide an excellent snapshot of the state of the art in those areas, and to offer a thoughtful perspective of the potential and emerging challenges of applying real-time image processing architectures and algorithms to realistic remote sensing problems.

The special issue comprises eight articles contributed by authors with extensive experience in the field of efficient

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processing of remotely sensed data sets, and with solid reputations and backgrounds. In particular, all the techniques and methods presented in this section are well consolidated, and cover quite nicely some of the most widely used techniques and high performance computing architectures used in remote sensing applications. Repetition of topics was specifically avoided in order to provide a timely compilation of realistic and successful efforts in the field, addressing several different application case studies with (near) real-time requirements. A summary of each contribution is provided below.

The article “Fast damage mapping in case of earthquakes using multi-temporal SAR data” by Trianni and Gamba describes two innovative approaches (unsupervised and supervised) to determine earthquake damages in urban areas through the exploitation of multi-temporal synthetic aperture radar (SAR) data. The unsupervised approach is based on the statistical analysis, while the supervised methods considered in this work include a Markov random field (MRF) classifier and a fuzzy Artmap neural network classifier. The two proposed approaches are compared using SAR imagery collected before and after an earthquake in Turkey, in 1999, and the computational burden and parallelization of the proposed techniques for effective exploitation is also discussed.

The article “Near real-time SAR based processing to support flood monitoring” by Cossu, Schoepfer, Bally and Fusco describes a near real-time SAR processing service to support the mapping of flooded areas through the utilization of grid computing technology to manage large volumes of data and to provide the computational resources to cope with demanding SAR image processing tasks. The grid computing infrastructure at the European Space Agency (ESA) is used to develop an extensive validation of the derived products, which shows reliable accuracy for co-registration of half a pixel.

The article “Near real-time parallel processing and advanced data management of SAR images in grid environments” by Cafaro, Epicoco, Fiore, Lezzi, Mocavero and Aloisio describes the process of parallelizing a sequential SAR processor based on the Range–Doppler algorithmic approach. A message passing interface (MPI) implementation is developed showing adequate speedups and achieving near real-time processing of raw SAR data even on a moderately aged parallel platform. Moreover, a hybrid two-level parallelization approach that involves the use of both MPI and OpenMP for multi-core implementation is also discussed. Finally, this contribution presents GridStore, a novel data grid service to manage raw, focused and post-processed SAR data in grid computing environments.

The article “A new software/hardware architecture for real time image processing of wide area airborne camera images” by Thomas, Rosenbaum, Kurz, Suri and Reinartz describes the software/hardware architecture of a new system for processing airborne remote sensing data using a camera at the German Remote Sensing Data Center (DLR). The discussed on-board image processing system is distributed over a local network, in which several PCs run tasks concurrently. The tasks comprise ortho rectification and mosaicing modules executed on a GPU, with a traffic-monitoring module (the main application for the proposed system) running on another PC in the on-board network. The resulting image data and evaluated traffic parameters are sent to a ground station in near real time, so that it is possible to support rescue forces and security forces in disaster areas or during mass events in near real time.

The article “Reconfigurable processing for satellite on-board automatic cloud cover assessment (ACCA)” by El-Araby, El-Ghazawi, Le Moigne and Irish presents the design and implementation of a reconfigurable computer for real-time on-board detection of clouds, a crucial aspect in many studies such as climate and weather-related investigations. The potential of using FPGAs for on-board cloud pre-processing is investigated by prototyping the ACCA algorithm for automatic cloud cover assessment (developed for Landsat 7 ETM+ multi-spectral data) on a state of the art reconfigurable platform. It is shown that the proposed approach provides higher detection accuracy and more than one order of magnitude in performance when compared to previously reported investigations.

The article “Convex regularization-based hardware/software co-design for real-time enhancement of remote sensing imagery” by Castillo-Atoche, Shkvarko, Torres-Roman and Perez-Meana describes a new approach for high-resolution reconstruction and enhancement of remote sensing in near-real computational time based on the aggregated hardware/software co-design paradigm. The software design is aimed at the algorithmic level to decrease the computational load of image enhancement tasks. The hardware design is oriented towards employing a Xilinx FPGA to improve computational efficiency of the same image enhancement operations. Performance issues and simulation results are provided in different application domains to illustrate the advantages of the proposed approach.

The article “Fast real-time on-board processing of hyperspectral imagery for detection and classification” by Du and Nekovei investigates real-time implementation of several popular detection and classification algorithms for remotely sensed hyperspectral imagery. An effective approach to real-time implementation of such algorithms is proposed using a small portion of hyperspectral pixel vectors in the evaluation of data statistics. An empirical rule of an appropriate percentage of pixels to be used is investigated, which results in reduced computational complexity and simplified hardware implementation. An overall system architecture is also provided, and experimental results are given in the context of two different applications: target detection for military purposes, and mineral mapping using the airborne visible infrared imaging spectrometer (AVIRIS) system developed by NASA's Jet Propulsion Laboratory.

The article "Real-time anomaly detection in hyperspectral images using multivariate normal mixture models and GPU processing" by Tarabalka, Haavardsholm, Kasen and Skauli investigates the use of GPUs for realtime processing of remotely sensed hyperspectral images. In particular, the paper studies a hyperspectral anomaly detection algorithm based on the normal mixture modeling of the background's spectral distribution, a computationally challenging task relevant to military target detection and other numerous applications. The computationally dominating parts of the algorithm are implemented on an Nvidia GeForce 8800 GPU using the compute unified device architecture (CUDA) programming interface. The GPU computing performance is compared with a multi-core CPU implementation. The experimental results indicate that the GPU implementation runs significantly faster and is close to real-time, particularly for those parts of the algorithm where data allow inherently a high amount of parallel access and contain complex arithmetic, simultaneously.

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Antonio J. Plaza, Guest Editor.

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