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Parallel processing opens new perspectives for hyperspectral imaging

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Developing computationally efficient processing techniques for massive volumes of hyperspectral data is critical for space-based Earth science and planetary exploration.

The wealth of spatial and spectral information provided by hyperspectral sensors (with hundreds or even thousands of spectral channels)[1] has quickly introduced new processing challenges. In particular, many hyperspectral imaging applications require a response in (near) real time in areas such as environmental modeling and assessment, target detection for military and homeland defense/security purposes, and risk prevention and response. The latter includes tracking wildfires, detecting biological threats, and monitoring oil spills and other types of chemical contamination.

Despite the growing interest in hyperspectral imaging technology, only a few parallel processing algorithms exist in the open literature. However, with the recent explosion in the amount and dimensionality of hyperspectral data, parallel processing is expected to become a requirement in most ongoing and planned remote sensing missions.

To address the need for integrated software/hardware solutions in hyperspectral imaging, we have been working on the development of highly innovative processing algorithms on several types of parallel platforms, including commodity (Beowulf-type) clusters of computers,[2] large-scale distributed systems made up of heterogeneous computing resources,[3] and specialized hardware architectures.[4]

To illustrate our most recent developments, we use here a hyperspectral image collected by the NASA Jet Propulsion Laboratory's AVIRIS (Airborne Visible/Infrared Imaging Spectrometer) system[5] over the World Trade Center (WTC) area in New York City on September 16, 2001. The data comprises 614 samples, 3675 lines, and 224 spectral bands, for a total size of 964MB. Figure 1 shows a false-color composite of a portion

Figure 1. *This false-color composite displays an AVIRIS hyperspectral data set that was collected over lower Manhattan on September 16, 2001.*

of the scene, in which the spectral channels at 1682, 1107, and 655nm are displayed as red, green, and blue respectively. Here, vegetation appears green, burned areas appear dark gray, and smoke appears bright blue due to high spectral reflectance in the 655nm channel.

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We implemented several parallel algorithms to analyze the AVIRIS data. We tested the algorithms on Thunderhead, a massively parallel Beowulf cluster at NASA's Goddard Space Flight Center.[6] To validate our results, we used ground-truth information available from the US Geological Survey.[7] The battery of algorithms consisted of various target detection algorithms, such as the parallel automated target generation algorithm (P-ATGP)[1], and parallel classification algorithms based on the identification of pure spectral components (endmembers),[8] such as the fast pixel purity index (P-FPPI)[9] and our automated morphological endmember extraction (AMEEPAR).[3,10] This is one of the few available parallel algorithms that integrate spatial and spectral information. Using 256 processors, AMEEPAR provided a 90% accurate debris/dust map of the full AVIRIS data in 10s, while the P-ATGP algorithm was able to detect the spatial location of thermal hot spots in the WTC area in only 3s.

We also implemented the parallel algorithms above in hardware platforms such as field-programmable gate arrays (which can be reconfigured on the fly) and commodity graphics hardware (which is subject to tremendous technological evolution due to the ever-growing demands of the video game industry). Parallel versions of AMEEPAR implemented on Virtex-II FPGA[4] and nVidia GeForce 7800 GLX boards[11] were more than 50 times faster than the single-processor code (implemented on a last-generation CPU). Such boards represent a cost-effective alternative to supercomputers, which are expensive and difficult to adapt to onboard processing.

Our recent developments in this area[12] indicate that the readily available computational power offered by last-generation computer architectures, combined with the design of effective parallel algorithms, may introduce substantial changes in the systems currently used for exploiting the sheer volume of Earth and planetary remotely sensed data that is now being collected on a daily basis.

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Dr. Antonio Plaza has authored or co-authored more than 100 publications in the areas of parallel computing, pattern recognition, and computer architecture. He serves on the editorial board of several journals and international conferences in these areas. He is editing a book on high performance computing in remote sensing for CRC Press, and a special issue on parallel hyperspectral imaging for the International Journal of High Performance Computing Applications.

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