HyCos

Hyperspectral Compressive Sensing and Unmixing

Airborne hyperspectral sensors collect large amount of Earth surface information. This information is processed and used for civil and military applications, often with real-time requirements. HyCos project aim to develop parallel compressive sensing methods. These methods are implemented in GPUs and FPGAs hardware for real-time on-board data processing and transmission.

Main Project Team	
Jose M. P. Nascimento	**PIA-Lx**
José Bioucas-Dias	PIA-Lx
Vítor Manuel Mendes Silva	MSP-Co
Gabriel Martín	PIA-Lx
António J. Plaza	UE-Spain
Sérgio García	PIA-Lx
Jorge Sevilla Cedillo	PIA-Lx
Indicators	
Funding	40k €
Journal Papers	6
Conference Papers	14
Concluded MSc	1

Two Main Publications

Sérgio García, Gabriel Martín, Jose M. P. Nascimento, José M. Bioucas-Dias, Vítor Silva, and António Plaza, "Parallel Hyperspectral Coded Aperture for Compressive Sensing on GPUs," "IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing", vol. 9, no. 2, pp. 932-944, Feb. 2016. doi: 10.1109/JSTARS.2015.2436440

Jose M. P. Nascimento and Mario Véstias, "System-on-chip Field Programmable Gate Array Design for Onboard Real-time Hyperspectral Unmixing," "Journal of Applied Remote Sensing", vol. 10, no. 1, p. 015004, January 2016. http://dx.doi.org/10.1117/1.JRS.10.015004

PROJECT WEBPAGE URL

https://www.it.pt/Projects/Index/1936

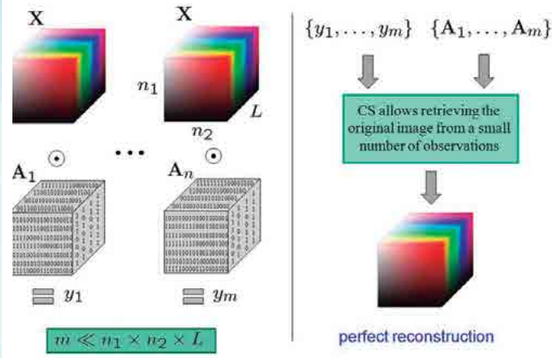

Fig. 1 Illustration of the compressive sensing strategy.

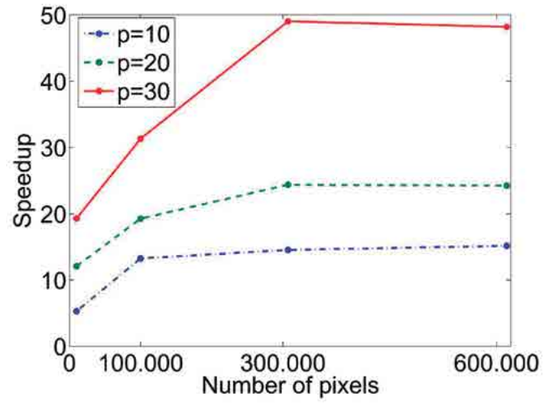

Fig. 2 Speedup of PSISAL method on GPU as a function of the number of endmembers and of the image size.

GENERAL MOTIVATION AND OBJECTIVES

Hyperspectral remote sensing imagery provides data at high spectral resolution which has been used to identify and quantify distinct material substances based on their spectral characteristics. Environmental monitoring, urban and regional planning, oil spill, and target detection are examples of applications that use this technology and often need a real-time response.

These high spectral resolutions typically generates large amount of data in a few seconds, which is usually collected by a satellite or an airborne instrument and sent to a ground station. Often the bandwidth connection between such platforms and the ground station is reduced, which limits the amount of data that can be transmitted. As a result, there is a clear need for (either lossless or lossy) compression of hyperspectral data on-board the imaging instrument.

HyCos project aim at the development and implementation in graphics computing units (GPU) and field programmable gate arrays (FPGA) hardware of parallel hyperspectral data compressive sensing techniques in order to perform real-time on-board hyperspectral imaging of Earth observation.

CHALLENGE

Development of compressive sensing methods to reduce the data to be transmitted. These techniques take advantage of the hyperspectral data sparsity and of spatial correlation present in the scenes.

This can be achieved by computing inner products between known vectors and the original data. However, this method is characterized by its high computational complexity. To alleviate the computational burden of hyperspectral compressive sensing, these methods are implemented in parallel, using GPUs, which are known by their extremely high floating-point processing performance, huge memory bandwidth and their comparatively low cost. In particular, they may be suitable in the future for real-time on-board processing due to their portability.

An alternative solution to GPUs, aiming at on-board remote sensing data processing scenarios in which low-weight and low-power integrated components are essential to reduce the mission payload in satellites and aircrafts, are FPGAs as their logic is fully reconfigurable, which allows to adaptively select the data processing algorithm and to obtain real-time results.

WORK DESCRIPTION AND ACHIEVEMENTS

Parallel Hyperspectral Coded Aperture (PHYCA) method has been developed for hyperspectral data compression. The implementation of PHYCA has several optimizations for accelerating the computational performance while maintaining the accuracy. The implementation of five different methods, including a constrained version and a Blind version of PHYCA, on GPU cards exploits the architecture at low level, using shared memory and coalesced accesses to memory. These works leads to very significant speedup factors.

A parallel spectral compressive acquisition method (PSPECA) has been developed to perform dimensionality reduction based on random projections on the spectral domain. The GPU implementation can provide real-time performance.

A demonstrator has been built based on FPGA architecture. This demonstrator has been developed for endmember's signature extraction. The Xilinx Zynq board with a Zynq-7020 SoC FPGA based on the Artix-7 FPGA programmable logic is used. The achieved results indicate the potential of the proposed platform to implement high-performance, low cost embedded systems, opening new perspectives for on-board hyperspectral image processing.

PSISAL is a method developed for hyperspectral unmixing which works on a pixel by pixel fashion and it finds the smallest simplex that contains the data set. This method solves a nonconvex optimization problem by a sequence of nonsmooth convex subproblems using variable splitting to obtain a constraint formulation and then it applies an augmented Lagrangian technique. The development of the method for GPUs has led to significant speedup factors