Earth observation using compressive sensing

Clément Thomas [a]*, *Marc Georges* [a], *Laurent Jacques* [b]

[a] *Centre Spatial de Liège (CSL), Université de Liège, Avenue du Pré-Aily, 4031 Liège*

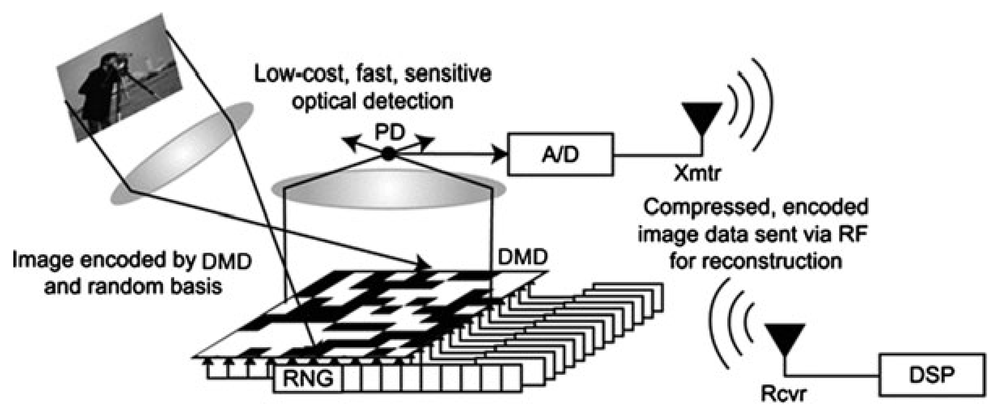
[b] *ICTEAM institute, UCLouvain, Avenue Georges Lemaître 4-6/L4.05.01, 1348 Louvain-la-Neuve*

**clement.thomas@uliege.be*

INTRODUCTION

Compressive sensing is an innovative signal processing technique which allows to merge the data acquisition and data compression steps. Its foundation lies in the sparsity of natural signals which means that any signal can be effectively approximated by a sparse representation in some basis. Using appropriate algorithms, CS allows us to efficiently capture and reconstruct complete signals by generalizing their sampling process at much reduced sampling rates. Practically, in imaging systems, this can be achieved with Spatial Light Modulators (SLMs) such as Digital Micromirror Devices (DMDs) for signal sampling. Then, knowledge of the masks applied on the SLM and of the resulting acquired data allows us to reconstruct complete images using specific algorithms. The method presents several features relevant in Earth observation: substantial reduction of data requirements, minimized detector dimensions, resolution enhancement, and possibilities of compact imager designs.

ARCHITECTURES



Credit: Duarte et al. (2008).

Single-pixel camera

This is the most extreme case of detector size reduction through CS. In this setup, the image is focused on the DMD which modulates the signal with random binary masks. The resulting light is then focused on a single -pixel detector. This yields one single data point for each pattern applied. The resulting data vector can then be reconstructed in a complete image by injecting prior knowledge of the masks in appropriate algorithms. The final image resolution is defined by the resolution of the DMD.

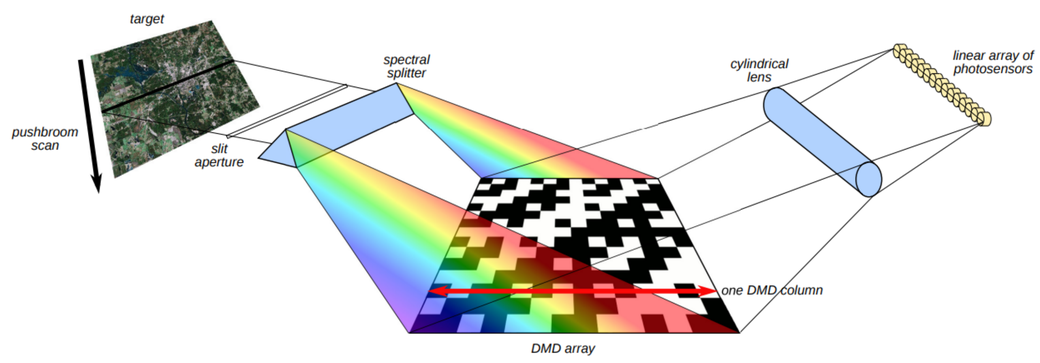
Compressive hyperspectral pushbroom sensor

In this conceptual architecture, the subsampling of data is not done spatially but spectrally, on the DMD columns. Each pixel of the linear sensor corresponds to one pixel of the PB scan and the entire spectral information can be reconstructed by applying several patterns on the DMD columns.

+ Data requirement reduction

+ Detector size reduction

- Increase of acquisition time



Credit: Fowler (2014).

SIMULATION

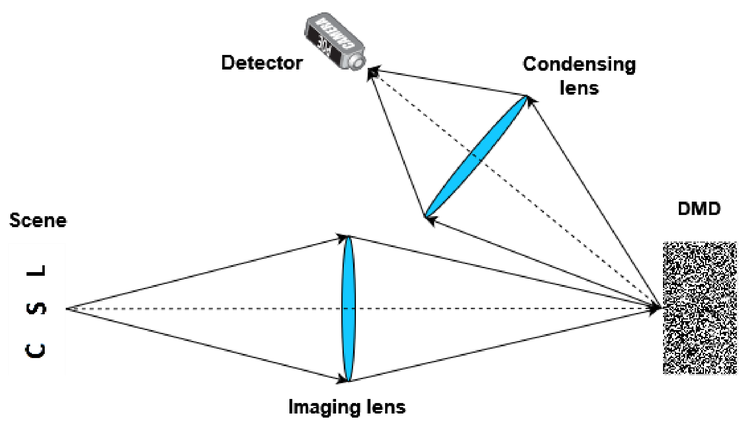
Agricultural fields image (Sentinel-2)

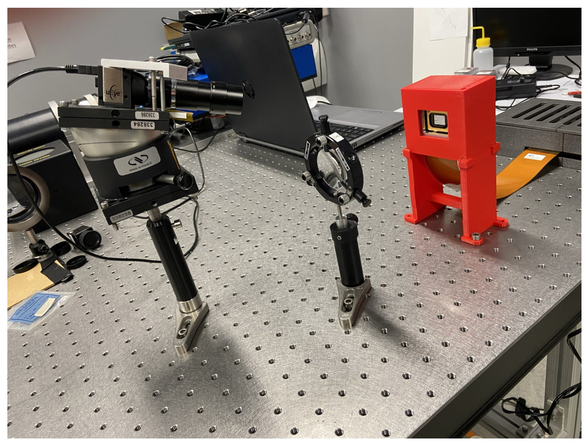
Subsampling 10% of the data

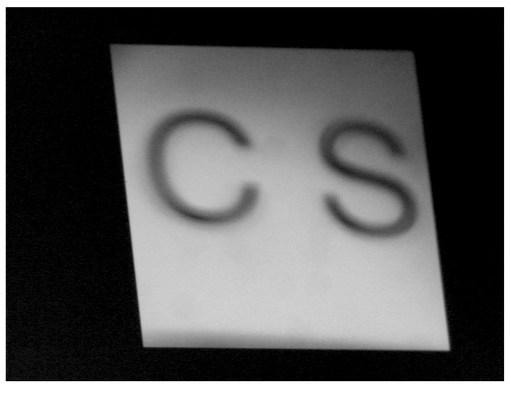
Reconstruction (ISTA-Net+)

PSNR: 81.03 dB, SSIM: 0.927

EXPERIMENTAL SETUP







Example of an image displayed on the DMD with a full square of ‘on’ mirrors

Same image with a 32x32 mask applied on the DMD

This research is part of the Space4ReLaunch project, which is supported by the SPW Economie Emploi Recherche of the Walloon Region, under grant agreement no. 2210181.