



HAL
open science

Reconstruction of randomly and partially sampled STEM spectrum-images

Etienne Monier, Thomas Oberlin, Nathalie Brun, Marcel Tencé, Nicolas
Dobigeon

► **To cite this version:**

Etienne Monier, Thomas Oberlin, Nathalie Brun, Marcel Tencé, Nicolas Dobigeon. Reconstruction of randomly and partially sampled STEM spectrum-images. Microscopy and Microanalysis Meeting (M&M 2017), Aug 2017, Saint-Louis, Missouri, United States. pp.170-171. hal-03658140

HAL Id: hal-03658140

<https://hal.science/hal-03658140>

Submitted on 3 May 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Open Archive Toulouse Archive Ouverte

OATAO is an open access repository that collects the work of Toulouse researchers and makes it freely available over the web where possible

This is an author's version published in:

<http://oatao.univ-toulouse.fr/19155>

Official URL

DOI : <http://doi.org/10.1017/S1431927617001532>

To cite this version: Monier, Etienne and Oberlin, Thomas and Brun, Nathalie and Tencé, Marcel and Dobigeon, Nicolas *Reconstruction of randomly and partially sampled STEM spectrum-images*. (2017) In: Microscopy and Microanalysis Meeting (M&M 2017), 6 August 2017 - 10 August 2017 (Saint-Louis, Missouri, United States).

Any correspondence concerning this service should be sent to the repository administrator: tech-oatao@listes-diff.inp-toulouse.fr

Reconstruction of Randomly and Partially Sampled STEM Spectrum-Images

Etienne Monier¹, Thomas Oberlin¹, Nathalie Brun², Marcel Tencé², Nicolas Dobigeon¹

¹ University of Toulouse, IRIT/INP ENSEEIHT, F-31071 Toulouse Cedex, France

² Laboratoire de Physique des Solides, CNRS UMR 8502, Univ. Paris-Sud, Univ. Paris-Saclay, Bât. 510, 91405 Orsay Cedex, France

Scanning transmission electron microscopy (STEM) offers the ability to acquire several single- and multi-channels signals generated simultaneously for each probe position: cathodoluminescence (CL), electron energy loss spectroscopy (EELS) and high-angle annular dark-field imaging (HAADF). However, in some cases, sensitive samples (e.g., biological samples or molecular structures) may suffer from irradiation damages during acquisition. As a consequence, it is often necessary to reduce probe current or dwell time, which could significantly lower the signal-to-noise ratio. Another approach consists in acquiring only a subset of pixels randomly chosen in a given region of interest. This particular experimental set-up has been implemented on the STEM VG HB501 (LPS, Orsay, France), with the beam following a predetermined random path. The reconstruction of HAADF images is then straightforward with well known algorithms. However, when reconstructing the associated spectrum image, the high number of energy bands makes the problem computationally expensive.

Meanwhile, recent works in signal and image processing have introduced new algorithms using arguments borrowed from the theory of compressed sensing (CS), which enables a full reconstruction from few measurements, provided the image is sparse in a particular well-chosen domain. More generally, a wide range of regularizations have been proposed in the last decade to approximately solve inverse problems through convex optimization. Applications include fast acquisition schemes in MRI [1], hyperspectral image fusion [2], as well as many standard image processing problems (denoising, inpainting, etc). Inspired by these works, we propose here a new reconstruction technique of the whole spectrum image from partial random measurements. To this end, we exploit the low-rank structure of the data, which assumes that the spectrum image can be represented as a linear combination of ρ elementary spectra. The reconstruction task is then formulated as a linear inverse problem which combines a low-rank representation and a spatial regularization that promotes the spatial coherence.

If we denote by X the full spectral image to be reconstructed, the proposed algorithm relies on the low-rank factorial decomposition $X = HS$ where H is a matrix spanning the signal subspace and S is the image represented in this subspace. The signal subspace H and the noise level are assumed to be previously estimated from the observations using a principal component analysis (PCA). Only the image in the subspace S should be estimated afterwards. For that purpose, assuming a Gaussian reconstruction error, we control the squared Euclidean distance between S and the observations while minimizing two penalties corresponding to the following assumptions. First, the image S is assumed to be spatially smooth, leading to the minimization of the spatial gradient energy. Second, the energy distribution of S along the different principal components of the spectrum image is assumed to match that of the observations. These three ingredients lead to a convex cost function which is minimized with an accelerated projected gradient algorithm [3].

To conduct a quantitative study of the proposed strategy, reference data has been generated by blurring a CL spectrum image, mainly to reduce the noise level and produce a spatially smooth image. Gaussian noise has been added to the resulting synthetic image with a SNR of 20dB, before random sampling of 20% of the pixels. Figures 1 and 2 illustrate the performance of the method on

this experiment. The reconstruction of one band of interest is displayed in Figure 1, while Figure 2 shows the ground-truth and reconstruction of two pixel spectra, one being initially sampled (top) and not the other one (bottom). By further implementing other appropriate estimation schemes and adaptively choosing the pixels to be acquired, we expect to improve the spectrum image recovery [4].

References:

- [1] Boyer, C., Weiss, P., & Bigot, J. SIAM Journal on Imaging Sciences **7(2)** (2014), p. 1080.
- [2] Wei, Q. *et al*, IEEE Transactions on Geoscience and Remote Sensing, **53(7)** (2015), p. 3658.
- [3] Beck, A., & Teboulle, M. SIAM journal on imaging sciences, **2(1)** (2009), p. 183.
- [4] NB thanks M. de Frutos, A. Tararan and A. Zobelli for providing samples and data.

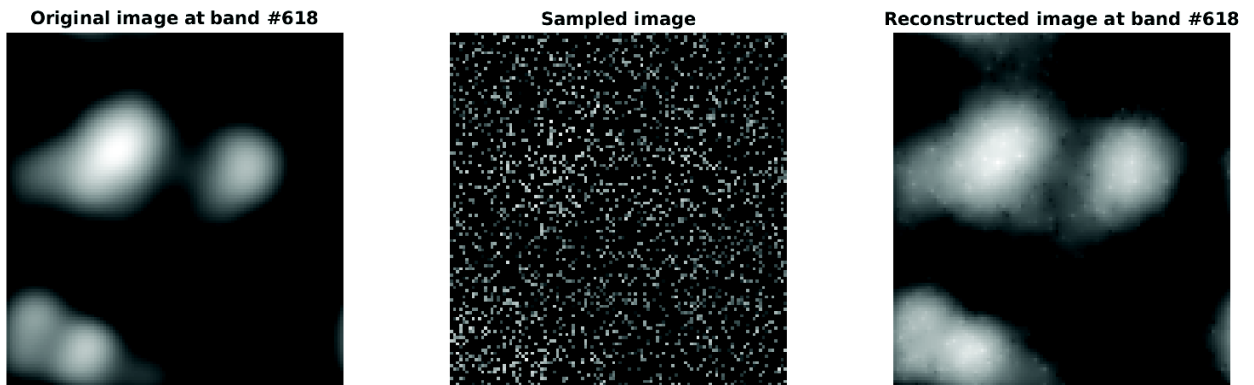


Figure 1. Reference, observed and reconstructed images at band #618 with 20% observed pixels.

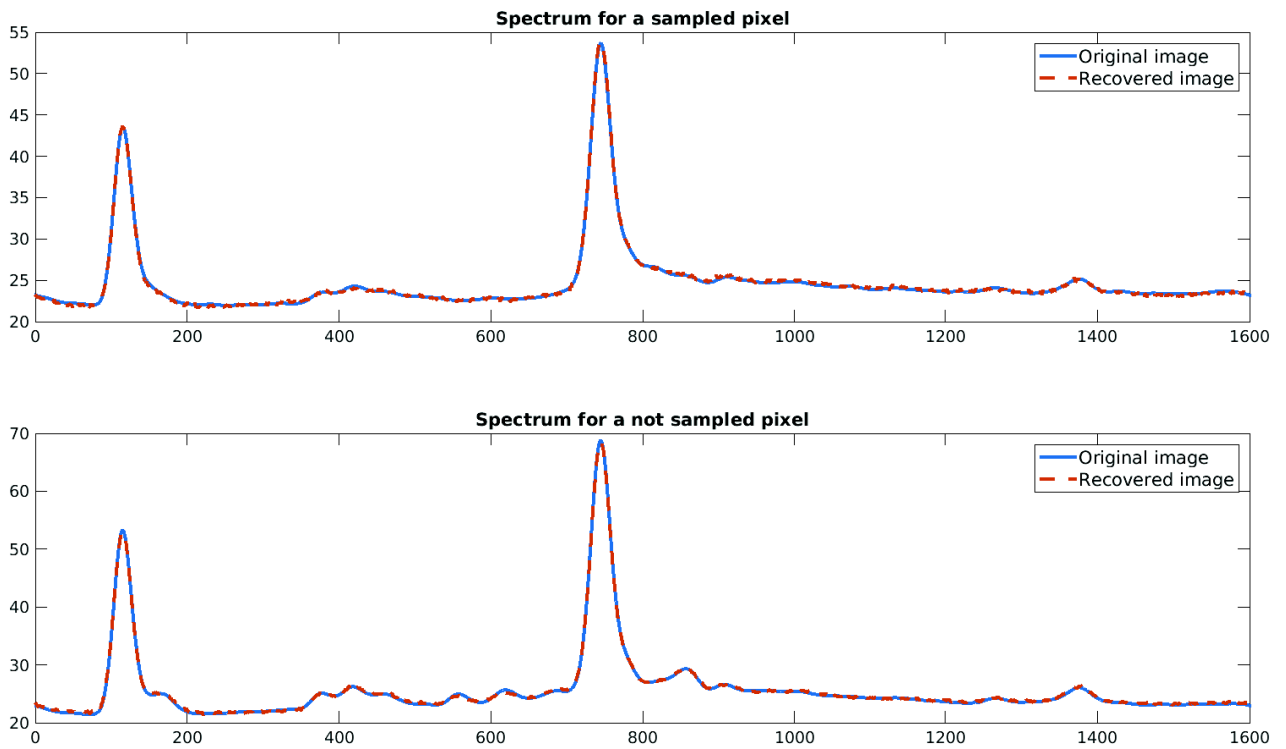


Figure 2. Original and reconstructed spectra for a sampled and a non-sampled pixel.