A Partial Random Sampling STEM Procedure For Sensitive Samples

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Scanning transmission electron microscopes (STEM) imaging is one of the most powerful methods for analyzing chemical components, especially by using EELS. Indeed, such acquisition allows for the identification and cartography of chemical elements forming the sample. Yet, this approach is limited for sensitive materials such as organic tissues where the electron beam may damage the structures [1]. Hence, new acquisition schemes where only specific pixels are sampled have been implemented [2]. Indeed, the evolution of the scanning modules for STEM makes now possible to generate arbitrary scanning patterns using pre-defined scanning matrices. The first implemented pattern consists in acquiring the pixels of the image in a random order. Following this acquisition, we can analyze the whole spectrum-image as usual. Yet, the dwell time should be small to prevent sample damages.

Our approach differs in considering only a partially pixel set. Then, for a same electron dose as in standard acquisition schemes, one could increase the dwell time for the visited positions which increases also the signal-to-noise ratio (SNR). However, a reconstruction procedure is required to get a complete spectrum-image. The reconstruction procedure is a convex optimization procedure chosen to promote smoothly varying images (which is a classical image processing hypothesis) and spectrally low rank images [3]. The details of this procedure can be found in [4].

To illustrate this, two full random acquisitions at dwell times 2ms and 10ms have been conducted on a biological sample with the STEM VG HB 501 microscope. The 2ms dwell time image (Full2ms) is used with all acquired pixels. Only 20% of the 10ms dwell time image (Full10ms) pixels have been kept to form the partially sampled image which has been reconstructed to form the Reconstructed image. Hence, the Full2ms and the Reconstructed images correspond to equivalent global electron doses. To compare the different approaches, the spectrum-images have been studied using unmixing techniques [4] that return principal elements spectra and abundance maps. Figure 1 shows the three first abundance maps given by the unmixing procedure for the different data sets. We can observe that the Reconstructed image gives less spatial precision. Yet, its energy resolution is better than for Full2ms and Full10ms images since the dwell time was higher and the reconstruction procedure has a denoising effect. More recent works focus on high-resolution EELS, in which the images are no longer smooth but sparse in the Fourier basis. In that purpose, a modified version of the reconstruction procedure is applied to anatomically resolved STEM image using 20% of available pixels. The results are given in Figure 2.

To summarize, the proposed reconstruction algorithm allows to fully exploit partially acquired spectrum-images. This technique offers potentials for investigate beam-sensitive materials, or to reconstruct a series of images corresponding to successive time intervals. Future work will be devoted to reconstruction of high-resolution spectrum-images and to online reconstruction of EELS images.

References:
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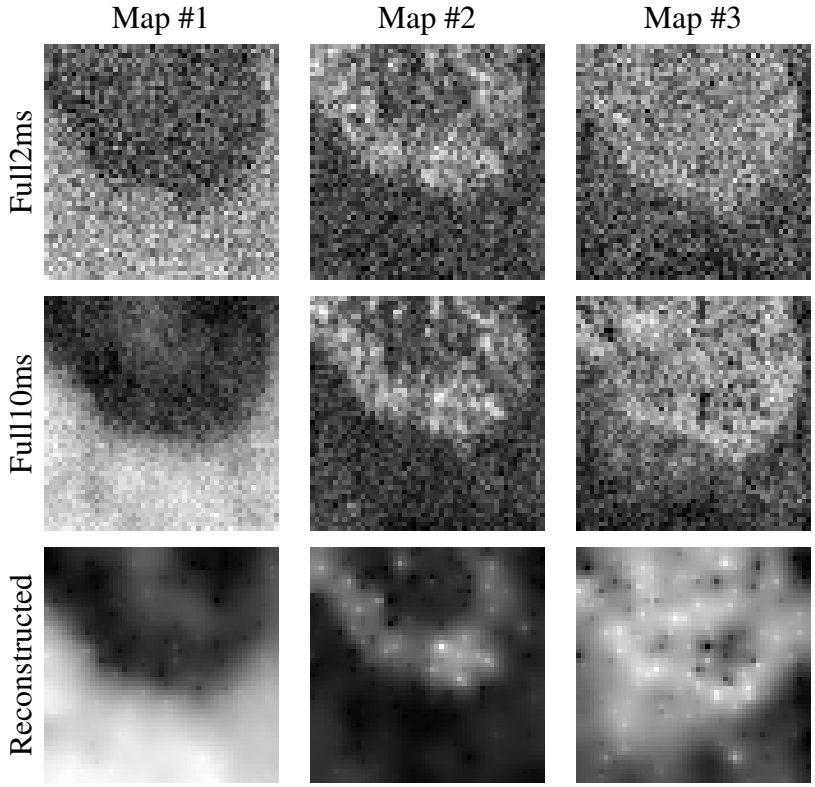
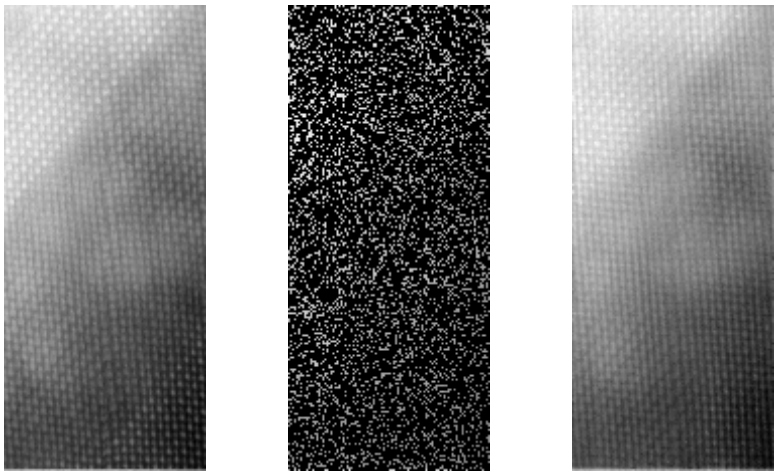


Figure 1: Abundance maps estimated by unmixing procedures applied to Full2ms, Full10ms and Reconstructed.



(a) Initial (b) Sampled (c) Reconstructed

Figure 2: A reconstruction procedure applied to high resolution nanoscale sample acquisition. The initial image is the sum of the EELS spectrum image bands.