

Subsampling Methods for Fast Electron Backscattered Diffraction Analysis for SEM

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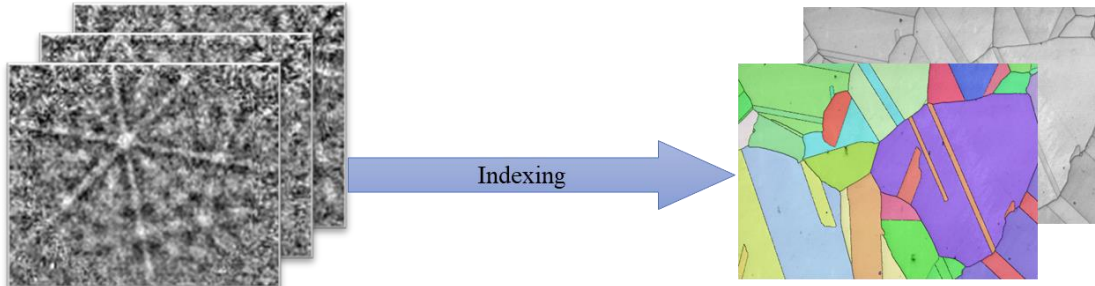
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Electron backscatter diffraction (EBSD) is an SEM based technique used for the characterization of microstructures, providing crystallographic information such as grain morphology and crystal orientation. Through a raster scan of the sample, a set of EBSD patterns are acquired which are indexed and processed to produce a full map of the sample, with each pixel representing one EBSD pattern. Acquisition speed and processing time has significantly improved over the years through innovations such as the CMOS detector, which enables high resolution images to be taken at higher speeds of 6000 patterns per second (pps), in comparison to the acquisition speeds of 1500 pps previously achieved by CCD detectors, which has previously been used for EBSD pattern acquisition [1]. Additionally, automated indexing is commonplace in commercial systems, allowing the Kikuchi bands to be easily detected and analysed. Despite these advances, EBSD still has long acquisition times, resulting in a compromise between quality and time to be reached [2].

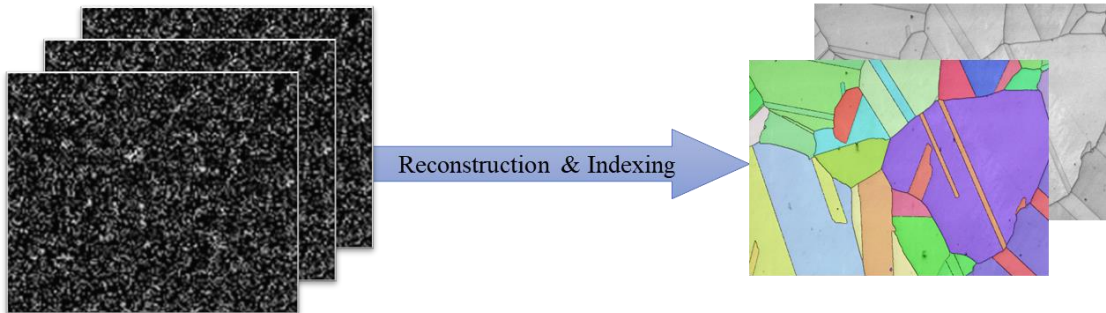
Compressive sensing is a signal processing technique, allowing data to be collected and processed efficiently through subsampling and reconstruction [3,4]. In recent studies it has been found to be effective in numerous microscopy applications, notably in scanning transmission electron microscopy (STEM) [5,6,7,8]. Through subsampling these signals, data can be acquired at a greater speed and reconstructed using an inpainting algorithm, which could significantly improve the speed of acquisition and processing with regards to EBSD detection.

Presented here is an application of compressive sensing methods to an EBSD dataset of a Ni-superalloy, with the motivation of taking advantage of the speed-increasing aspects of compressive sensing. The subsampling approaches proposed are camera subsampling, probe subsampling and combined subsampling. Camera subsampling is simulated by randomly subsampling the produced EBSD patterns from a full raster scan of the area which are then reconstructed before being processed in order to produce a full map. In order to simulate probe subsampling the full EBSD patterns would be retained, simulating a random subsampled scan of the sample. Combined subsampling combines both of these concepts, with subsampled EBSD patterns being reconstructed to generate an incomplete map of the area, which can then be reconstructed to produce qualitatively equivalent data to a fully sampled sample, whilst increasing the theoretical acquisition speed. An application of 10% camera subsampling and 10% probe subsampling is, in theory, 100 x faster.

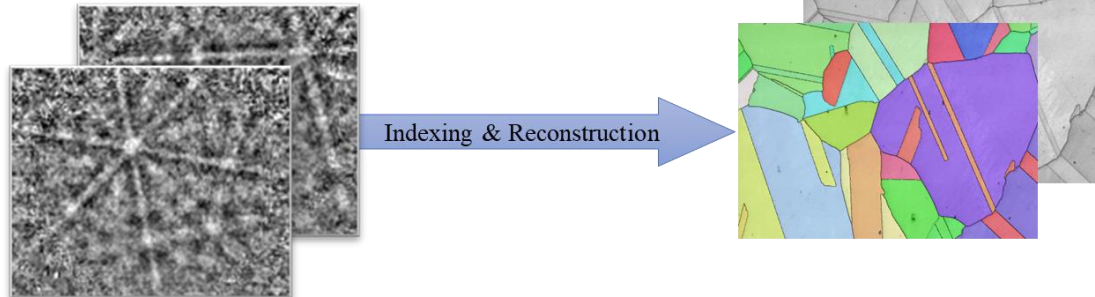
A) Current process



B) Camera subsampling



C) Probe subsampling



D) Combined subsampling

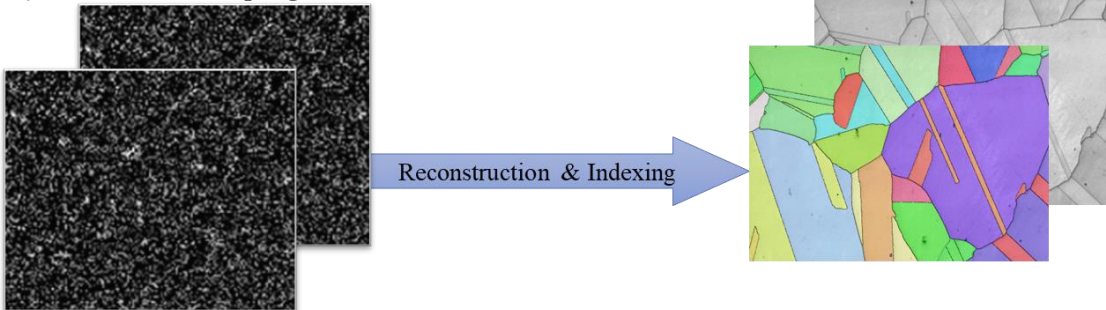


Figure 1. Proposed subsampling and reconstruction methods for EBSD: (A) Current method of full data acquisition; (B) Camera subsampling: subsampling of the EBSD pattern; (C) Probe subsampling: subsampling of the scanned sample; (D) Combined subsampling: subsampling of the sample and of the EBSD pattern.

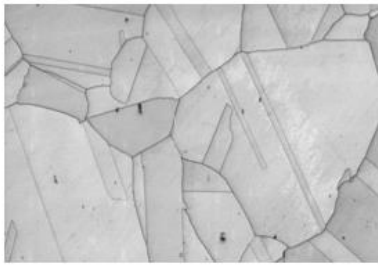
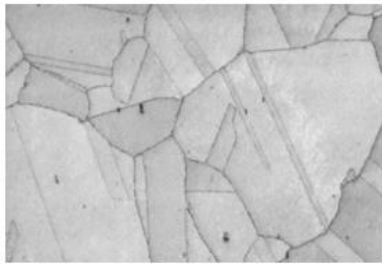
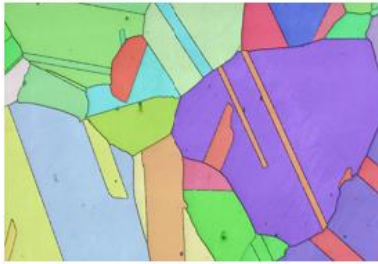
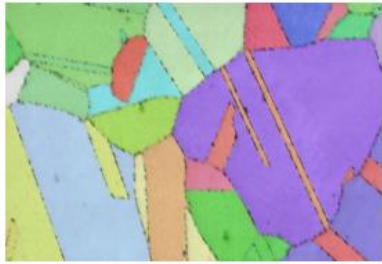
	Fully Sampled	10% Sampled
Band Contrast Map		
Overlaid Band Contrast, Inverse Pole Figure and Grain Boundary Map		

Figure 2. Comparison of fully sampled maps and maps obtained through reconstruction after 10% sampling ratio probe subsampling simulation

References:

- [1] J. Goulden et al., *Microsc. Microanal.*, 24 (2018): 1128-1129
- [2] B. Winiarski et al., *Ultramicroscopy* 226 (2021): 113315
- [3] E. J. Candès et al., *IEEE Transactions on Information Theory*, 52(2) (2006) : 489-509
- [4] D. L. Donoho, *IEEE Transactions on Information Theory*, 52(4) (2006) : 1289-1306
- [5] N. D. Browning et al., *Applied Physics Letters*, 122 (2023): 050501
- [6] D. Nicholls et al., *Ultramicroscopy* 223 (2022): 113451
- [7] D. Nicholls et al., *IEEE International Conference on Acoustics, Speech and Signal Processing*, (2022): 1586-1590
- [8] D. Nicholls et al, *arXiv preprint* (2022), arXiv:2211.03494