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Non-local Denoising of EBSD Patterns for Enhanced Indexing

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Electron Backscattered Diffraction (EBSD) within an Scanning Electron Microscope is often considered a method for determining the crystal orientation at a localize point on the sample surface. While EBSD mapping has been a part of EBSD analysis, some do not consider it a normal imaging technique. This bias may be due in part of the very slow nature of collecting EBSD data, with scans typically requiring hours to collect even a moderate pixel density. However, through steady progress in both phosphor sensitivity as well as faster more sensitive cameras, the current EBSD system can achieve over 1000 points per second. We will show that through post-processing of the Kikuchi patterns collected, even higher collection rates are possible.

Until recently it was impractical to store the individual diffraction patterns from each point, and the patterns were indexed as they were collected, then discarded. With modern computational processing, memory and storage capabilities, it is now practical to store the entire set of patterns (typically consisting of multiple gigabytes of data) to be processed at a later point, allowing for much more complex pattern processing and indexing methods can be deployed. For instance, EDAX Inc. has recently developed Nearest Neighbor Pattern Reindexing (NPAR), an algorithm where the images of the nearest neighbor patterns are averaged with the central pattern before indexing [1], allowing for shorter collection times for each pattern. However, it is found that using more than nearest neighbors can lead to a degradation of signal near interfaces. Another recent approach by M. DeGraef [2] uses a pre-calculated dictionary of all possible patterns. This method is very good at identifying patterns in very low quality signals. The current drawback of the dictionary approach is that it is highly computationally intensive. Even on highly specialized computer hardware the search algorithm requires about two orders of magnitude longer to index a set of points when compared to the traditional indexing algorithm.

In this work we will took lessons learned from de-noising algorithms in image processing [3] to develop a Non-Local Pattern Averaging Reindexing (NLPAR) method that can utilize much larger smoothing kernels than NPAR without losing signal integrity near the interface boundaries, and operating on timescales that are similar to the traditional indexing algorithm. This is done by weighting each pattern in a large smoothing kernel according to a similarity metric, which in this case is an exponential decay of the l^2-norm between the patterns within the smoothing kernel. This allows for similar, but not necessarily nearby patterns to be averaged with the pattern of interest, while simultaneously rejecting highly different patterns even though they may be spatially nearby.

Results are shown in Figures 1&2, using a testbed nickel dataset provided by EDAX Inc. Fig. 1a shows an original pattern collected with an exposure of 0.23 msec, demonstrating a low signal to noise ratio. Fig. 1b shows the same pattern after processing with NLPAR. There is an obvious improvement in the signal-to-noise, and the features of the diffraction pattern can be much more clearly detected. Fig. 2a shows the Inverse Pole Figure (IPF) created by indexing the original patterns. Due to the poor signal within the patterns many of the points are mis-indexed or not indexed at all. Fig. 2b shows the same scan using NLPAR to process the patterns before indexing. Nearly all the points are indexed while still resolving small features and domains such as the thin twins present within the structure. It should be noted that NLPAR is a computationally efficient algorithm; the unoptimized NLPAR code processed all of the patterns in this 186×151 EBSD scan using a standard desktop computer in less than 10 seconds, which is less time than is required for the indexing algorithm to determine the orientations from the patterns. [4]

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[3] A. Buades, B. Coll, and J. M. Morel, Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2005, **vol.** 2, (2005) p. 60

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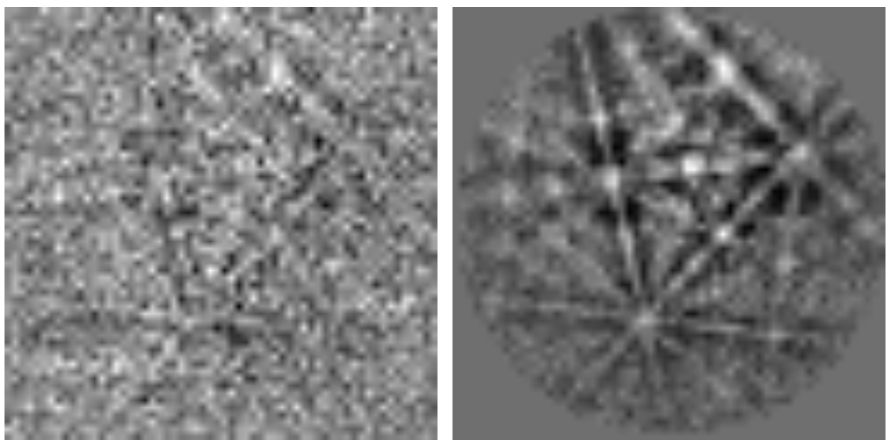
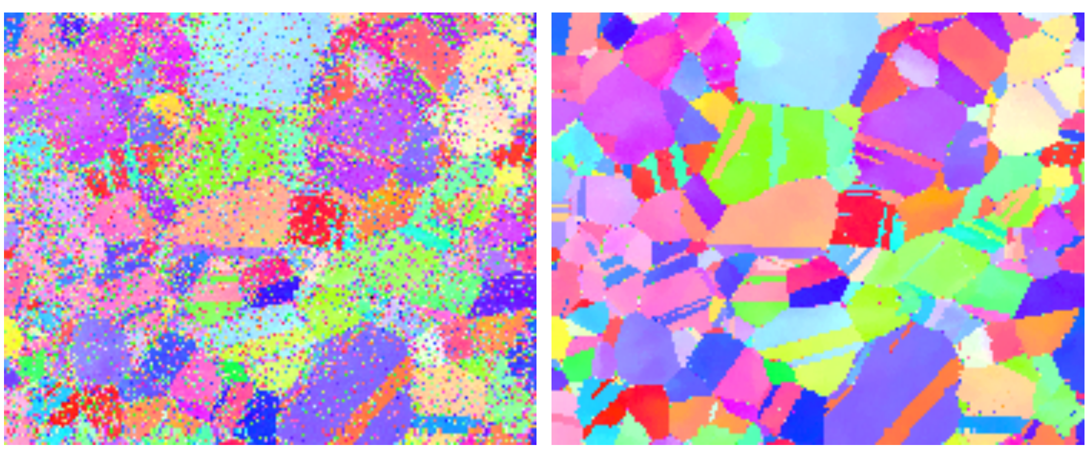


(a) **(b)**

Figure 1: (a) A unprocessed EBSD pattern collected at 0.23 msec. (b) The same pattern after processing with NLPAR.



(a) **(b)**

Figure 2: Inverse Pole Figure (IPF) maps from the reference nickel EBSD scans, indexed using the standard EDAX indexing algorithm. (a) IPF from the as-collected diffraction patterns and (b) IPF from the NLPAR processed diffraction patterns.

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