Advanced EBSD Pattern Indexing and Analysis for Real-Time Phase Transformation Studies

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Abstract

Recent advancements in Electron Backscatter Diffraction (EBSD) cameras—from traditional CCD and CMOS[1] sensors to cutting-edge, high-speed direct electron detectors[2]—are revolutionizing *in situ* characterization. These developments include increasingly sophisticated mechanical and temperature in situ stage loaders, enabling dynamic, real-time observations of phase transformations under diverse loading and thermal conditions[3]. Such capabilities call for equally advanced pattern indexing and analysis approaches that can handle large data volumes, remain robust to noise and deformation-induced pattern variability, and support multi-phase sample analyses. This talk will present three complementary methods addressing these challenges:

1. **Deep Learning-Driven Pattern Simulation**: A generative adversarial network (GAN)-based deep learning framework, employing the pix2pixHD model, effectively translates rapidly computed kinematical EBSD patterns into high-fidelity dynamical patterns[4] (Figure 1).

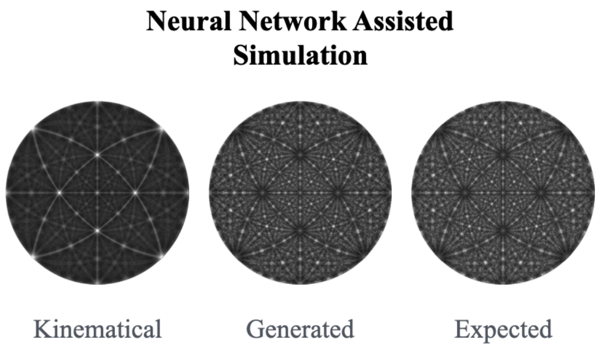

Figure 1: Dynamical EBSD master pattern generation from approximate kinematical simulation

2. **High-Efficiency Indexing with PCA, Quantization, and HNSW**: The integration of Principal Component Analysis (PCA), quantization, and Hierarchical Navigable Small Worlds (HNSW) graph-based indexing techniques significantly boosts indexing speed and accuracy[5], [6](Figure 2).

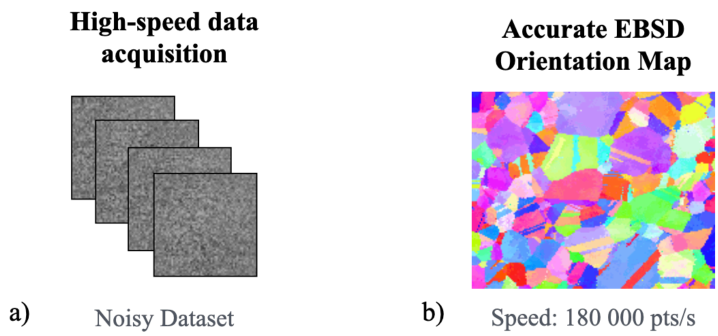

Figure 2: a) Raw and noisy EBSD patterns; b) Accurate EBSD orientation map.

3. **Clifford Torus for Orientation/Disorientation Visualization**: By mapping orientations onto a 2D square torus (ST), these methods provide intuitive, real-time analysis of texture evolution and grain boundary misorientations in single- and multiphase materials [7], [8]. Subtle orientation correlations that might otherwise be overlooked become readily apparent, further enhancing EBSD's analytical capabilities.

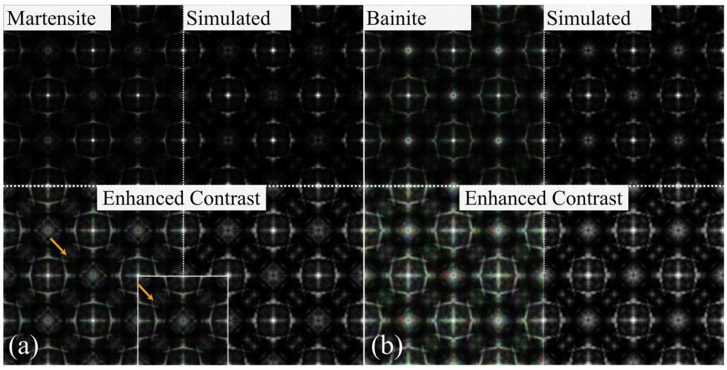

Figure 3: a) (upper-left half) ST map for the experimental Martensite dataset; (upper-right half) simulated ST map; (bottom) contrast enhanced versions; (b) (upper-left half) ST map for the experimental Bainite dataset; (upper-right half) simulated ST map; (bottom) contrast enhanced versions.

Taken together, these innovations—when combined with the latest mechanical and temperature in situ stage loader developments—could potentially broaden EBSD's applicability to more complex microstructural analyses. In principle, this integrated approach might allow researchers to achieve near real-time insights into texture evolution and disorientation dynamics during phase transformations, even under demanding experimental conditions.

References

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