IQ-X: Reference-Based Assessment of AFM Image Quality Using SEM

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Abstract

AFM image quality is often affected by instrument-specific artifacts such as tip convolution, blur, and feedback instabilities, which can evolve during extended measurements. Disentangling these effects from true sample morphology remains challenging. We present **IQ-X**, a reference-based framework that assesses AFM image degradation using SEM as a non-contact stability baseline. IQ-X employs physically interpretable image descriptors and defines AFM degradation as a standardized deviation from paired SEM metrics. Applied to a time-ordered AFM–SEM dataset, IQ-X reveals that AFM image degradation is dominated by resolution-related effects, while double-tip and feedback artifacts remain stable.

1. Introduction

AFM provides high-resolution surface characterization but is sensitive to probe condition and feedback dynamics. Common image metrics often conflate instrument artifacts with genuine morphology, limiting their diagnostic value. SEM, which does not rely on a physical probe, offers a stable reference when imaging the same region. IQ-X leverages this complementary modality to provide a transparent, reference-based assessment of AFM image quality.

2. Methods

IQ-X computes a set of artifact-aware image descriptors sensitive to distinct degradation mechanisms. Blur and resolution loss are captured using frequency-domain and gradient-based metrics, including high-frequency power ratio, gradient energy, Laplacian energy, and autocorrelation-based correlation length.[1-2] Double-tip artifacts are probed using autocorrelation side-peaks, while feedback instabilities are assessed through scan-axis anisotropy and line-wise intensity variations.

All descriptors are computed for both AFM and SEM images. SEM is treated as a stability reference and is not assigned a degradation score. AFM degradation is defined as the standardized deviation of AFM metrics from their paired SEM counterparts, scaled by the SEM variability. A single AFM degradation score is obtained by aggregating these standardized residuals.

3. Results

Across the dataset, SEM metrics remain comparatively stable, indicating minimal sample-driven or contrast-induced variability. In contrast, AFM exhibits coherent temporal trends primarily in blur-sensitive descriptors, while double-tip and feedback-related metrics remain largely unchanged. Principal Component Analysis of AFM–SEM residuals shows that most variance is captured by a single dominant mode, indicating that AFM degradation is low-dimensional and systematic rather than random.

4. Conclusions

IQ-X provides a simple, interpretable framework for diagnosing AFM image degradation using SEM as a reference. By focusing on physically motivated descriptors and relative deviations rather than absolute thresholds, IQ-X identifies resolution-related degradation as the dominant mechanism in the studied dataset. The approach is general and can be extended to other multimodal microscopy workflows for instrument health monitoring.

References

[1] Villarrubia, J. S. (1997). Algorithms for scanned probe microscope image simulation, surface reconstruction, and tip estimation. *Journal of research of the National Institute of Standards and Technology*, *102*(4), 425.

[2] Gonzalez, Rafael C. Digital image processing. Pearson education india, 2009.