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Technology Offer

Electron Microscopy: Deep Learning-Based Autofocus and Astigmatism Correction

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Abstract

This invention presents a novel AI-based method for optimizing imaging settings in electron microscopy, specifically targeting autofocus and astigmatism correction. By applying deep learning, the system rapidly estimates and adjusts key imaging parameters in real time, significantly enhancing both image quality and efficiency. Unlike traditional physics-based approaches, this method generalizes well across different microscopes and configurations. It operates using pairs of images with known deviations around a current setting, enabling autonomous correction without intricate modeling. The result is a fast, robust, and scalable solution for high-throughput and precision electron microscopy. This technology is ideal for researchers and facilities aiming to streamline imaging workflows while maintaining exceptional image fidelity.

Background

Modern electron microscopy demands high precision in focusing and astigmatism correction due to increased resolution and sample complexity. Existing automatic methods often rely on mathematical models of specific microscopes, requiring deep domain knowledge and extensive computation. These limitations make them slow and inflexible, especially when imaging large or diverse samples. Furthermore, their lack of general applicability hinders broader adoption. As imaging needs scale in terms of both volume and precision, a universally adaptable and efficient optimization tool becomes essential. The present invention addresses these shortcomings with a data-driven, learning-based solution that performs fast, accurate adjustments across multiple setups.

Technology

The invention introduces a deep learning-based method for the automatic adjustment of imaging parameters in electron microscopy, specifically focusing on working distance and astigmatism correction. The core innovation lies in replacing traditional model-based optimization routines with a data-driven approach that is fast, generalizable, and easy to integrate.

In the optimization process, two images are acquired from the microscope with known perturbations applied to the current suboptimal settings. These image pairs are divided into multiple subregions (patches), which are then processed by a convolutional neural network trained to estimate correction values for each image patch. The network outputs predicted adjustments for the working distance and both x- and y-components of astigmatism. These individual predictions are then aggregated to calculate a single, robust correction vector for the overall image.

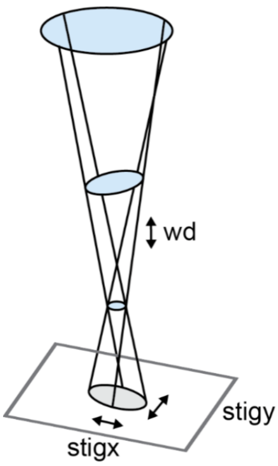

Figure 1: Visualization of key electron microscopy parameters: working distance (wd) controls focus depth, while stigx and stigy correct horizontal and vertical astigmatism to improve image sharpness.

After applying the calculated correction, a new image is taken, and the process is repeated until optimal image quality is achieved - typically within three iterations. The system requires only standard computational hardware (CPU with memory), making it suitable for integration into existing microscopy platforms.

The method is adaptable to different microscopes and imaging tasks, and its modular structure allows for the inclusion of additional adjustable parameters. It enables real-time, automated optimization with minimal user intervention and high reproducibility across diverse imaging conditions.

Max-Planck-Innovation GmbH
Arnulfstr. 58
80335 München
www.max-planck-innovation.de

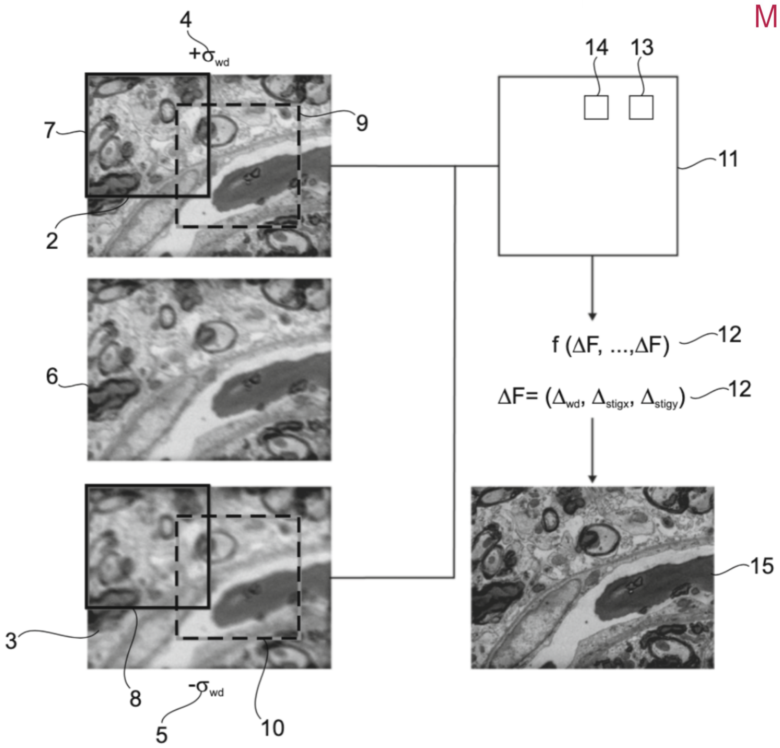

Figure 2: Workflow of the AI-based autofocus method: Two perturbed images (2, 3) with known deviations in working distance are compared to the flawed image (6). Corresponding patches (7/8 and 9/10) are analyzed by the processing unit (11), which predicts corrections (12) for focus and astigmatism. The optimized settings result in an improved image (15).

Advantages

- **Ready-to-use solution**: Easily integrates into existing microscope systems without hardware changes.
- **Single environment-specific training**: One-time training adapts the AI to specific microscope setups.
- **Wide compatibility**: Works across different microscope types, models, and parameter sets.
- **Fast and efficient**: Provides reliable correction results within just a few iterations and minimal processing time.
- **Scalable and flexible**: Accuracy and scope can be extended by adjusting input image volume or applying the method to additional imaging parameters.
- **Minimal user input**: Once trained, the system operates autonomously, reducing operator workload.

Potential applications

- **Scanning Electron Microscopy (SEM)**: Improves focus and distortion correction in standard SEM applications.
- **High-dose imaging**: Maintains focus precision under strong electron beam conditions.
- **Automated 2D/3D imaging**: Integrates into high-throughput and robotic acquisition pipelines.
- **Large-sample imaging**: Optimizes focus and astigmatism in wide-field or high-content microscopy.
- **Precision research and diagnostics**: Useful in disciplines requiring sharp, consistent image quality, such as materials science or biomedical research.

Patent Information

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Contact

Dr. Bernd Ctortecka

Senior Patent- & License Manager, Physicist
Phone: +49 (0)89 / 29 09 19 – 20
eMail: ctortecka@max-planck-innovation.de

Max-Planck-Innovation GmbH
Arnulfstr. 58
80335 München
www.max-planck-innovation.de