Application of reinforcement learning to aid the alignment of an electron microscope

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Background incl. aims

In both SEM and TEM, the alignment process for each experiment is unique and not replicable. If not done well this also has major implications on the stability of the experiments and the quality of the obtained data regardless of the specimen or sampling technique. It requires days of diligent practice on a variety of electron microscopes in order to become an expert and be able to collect data with the highest possible resolution consistently across experiments.

A proposed solution to this skill barrier is a digital twin for an electron microscope, with the purpose being to make experiments more reproducible, efficient and improving the overall reliability and resilience of experiments [1]. The initial steps in this is to automate the alignment process, starting with the eucentric height using machine learning (ML) techniques.

Methods

The proposed method for finding the optimal eucentric height is reinforcement learning (RL), a subset of ML where an agent learns how to interact with an environment in order to make decisions. Using a q-learning function and a reward function the agent is able to determine the optimal action in order to achieve the correct z-height. For training an agent on images at different z-heights learning a q-table is sufficient due to the small and finite action space. However, for applications on a microscope, a deep-q-network (DQN) is required, which instead of knowing the possible rewards from a trained q-table estimates the rewards and works for larger action spaces [2].

Results

Initial tests on a small state space where the environment is defined as images taken at different z-heights with intervals of 2µm ranging from 0µm to 50µm (including the eucentric height), show that the agent is able to learn a q-table within 10000 iterations. With this initialized q-table the agent is able to find the image that was taken at the eucentric height instantaneously.

Conclusion
Preliminary tests indicate that reinforcement learning holds promise as a viable solution for automating the alignment process of an EM, potentially reducing the expertise needed to conduct experiments effectively and accurately.

Graphic:

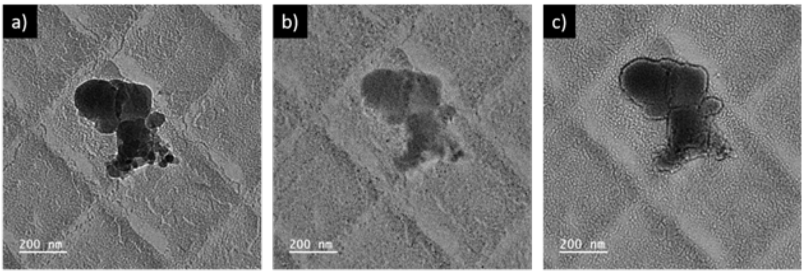

Figure 1. Images taken at different z-heights in order to facilitate the training of a RL agent. (a) 0µm, (b) 26µm and (c) 50µm.

Keywords:

Digital Twin, Reinforcement Learning, Deep-Q-Network

Reference:

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2. Mnih, Volodymyr, et al. "Playing atari with deep reinforcement learning." arXiv preprint arXiv:1312.5602 (2013).