Machine Learning for Rapid Defect Quantification in Static and Dynamic Electron Microscopy Experiments

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Electron microscopy has been one of the hallmark techniques for observing and quantifying the microstructure of materials, including irradiated nuclear materials. From its conception, microscopists have dreamed of method(s) to automatically quantify features in their images but factors such as computational power and need for user interaction has prevented such a tool to fully materialize. Recent advances in computer hardware and machine learning algorithms for image feature detection have now made automatic feature detection in electron microscopy images possible. In this work, we will demonstrate the application of machine learning for rapid defect detection in both static, ex-situ images as well as dynamic, in-situ videos with a specific focus on quantifying dislocation loops in irradiated FeCrAl alloys. Specially, two frameworks will be demonstrated, the Faster R Convolution Neural Network (Faster R-CNN) detection system for static image inputs and the You Only Look Once (YOLO) real-time object detection system for video processing and quantification. We will show that the performance of the deployed frameworks is comparable to human analysis even when using relatively small training datasets. Furthermore, we will show that the machine learning frameworks are flexible and capable of detecting and categorizing different features (e.g. loop types) within the same image. The demonstration will show that the microscopists dream is now a viable reality with the proposed methods being readily scalable techniques for rapid, repeatable, and robust analysis of electron microscopy images.