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UTILE: A Deep Learning-Driven Imaging Journey Across Dimensions

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Bridging the gap between the novel advancements in deep learning and computer vision and the pressing challenges in energy materials research is as crucial as the individual pursuits in both domains. Particularly relevant are those innovative techniques in energy materials characterization, where rapid progress is essential to address the current global energy challenges. In the "UTILE: Autonomous Image Analysis of Energy Materials" project, we focused on automating the analysis of images related to energy materials using deep learning approaches to accelerate and enhance the work of experimentalists in these specialized fields. This work presents three distinct use-cases, each with a tool developed to process images, segment regions of interest, extract features from segmentation maps, and visualize the outcomes.

The exploration begins with autonomous 2D Transmission Electron Microscopy (TEM) image analysis for the size and shape assessment of Platinum nanoparticles on Carbon supports, aimed at investigating polymer electrolyte membrane fuel cells (PEMFC). [1,2] Next, we introduce a temporal dimension, developing a tool for detecting oxygen bubbles in optical videos from polymer electrolyte water electrolysers (PEMWE). This tool facilitates time-resolved analysis of bubble dynamics in the water electrolyser's flow field. [3] The final stage of our journey incorporates space as the third dimension, enabling 3D analysis of hydrogen bubbles within vanadium redox flow batteries using synchrotron X-ray tomographs. This software provides swift and reliable analysis of bubble size, shape, and distribution, coupled with 3D visualization and advanced characterization features. [4]

[1] André Colliard-Granero et al., "Deep learning for the automation of particle analysis in catalyst layers for polymer electrolyte fuel cells,"Nanoscale, vol. 14, no. 1, pp. 10–18.

[2] André Colliard-Granero et al., "UTILE-Gen: Automated Image Analysis in Nanoscience Using Synthetic Dataset Generator and Deep Learning,"ACS Nanoscience Au, vol. 3, no. 5, pp. 398–407

[3] André Colliard-Granero et al., "Deep Learning-Enhanced Characterization of Bubble Dynamics in Proton Exchange Membrane Water Electrolyzers,"Physical Chemistry Chemical Physics, 2024, Accepted Manuscript. DOI: https://doi.org/10.1039/D3CP05869G

[4] André Colliard-Granero et al., "Deep Learning for Autonomous 3D Bubble Analysis of Vanadium Flow Batteries from Synchrotron X-ray Imaging,"under preparation.

Primary author: COLLIARD, Andre (IEK-13 FZJ)

Presenter: COLLIARD, Andre (IEK-13 FZJ)

Session Classification: Thematic Session: Data Acquisiton / Image Format - part III

Track Classification: Data Acquisition & Image Formation (focus on real-time imaging): Thematic focus: Data Acquisition & Image Formation