

Automated Spectrum Imaging Using Hybridized DMScript and Python Code in DigitalMicrograph

Liam Spillane^{1*} and Bernhard Schaffer¹

¹ Gatan Inc., Pleasanton, CA.

* Corresponding author: liam.spillane@ametec.com

Spectrum imaging (SI) in the (scanning) transmission electron microscope ((S)TEM) is well established as a powerful acquisition method for acquiring spatially resolved electron-energy loss spectroscopy (EELS), energy-dispersive x-ray (EDX), and/or crystallographic data (4DSTEM) at sub-nm spatial resolution. Target SI regions of interest are selected manually during a given experiment, with acquisition areas typically defined as: rectangular 2D arrays, line profiles, or arrays of points (multipoint). This manual workflow is well suited to small sample areas ($< 1 \text{ um}^2$) but becomes impractical for surveying ultra large sample areas at high spatial resolution, particularly where regions of interest are relatively sparse or irregular in the overall survey area.

Gatan DigitalMicrograph has longstanding and mature capability for customized data acquisition via scripting [1]. Imaging filter, spectrometer, camera and scan control, as well as high level microscope command and control functions are comprehensively supported in the native DMScript language. The recent addition of Python as a supported scripting language in DigitalMicrograph expands this customization capability to include advanced image and data processing methods such as: automatic feature recognition, multivariate analysis, and machine learning. A vast number of Python libraries are freely available, and the agile nature in which they are updated and created makes Python scripting a highly compelling addition to DMScript.

Here, we demonstrate a hybrid scripting approach where DMScript and Python code are combined in a modular and customizable framework, providing a workflow for automated acquisition of spectrum images as summarized in figure 1. A STEM survey image is acquired and passed to Python as a NumPy array for processing. Image analysis performed in Python is then used to define SI acquisition parameters such as the SI region, or regions of interest for data acquisition. A multipoint acquisition example from a semiconductor device is shown in figure 2. In this case, an ADF image was acquired which was then analyzed using the scikit-image Python library to automatically identify the edge of a tungsten plug in the device. SI acquisition points were defined around the plug boundary and the SI data acquisition launched, all within the hybrid script. This selective assignment of data acquisition points is highly compact in comparison to a large 2D array, both in terms of overall acquisition time and dataset size.

In addition to multipoint SI acquisition, automated line profile and 2D array SI examples are explored. Further application examples utilizing automated stage movement and autofocus are also presented. All scripts used will be made available as templates for modification, freely available on the Gatan website.

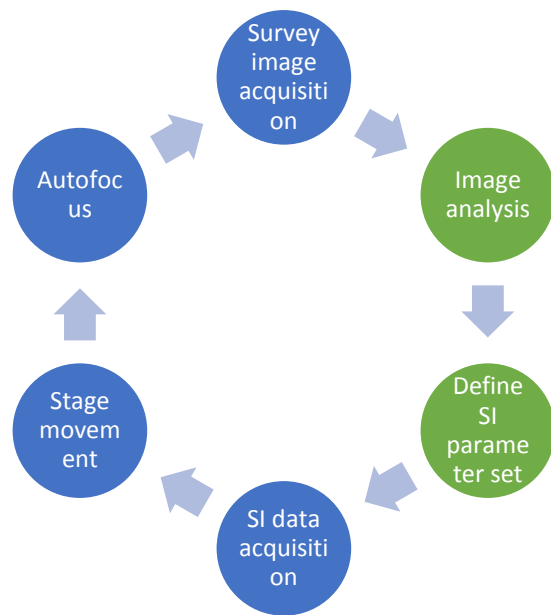


Figure 1. Schematic showing acquisition and processing steps in hybrid script SI acquisition framework. DMScript steps are shown in blue and Python script steps are shown in green. Stage movement and autofocus steps are optional.

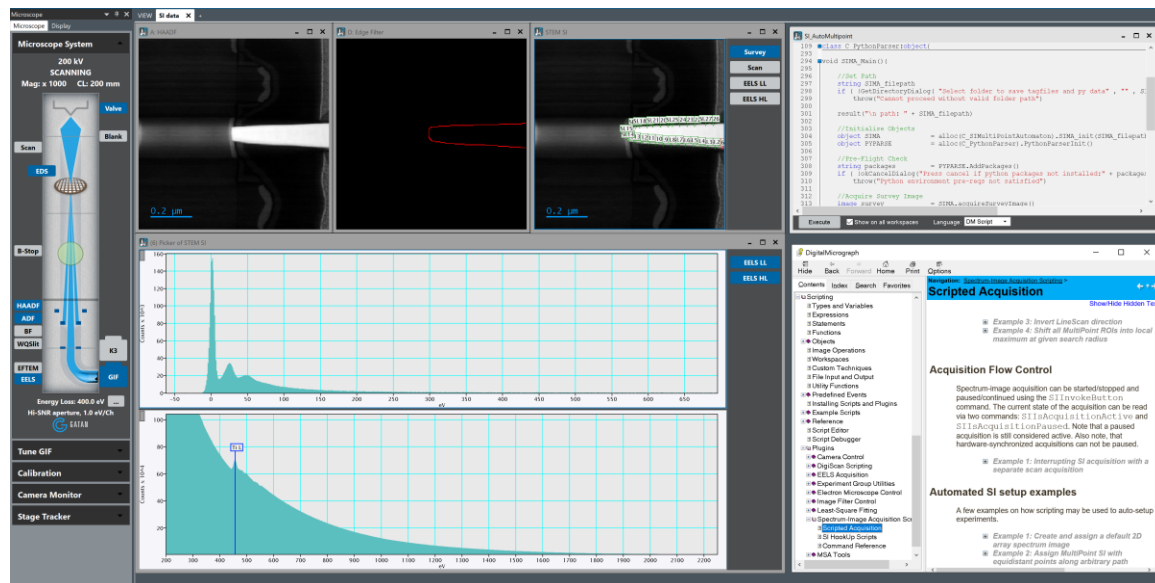


Figure 2. DigitalMicrograph screenshot showing full output from a custom multipoint SI acquisition launched using a hybrid script. Raw HAADF image (A), edge filter image (D) and STEM SI showing the multipoint acquisition points are shown. Dual-EELSTM spectra summed from all acquisition points are also shown, in addition to the SI_AutoMultipoint hybrid script.

References:

[1] B Schaffer in “Transmission Electron Microscopy Diffraction, Imaging, and Spectrometry”, ed. CB Carter and DB Williams, (Springer International Publishing) p. 167.