Paper Title: Interactive Measurements of Terabyte-sized SEM-EDS Images

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As one part of a cultural heritage study, an artifact from Peru (Moche Cast figure) was imaged by a scanning electron microscope with energy-dispersive X-ray spectrometry (SEM-EDS) [1]. Figure 1 (left) shows the front and back views of the artifact. The scanning process yielded a 3D volume with about 236 billion pixels. The 3D dimensions are 11,520 x 9,984 x 2048 pixels with 16 bits per pixel. The dimensions correspond to spatial 11,520 x 9,984 measurements (x-y frames) over a range of 2048 electron energies. Each pixel corresponds to 0.9 micrometers in x and y dimensions, and the acquisition of all pixels took 51.2 hours. Given this 3D volume, the problem arises in performing interactive exploratory measurements of the Moche artifact. In particularly, material scientists need to match peaks along the electron energy dimensions to material elements and to determine the presence or absence of them at any spatial location based on the front (x-y) and side (x-energy) views of this 3D volume.

We addressed the problem of interactive measurements of terabyte-sized SEM-EDS images by extending the Deep Zoom approach for large 2D images. The Deep Zoom approach is based on the multi-resolution pyramid representation of a 2D image with large pixel counts (e.g., gigapixels and more) for the efficient transmission and viewing of images [2]. The initial 2D support was extended to 3D for medical image volumes [3] and to other informative visualizations [4] with an open source project leading to many additional functionalities (see the OpenSeaDragon project [5]). We leveraged the OpenSeaDragon project [5] for building functionality plug-ins. We focused on enabling interactive visual inspections and measurements by supporting visualization of terabyte-sized 3D volumes, performing off-line re-projections and providing on-demand scale and energy lines via a scale bar and information overlays. In order to allow further processing and exploration of smaller subsets of terabyte-sized 3D volumes, we added sampling capabilities executed either on a client (browser) or server side that includes a file with provenance information about the sampled data set.

In our experiments, we created pyramid representations of the Moche 3D volume that include x-y and re-projected x-energy views of the volume as illustrated in Figure 1 (right). The pyramid set representation corresponding to the x-y view consists of 4,890,627 input pyramid files in 32,768 folders. The pyramid set for the x-electron energy view is composed of 4,976,641 output pyramid files in 184,320 folders. Figure 2 shows some of the interactive functionalities

accessible in a browser for the x-energy view point. The current capabilities have been deployed at NIST at http://vote-testing.nist.gov/moche/microscopeWebVisualization.html.

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Disclaimer

Commercial products are identified in this document in order to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the products identified are necessarily the best available for the purpose.

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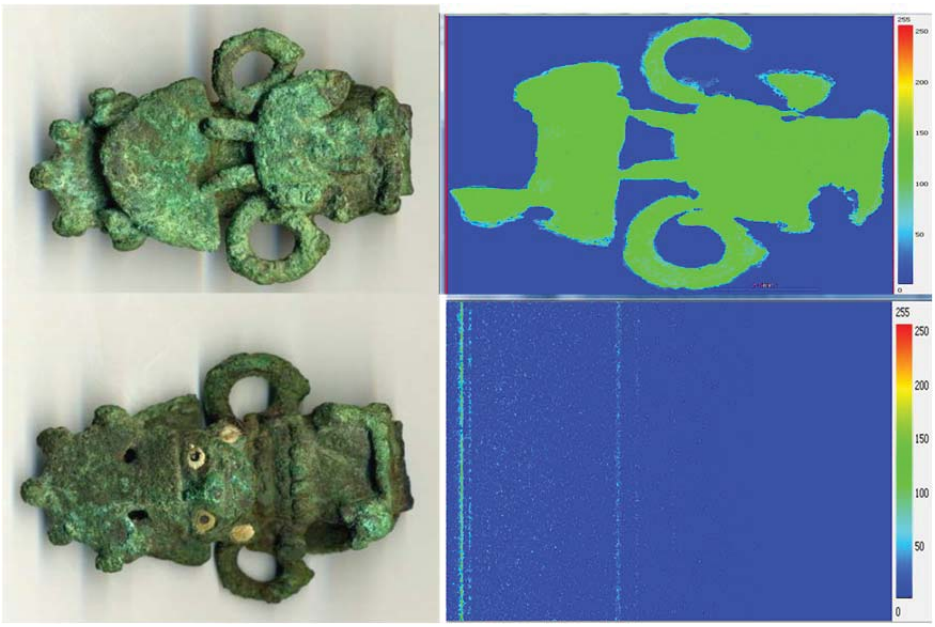

Figure 1. Left – Front and back views of the Moche Cast Figure. Right - Spatial X-Y view (top) and X-Energy view (bottom) of Moche imaged by SEM-EDS. The 3D volume contains 2048 spectral frames with spatial dimensions of 11,520 x 9,984 pixels per frame.

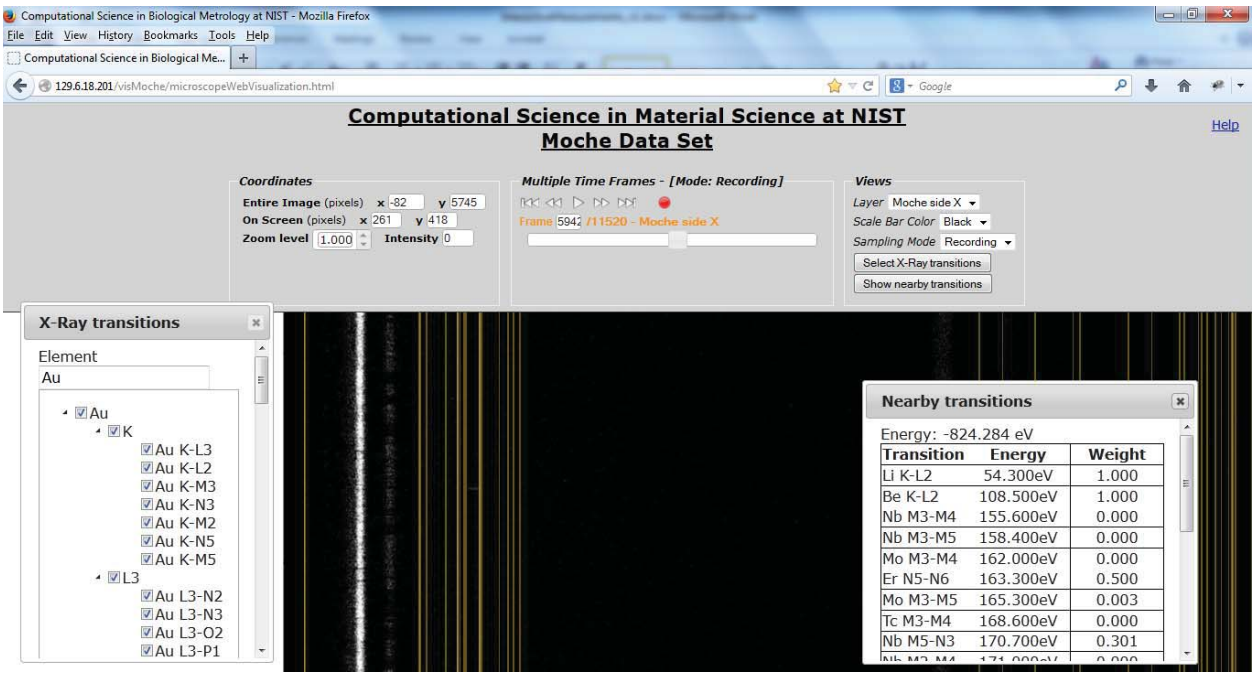

Figure 2. The side X-Energy view of Moche 3D volume in a browser with the element selection dialog (bottom left) and the nearby element transition dialog (bottom right).