Problem Statement and Goals
ImgBeamer

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Table 1: Revision History

Date	Developer(s)	Change
2023/01/20	Joachim de Fourestier	First version

1 Problem Statement

1.1 Problem

In the realm of Electron Microscopy (EM), or even images in general, there is a common misconception that a sharper image is generally more desirable or better because it gives the impression of better "resolution" or *clarity*. However, that is not always the case.

The concern is with the perceived image *quality* and sampling, not resolution. Resolution can be defined as the minimum distance by which two points can be distinguished, known as the Rayleigh criterion [1].The meaning of the term "image resolution" can be ambiguous since there are many "types" of image resolutions. The main two types of concern are spatial resolution and pixel resolution (or pixel count). Spatial resolution of an imagepertains to the actual physical dimensions of an image where the size of the pixels can be expressed in physical units such as micrometers or nanometers. Conversely, "image resolution" may be used to simply express the "image size" (such width and height) in terms of *virtual* units (e.g., number of "pixels").

Images in an SEM are produced using electron optics where electromagnetism is used to deflect and focus a very fine and continuous beam of electrons (producedby an electron gun) within a vacuum chamber over a sample surface. This electronbeam is then *raster scanned* over discrete locations on the surface and interacts with a volume within the sample (called interaction volume)[2]. From this interaction volume, different types of radiation are generated, such as Backscattered Electrons (BSE) and Secondary Electrons (SEs). Based on the electron beam's energy and the sample nature, the interaction volume may grow larger or smaller depending how much the electrons scatter. Detectors

then collect the electrons and convert them into *signals* based on their energy and count. That said, "extra" electrons (of generally lower energy) may be produced by cascading interactions as they scatter around against the sample, the chamberwalls, the sample stage, and other apparatus leading to *noise*.

The resolution of a Scanning Electron Microscope (SEM) can be improved by aberration corrections and other advanced techniques [4]. Besidesaberrations and many other factors, the resolution and quality of an SEM image is inherently limited by the beam spot size, the interaction volume, and the Signal-to-Noise Ratio (SNR). There is a general inverse relationship between resolution and SNR. For example, an image with a finer beam will produce an image of higher resolution but will have less signal resulting in a noisier image (low SNR). An image with a larger beam diameter will result in more signal(higher SNR), but this image will be of lower resolution [3].

Apart from resolution, the sampling pattern also affects the image quality. Eachdiscrete location over which the beam scans, the spot profile (size and shape ofbeam) with respect to the pixel size (discrete location with the raster grid) may overlap already covered areas of the sample as it travels between each discrete location. This may result in over-sampling, producing a blurrier image.If the spot is too small, there is little or no overlap, the sample is under-sampled and the resulting image may look sharper (or sometimes more pixelated), but there can be a significant loss of information. Some may want tounder-sample to make the image to make it look sharper, but this may lead to a loss of information.

The quality and information content of an image is important because the lack of it may ultimately lead to misinterpretation or flawed research.

1.2 Inputs and Outputs

1.2.1 Inputs

The inputs will be given or preloaded images (representing sample surface groundtruth), the spot profile (shape and relative size with respect to the output pixel or cell size), the raster grid parameters (split the image into how many cells or pixels, i.e., rows and columns), and optional subregion of the full image.

1.2.2 Outputs

The outputs will be two generated images from resampling based the given image and parameters: a subregion preview and the resampled full image.

1.3 Stakeholders

The stakeholder or interested parties may include students, professors, and researchers that are involved with SEM. This may include disciplines such as materials science, biology, geology, and semiconductors.

1.4 Environment

Web-based (Cross platform i.e., Windows, Linux, or Mac) on any modern laptop or desktop computer.

2 Goals

- Easy-to-use (for anyone with basic EM knowledge) and accessible (no installer or initial setup needed) tool to help understand the interplay between
  - Imaging parameters: spot size, shape, overlap, pixel size, and resolution (pixel count).
  - Information content (type of image, e.g., grayscale, brightness and contrast, bit depth)
- Show how (relatively) the spot profile (size and shape) vs. pixel size can affect the resulting image.
  - This could be used to simulate defocus and astigmatism.
- Better elucidate the issue of oversampling vs. undersampling, similarly tothe Nyquist sampling rate where:
  - Undersampling may lead to missed or last information.
  - Oversampling may lead to over-averaging or obscuring information.
- Different spot profiles
  - Intensities
    - Uniform / Flat distribution
    - Normal / Gaussian distribution
  - Shapes and size
    - Circle
    - Ellipse

3 Stretch Goals

- Concept of scale in physical units (e.g., mm, µm, nm)
- Support multiple channels simultaneously, such both an image for BSE and SE signals.
- Additional spot shapes
  - Rings

  - Halo shaped beam with "bright" middle

- Simulate simplified physics of sample and beam interactions.
  - Simulate basic noise or SNR.
  - Charging effects
  - Sample topography and "Edge effect" from SEs
  - Different classes or nature of samples, e.g., alloys, polymers, resin-embedded bacteria, integrated circuits

References

[1] A. M. Blackburn and T. Sasaki. Particle diameter, signal-to-noise ratio and beam requirements for extended Rayleigh resolution measurements in the scanning electron microscope. *Microscopy*, 69(4):248–257, 04 2020.

[2] J. I. Goldstein, D. E. Newbury, J. R. Michael, N. W. M. Ritchie, J. H. J. Scott, and D. C. Joy. Image Formation. In *Scanning Electron Microscopy and X-Ray Microanalysis*, pages 93–110. Springer, New York, NY, 2018.

[3] JEOL. Scanning Electron Microscope A To Z. page 32, 2013.

[4] D. C. Joy. The aberration corrected sem. *AIP Conference Proceedings*, 788(1):535–542, 2005.