Microsc. Microanal. 28 (Suppl 1), 2022
doi:10.1017/S1431927622008443

Digital Image Processing in C++ in SEM Images

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Scanning Electron Microscopy (SEM) produces digital images in gray scales. They are represented by elements that belong to a matrix of size A_{MXN}. Grouping this set of elements will give rise to a digital gray image. The size of the digital image can be calculated from the number of horizontal and vertical elements of the grayscale image matrix, it is normally in Megapixels (MP). Each element of the matrix is known as a pixel i.e., the minimum unit of a digital image. Each pixel can have an 8-bit value where values can be represented within the range of 0 to 256 i.e., the grayscale. The human eye is capable to distinguish only 16 shades of gray. Thus, it is proposed to process the image from gray scale to color (RGB) by means of a C++ program. This involves a minimum of computer resources when executing the program with the advantage of having a color image, where a more exhaustive analysis can be developed [1].

Digital images are composed of a mathematical matrix containing A_{mn} elements with values as integers within the range of 0 to 255 (8 bits). They will represent a tone that goes from black (0) to white (255) i.e., a pixel. The resolution of an image will depend on the number of elements that the A_{MN} matrix contains, by having a smaller number of elements it will have a reduced resolution, on the other hand if the number of elements is large enough it will have a better resolution. Additionally, the color within an image is represented by 3 layers which are RGB (Red, Green and Blue) which each layer is represented by 8-bit values on the scale from 0 to 255. The intensities of each layer will depend on the number assigned from 0 to 255 and by modifying the value of each layer, a new hue or color can be developed [2].

There is a mixture of colors that are more sensitive to the human eye within the range of colors generated in the RGB layers. Green is the most and blue and red the least sensitive colors to the eye. Image processing is already commercially available, but it requires the use of high-performance equipment and a software license that normally involves a high cost. The present investigation directed towards a low-cost software but still capable of optimizing the available computing resources. The images obtained in the scanning electron microscope are represented by a shade of gray scale, usually being 8-bit images, but there is the problem that the human eye only can distinguish only 16 shades, making it complicated [3].

Figure 1a shows an SEM image, it is in the usual grayscale. This image shows contrast differences that can be related to differences in the sample topography. Nevertheless, the contrast differences are sometimes rather small because of the proximity of the grayscale values. Thus, the topography becomes more difficult to appreciate. Figure 1b sows the same images but after the here proposed digital image processing. The topography appears to be clearer. The choice in this case can be summarized as two shades of colors. On one hand green is used for the weakest electron detection and blue is representing the highest electron rate arriving to the detector. The color difference presents the topography in a higher contrast and tends to show a tridimensional type of image.

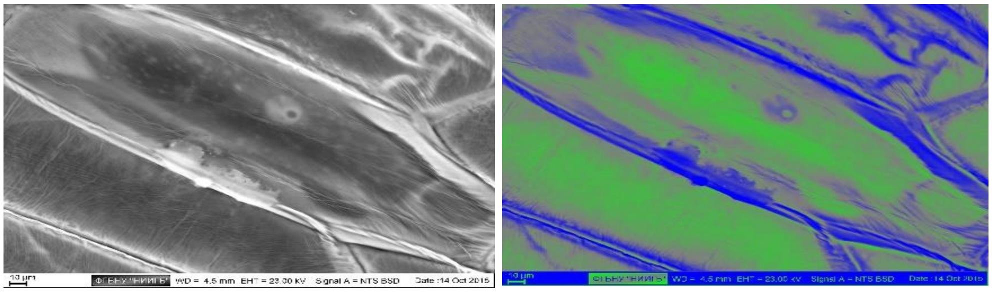

Figure 1. Scanning electron microscopy image. The topography in the gray scale image (a) is better presented in the color processed image (b). Processing of the image is done by using sensitive colors for the human eye, for example green. The result is an improved perception of the contrast and a 3D effect.

Figure 2a shows an SEM image in the usual grayscale. Three different color shades are used to develop Figs 2b-d. Depending upon the color range, the image acquires different characteristics. But in all of them there is emphasis in the resolution among the different parts of the image. Clearly Fig 2d gives a better visualization of the topography of the analyzed sample. As a future development of this work, the processing of the image will have a broader template of colors in order to achieve a more defined topography.

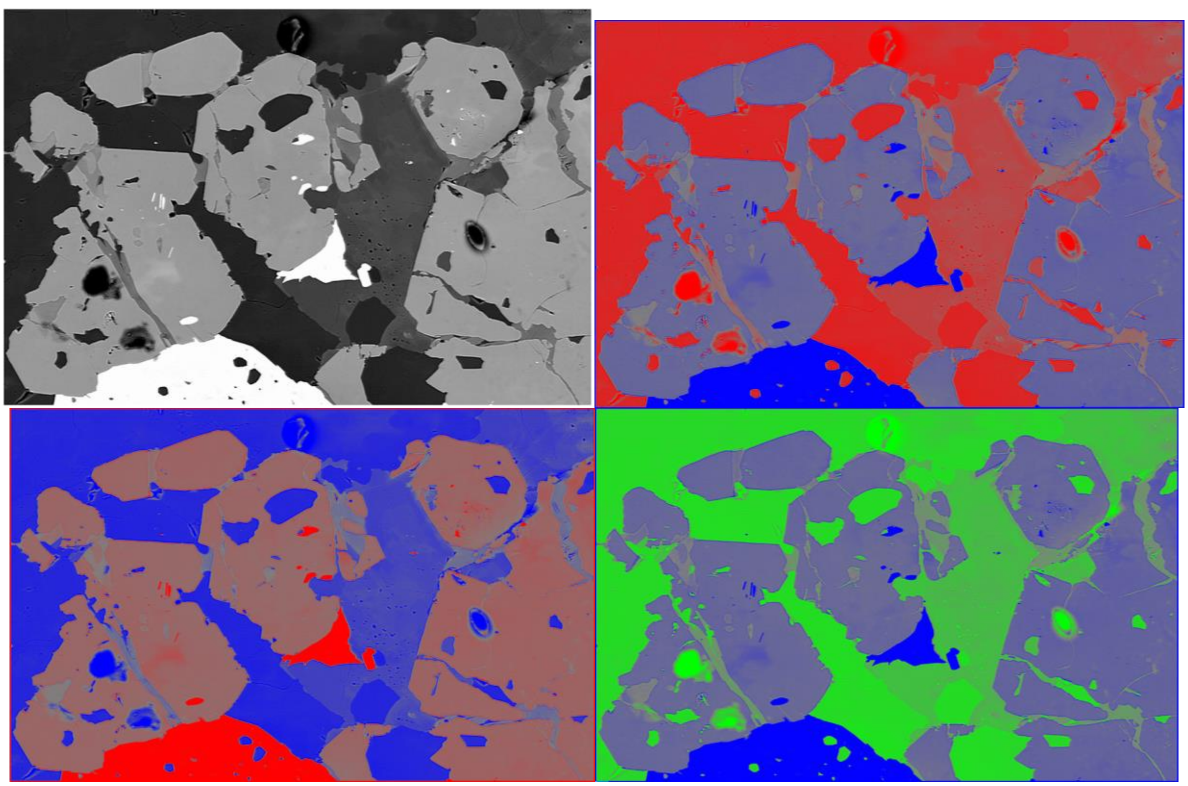

Figure 2. (a) Scanning electron microscopy image in gray scale, the image is processed with different shades of colors from the least sensitive for blue and red eyes (b, c) to the green color (d) that is the most sensitive.

https://doi.org/10.1017/S1431927622008443 Published online by Cambridge University Press

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