Determining optimum red filter slide distance on creating 3D electron microscope images using anaglyph method

W P Tresna and Isnaeni
Research Center for Physics - Indonesian Institute of Sciences, Bld 442 Puspiptek Area, South Tangerang 15314 Indonesia

Email: wild005@lipi.go.id

Abstract. Scanning Electron Microscope (SEM) is a proven instrument for analyzing material in which a 2D image of an object is produced. However, the optimization of a 3D image in the SEM system is usually difficult and costly. There is a simple method to produce a 3D image by using two light sources with a red and a blue filter combined in a certain angle. In this experiment, the authors conducted a simulation of the 3D image formation using an anaglyph method by finding the optimum point of shifting the red and blue filters in an SEM image. The method used in this experiment was an image processing that employed a digital manipulation on a certain deviation distance of the central point of the main object. The simulation result of an SEM image with a magnification of 5000 times showed an optimal 3D effect that was achieved when the red filter was shifted by 1 μm to the right and the blue filter was shifted by 1 μm to the left from the central position. The result of this simulation can be used to understand better the viewing angle and the optimal position of the two light sources, i.e. red and blue filter pairs. The produced 3D image can be clearly seen using 3D glasses.

1. Introduction
An understanding of dimensions will always be associated to field or space. One-dimension (1D) is defined as a point or a line, two-dimension (2D) is defined as the plane of a space and three-dimension (3D) is defined as 3-dimensional space in the vector called x, y, and z. In the case of visual 3D images, it can be produced from modified 2D images with the help of 3D effect software. 3D effect has been used to provide better understanding and view of an image that is seen by eyes. In the world of visualization, the major factor in determining the quality of the 3D image is the logic of the eyes, and this could be pragmatic and subjective from the perspective of the viewers. Although the language of logic in the eye can be translated into real numbers regarding the description of the image, but sometimes tastes and feeling become dominant factors in the industrial market. Simulation of 3D effect with a software is the first step in creating a 3D effect by adjusting and manipulating the position of the light sources [1, 2]. This method can also be applied to microscope, SEM or visual entertainment images.

Some 3D images can be generated using two cameras at a certain position and tilting angle. However, the main problem in producing 3D images from SEM images is to determine the position of proper light sources, which corresponds to the red and blue filter light sources [3, 4]. 3D image produced from SEM images should have illusion effect that shows depth and sharpness of every object and point in the image, so that it will give the impression of parallel horizontal position difference with...
The aim of this paper is to suggest a variety of new ways in which anaglyphs can and should be reproduced to create a full-color-stereo-pair image. In this work, we only use single image to produce 3D image. The degree of light source angle in digital manipulation can produce a new perspective of 3D image. Below are a brief description related to 3D image production. Some part of this description will be utilized to generate 3D image from an SEM image.

Digital image capturing process, to produce 3D images, usually requires dual camera rigs. There are two methods regarding dual camera rig, i.e. side-by-side method and mirror rig method. In the side-by-side method, two identical cameras are placed side by side to capture the same object. In the mirror rig method, a camera with a mirror as a splitter is used to produce two shifted images. The problem in side-by-side method is that the interocular or interaxial (distance parallel perspective of two lenses of the two cameras) are not small enough for close-up shots [5]. As a result, the images will be distorted on the sides lengthwise. Meanwhile in the method of mirror rig, it usually tackles the problem above successfully, however it has other drawbacks, such as polarization, reflectance or reflection on the object. This problem can be corrected using a polarizer filter on the lens that contains reflective layer. As a result, the light that enters the camera will change [5, 6].

In computational photography, deconvolution is commonly used to sharpen a "blurry" image. The key concept is that each pixel in the original image, \( d_i \), has a convolved value:

\[
d_i = \epsilon_i + \sum p_{ij} u_j
\]

where \( \epsilon_i \) is small level of noise, \( u_j \) represents each point in the scene or image, and \( p_{ij} \) is fraction contributed to the images that is determined by the point spread function (PSF). A wide range of deconvolution techniques, largely involving analysis in the frequency domain, are mainly use PSF to determine \( u_j \) values. It is assumed that the PSF is given as a known input; where it is not specified, it is determined automatically as a part of blind deconvolution [7].

A 3D image, if described in a flat plane, will be like the cardinal directions with the center position as the center of interest. In the most image processing software, front position (front), rear (back), right (right) and left (left) are perspectives that can be changed. While the position of the wind amid such as South East (Southeastern), South West (Southwestern), North West (Northwestern) and North East (Northeastern) are very useful to improve the main perspective, as describe in figure 1 [2, 8-10].

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2. Method

In this simulation experiment, the material used was an SEM image of particle sample that contained 72% Fe. It was taken using 5000X magnification in the secondary electron (SE) mode, which focused on the morphological image only. This image was selected because of its clearness, intact and round shape, and there were clear spaces between the main objects (particles) that would make the observation easier. The size scale obtained from 5000X magnification was 10 \( \mu \)m. The SEM image was then processed further using an image processing software. The software used was Photoshop.
CS5 portable with friendly features that are quick and simple, therefore it is easy to use even for a beginner.

The image processing step was started by selecting an SEM image which had simple shape and no extreme shadow. The image was selected based on certain criteria to allow better observation using 3D glasses. Firm image boundary which contains not too many color will provide clearer information to the viewer about the depth of field. An example of SEM image used in this work is shown in figure 2.

![Figure 2](image_url)

**Figure 2.** The original image file which is selected as a sample.

The next step was processing the image using the image processing software in which several processes needed to be carried out, such as shown in figure 3. The first was going through Action section to sharpen the left and right sides of the image. In this technique, one important thing to understand is the proportionality of an image so that an image will always look identical when viewed by the left and right eye. Second, the SEM image underwent Blending process, which was the use of color filters to sharpen the contrast, depending on the image. Some colors are usually avoided, such as bright red, orange, pink and cyan. This is in contrast with the colors that can be received in digital processing such as red, maroon, blue, green, purple and brown organic as well as the most dramatic effect, such as metallic color. Insulation colors can also be done on layer style to produce a monochromic infrared image. Finally, a finishing touch was done by combining the working layers together and export it into psd or jpg format.

![Figure 3](image_url)

**Figure 3.** Isolation color can be done with a layer style.

In 3D image simulation using the anaglyph method, one of the important qualitative parameters to be achieved was the convenience of the viewer's eye when observing the 3D image. The convenience factor includes the maximum power of accommodation, the level of alignment with the horizon as well as the brightness of the image.
3. Result and discussion

The resulting 3D image from this simulation using anaglyph method was obtained from an original image which was duplicated to give red and blue effect. After that, the separation of the two images (red and blue filtered images) became a major factor in creating the 3D image.

Figure 4 shows the SEM image that had been sharpen. In this step, the process of action increased the sharpness of the image, so that the difference between high and horizontal surfaces were more easily observed. Meanwhile, the process of blending in the figure 5(a) and 5(b) was done by adding red filter and blue filter separately. The addition of the red filter reduced other colors but red as shown in figure 5(a), while the addition of blue filter reduced other colors but blue as shown in figure 5(b). Those two figures were almost similar since there was not much color variation in the original image.

![Figure 4](image1.png)

**Figure 4.** Action in the software process increased the sharpness of the image.

![Figure 5](image2.png)

**Figure 5.** Blending process was done by adding (a) red filter and (b) blue filter, separately.

Figure 6 shows red and blue anaglyphs of the color stereo pairs produced by reprocessing them using an algorithm based on color analysis. Analysis was also performed on two images with different shifting position, i.e., 0μm, 1μm, 2μm and 3μm. The image with red-blue shifting position of 0 μm, did not give the impression of 3D anaglyph. Meanwhile, the shifting position of 3 μm generated an extreme image, so that it was uncomfortable for human eyes. Therefore, using anaglyph method, the ideal position was achieved by shifting the red and blue filtered images by 1 μm.

Figure 7 shows the images with shifting distances of 2μm (a) and 3μm (b). The shifting distance between the two images with different filters (i.e., red and blue filters) corresponded to the right eye and the left eye. Largely shifted images made it difficult for human eyes to observe every point in the images as single point. Therefore, creating a 3D image that came from a single image required a digital manipulation, which was done by sliding it towards the opposite side for a few degrees and combining both of the processed images back together.
Figure 6. Anaglyph 3D image when two filtered images were shifted by 1µm.

Figure 7. 3D images with shifting distance of (a) 2 µm and (b) 3 µm.

4. Conclusion

We have managed to create a 3D image using anaglyph method from one original SEM image. The image was duplicated and filtered using red and blue filter. The simulation showed that the optimal 3D effect was achieved when the difference between red and blue filtered images was about 1 µm. The research showed that the 3D image quality was affected by the angle of the filter, the position of the viewer and the polarization. The generated 3D image can be clearly seen using 3D glasses. For further research, it will be useful to apply two light sources (red and blue) on the microscope or SEM to generate anaglyph images.

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