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Edge Detection in Scanning Electron Microscope (SEM) Images using Various Algorithms

G Elizabeth Rani
Department of CSE,
Kalasalingam Academy of Research and Education
Anand Nagar, Krishnankoil, India.
g.elizabeth@klu.ac.in

R Murugeswari
Department of CSE,
Kalasalingam Academy of Research and Education
Anand Nagar, Krishnankoil, India.
r.murugeswari@klu.ac.in

N Rajini
Department of Mechanical Engineering, Kalasalingam Academy of Research and Education,
Anand Nagar, Krishnankoil, India.
rajiniklu@gmail.com

***Abstract*—In Image Processing Edge detection is very important. It is an essential technique to improve image quality in various fields including medical, space, biological materials etc. Images are generally represented by its intensities either in grey scale or in color scale. Scanning Electron microscope providing information about images but during deep analysis, users are not able to analyze the problems such as voids, cracks and fiber pullout. Edge is an important part of the image. The extraction of image should not change any features in extracted images. In our proposed work three algorithms are chosen for edge detection i.e. Sobel, Laplacian and Hough Transform detection algorithm is used to detect the edges and removed noise at the same time in SEM images for both metal and non-metal images. Finally, the comparison was done for these algorithms by using various parameters like the speed of execution, noise removal and accuracy in edge detection. In this paper it is concluded, Laplacian gives better result compared to other detection algorithms in terms of voids, boundary, lines or curves and orientation detection.**

Keywords— edge detection, scanning electron microscopic, Sobel edge detection, Laplacian edge detection, metal and non-metal images.

I. INTRODUCTION

Today, Image Processing is playing a key role in medical science technology and it has taken the field to the next level [1]. It is helpful in diagnostics and interventional treatment for complex diseases and injuries (e.g., interpretation of X-ray images, blood/cellular microscope images). The image processing techniques and algorithms help to identify the symptoms in images at an earlier stage so, it is very safe to patient and cost is low.

In Space science, the image processing and analysis helps in predicting weather, climate and geographic mapping [2]. By using advance automatic images analysis the major disasters can identify previously. For Biological materials, the image processing and analysis helps in structure analysis and future synthesis.

In this paper, the material science field is chosen. Materials are everywhere so it is essential in all the fields. It is applicable in several scientific applications such as space, medical and physical sciences. Edge detection is very important in identifying the information associated in the image [3]. Scanning Electron microscopic (SEM) helps in imaging a material. In metal and non-metal images, the mechanic experts are not able to identify the accurate voids, cracks and fiber pull-out presence. Many edge detection algorithms are available such as Prewitt Operator, Sobel Operator, Robinson Compass Masks, Krisch Compass Masks, Laplacian Operator and canny edge detection [4]. Here three algorithm is used ie. Sobel and Laplacian and Hough Transform detection algorithm. Sobel is a multi-stage algorithm to detect the multiple edges of images and it accepts the gray scale image. Laplacian works better in the following parameters such as noise removal, execution speed and detection of accuracy in edges. It helps in identifying the clear edges of voids or pores, cracks deflection and fiber pullout in both metal and non-metal. The mechanical expertise gets a clear solution of SEM images in an improved manner in detecting voids, boundary, line or curves and orientation. Hough Transform technique is applied to extract different shapes in SEM images such as circle, lines, curves etc. In this paper, three algorithms are compared by using different parameters and also same time mechanical parameters are also compared.

II. BACKGROUND WORK

Ashi Agarwal et al.[5] have evaluated centre detection algorithm is used to detect the edges of optic regions but it is provided with the solution at centre regions but the side of boundary regions is missing. It is not able to identify the true and false edges. Active contour snake based model is used to combine all the points in the boundary line but it is not working as much expected. Qin Zhongynan et al.[6] described that adaptive snake algorithm which is not adjusting the boundaries of neighbourhood and not choosing neighbourhood edges.A greedy algorithm was used but it is not providing a correct solution for each boundary line. M. Benjelloun et al.[7] have mentioned polar signature is not able to apply for a large dataset and at the same time contour edge detection is not working properly. Closed contours detection not separating each vertebra separately. Template matching is missing for each image of contour detection and limits the user to click only one point at the beginning time of the user. Wangmeng Zuo et al.[8] proposed that an automated segmentation algorithm is used to detect the object presence in boundary segmentation but the gradient operator has not detected the edge boundary of the tounge. Edge polar technique missed finding individual boundary segmentation of the tounge. Yang Li et al.[9] described that innovative and contour extraction

algorithm is used the noise removal is not done properly so many true edges are missing. It is failed to find multi objects during the calculation of boundary line. Zhaozhong Wang et al.[10] the described that the edge detection is not so speed and the same time it failed to find rotation and translation.Canny edge detector performance is not so good in removal of noise and different shapes in the image. Wenge Zhang et al.[11] proposed that canny operator applied in SAR image it detected the edge was best but for blur image it is not able to detect the edges properly and it removed the edges but it failed to reconstruct the edges after the extraction the result reflects in despecking and edges reframing. Jie Huang et al.[12] described that the edge detection working good for homogeneity images but not for inhomogeneity. Classical edge detection was used to detect the edges it given result as incomplete and not closed edges it made a big error.

III. PROPOSED METHODOLOGY

Fig 1 explains the process flow that the color SEM images are converted into gray scale image or the gray scale image are taken as it is. After converting gray scale image is converted into binary scale image. The Improved Sobel and Laplacian detection algorithm helps to detect the edges and

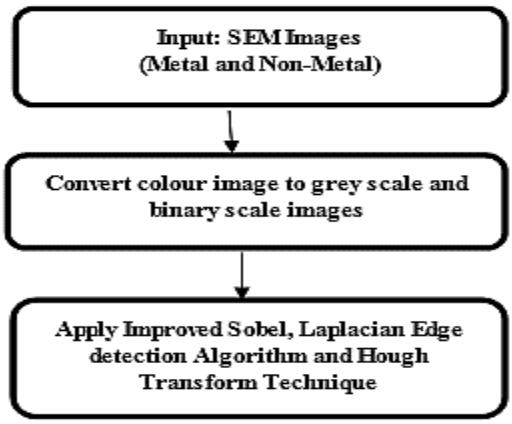

Fig 1. Process flow

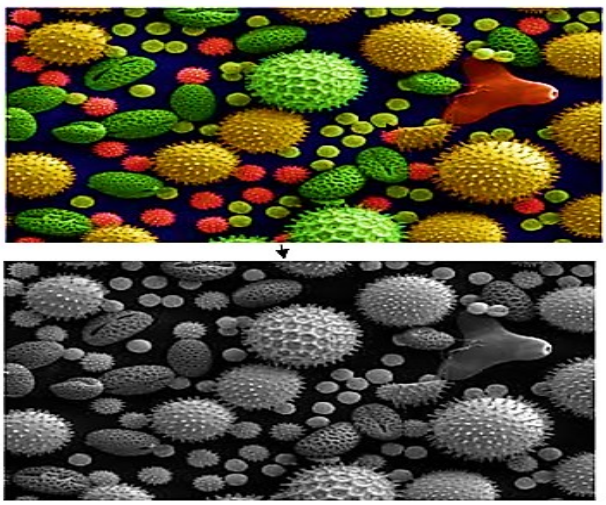

Fig 2. Converting color SEM image into Gray scale

The detailed explanation of each block is discussed in the following section.

Conversion color image into gray-scale images:

SEM images of both metal and non-metal are taken for conversion. Fig 2 shows that Gray scale images requires 8-bit in each pixel. Likewise color image based on 24-bit pixel.

1. Segmentation and calculation of white and black pixels.

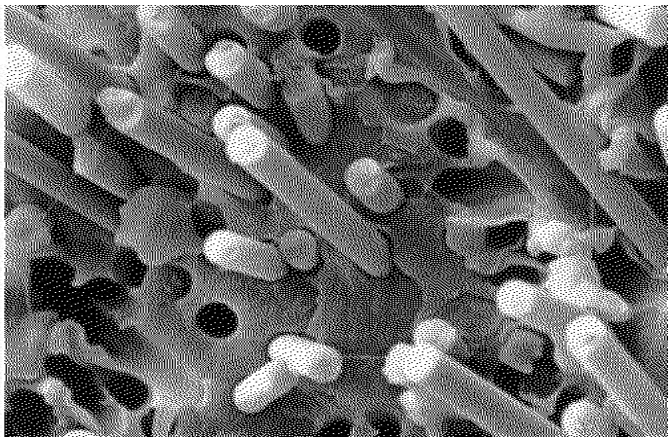

Fig 3. Binary scale or Digitalized SEM images

Fig 3 proposes the Adaptive threshold Gaussian algorithm is used to calculate the neighborhood area of the SEM image. It calculates the neighbor threshold value of different regions so it will remove noise and provide good binaryzation. It helps to identify voids and flocs presence in SEM images. It helps in calculating the occupied region black and white pixels in SEM images. From this, it is possible to calculate the voids or flocs occupied area in the SEM image for both metal and non-metal. It splits the black and white pixels separately in digitalized form as 0's and 1's.

2. Sobel Gradient:

It is used for edge detection techniques. It works by calculating the gradient of image intensity at each pixel within the SEM image. It helps in differencing each pixel from darker to brighter [13].

Sobel operator provides very fast execution and the same time it provides the same output during execution over an image (without any changes of the input image). It is the method of stable edge detection. It is a 3x3 convolution kernel. Sobel uses two masks with 3X3 sizes, one helps in estimating the gradient in X-direction and other for Y- a direction in gradient. It is a row edge detector

-1	0	+1
-2	0	+2
-1	0	+1

Gx (Horizontal)

+1	+2	+1
0	0	0
-1	-2	-1

Gy (vertical)

Fig 4. Mask filter of sobel in x and y direction

The kernel can be applied separately to input image for obtaining gradient component in each orientation i.e. GX and GY shown in fig 4.

The magnitude or strength of the edge [14]

$$|G| = \sqrt{Gx2} + \sqrt{Gy2}$$

The center point helps in identifying the left and right pixels which is closer to the center point. So automatically edge will be formed. The output is shown below in formulae

Rows= M-m+1
Columns=N-n+1

Algorithm of Sobel Edge Detection:

Step 1: Take Input SEM image

Step 2: Apply mask filter in Gx and Gy

Step 3: Apply sobel edge detection algorithm and the gradient

Step 4: Mask operation separates Gx and Gy in input SEM image.

Step 5: Results combined to discover absolute magnitude of gradient

Step 6: The final edge output is absolute magnitude

Laplacian based gradient: Laplace operator detects not only detect edges but also noise. It uses only one kernel and calculates second order derivatives for single pass. The laplacian of Gaussian (LoG) techniques used here with 5x5 kernel which is shown in fig 5. It always keeps the homogeneous region as zero. [15]

$$\begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 2 & 1 & 0 \\ 1 & 2 & -16 & 2 & 1 \\ 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

Fig 5. Mask Filter of Laplacian of Gaussian (LoG)

LoG is a Gaussian filter which helps in reduction of noise and smoothing of the image is better comapre to Sobel. It will consider only present at the center point. The left and right side pixes are eliminated. So many false edges are eliminated. The formula for output image is

Algorithm of Laplacian Edge Detection:

Step 1: Apply LoG in input SEM image

Step 2: Zero crossing is detected in image

Step 3: Finding threshold in zero crossing

Step 4: Suppress the weak zero crossing in SEM images.

Step 5: Final output edges are detected.

Negative side Output = Resultant (result image) + original Image

Positive side Output = Resultant (result image) - original Image

3) Hough Transform Technique

It is a technique used to detect various shapes which is present in both metal and non-metal images. It is good to detect lines, curves circles and ellipses shapes. In Material SEM images mostly the voids are in the form of circle or ellipse shape. It helps detect those shapes easily and quickly.

For line detection, using the formulae

$$x \cos\theta + y \sin\theta = r$$

r= length to origin to x and y axis
θ= Orientation

For finding circle the formulae used as

$$(x-a)^2 + (y-b)^2 = r$$

a, b= coordinates to the center of circle
r = radius

Algorithm of Hough Transform

Step1: Input SEM images

Step 2: Find straight lines in given image

Step 3: Image is binarised

Step 4: Hough space is calculated at each point(d,T) where D= angel and T= distance from origin

Step5: Final output different shapes in images are detected

IV. Visual Comparison Results of Sobel, Laplacian and Hough Transform Technique

The Paper represents a practical implementation of three edge detection algorithms and is easily able to find which method is best. In this section, the edge detection and feature extraction results are shown. The latest version Python3.8 Programming is used for implementation. The Program is executed with more than 50 image samples. Here the results of three methods are shown for both metal and non-metal images.

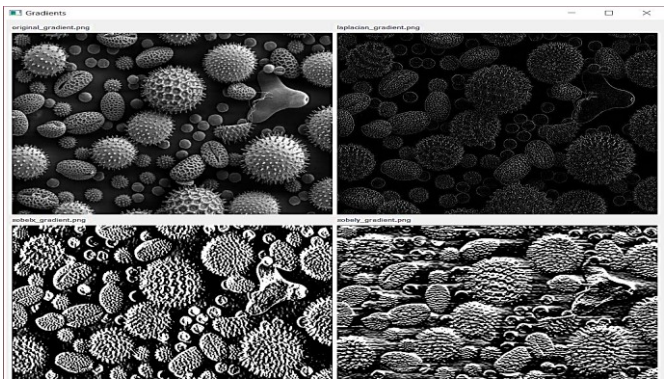

Fig. 6 Sobel and Laplacian Results of non- metal image (pollen grains)

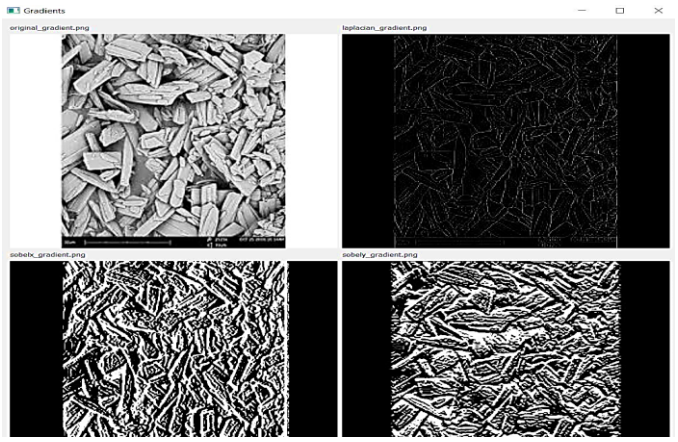

Fig 7. Sobel and Laplacian Results of metal image

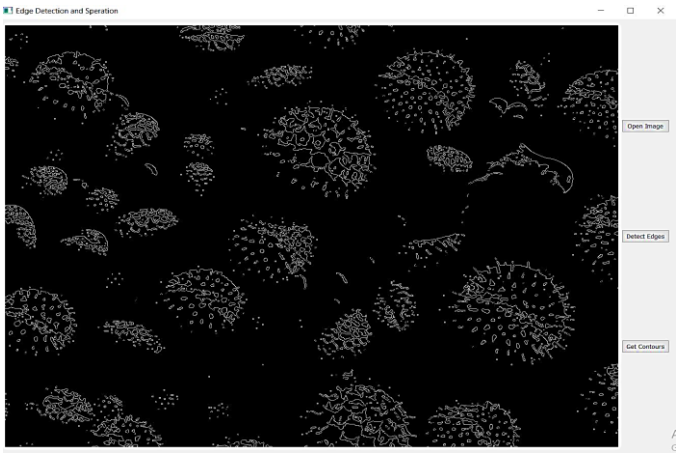

Fig 8. .Edge detection using Hough Transform Technique

In fig 6 and 7 shows the result of sobel edge detection algorithm is done for both metal and non-metal images. It is analyzed in both x and y direction. It detect the edges where magnitude is high where the sharp edges are not detected as like Laplacian. In Sobel edge detection the voids or pores, cracks is not showing clearly comparing to laplacian but for fiber pullout in y direction it is showing very clearly. Sobel detector cannot produce accurate edge detection with thin and smooth edge The Laplacian Edge detection is highly suitable for SEM images. It is eliminating the false edges and it provides true edges to the users. At the same time it is giving the output of boundary detection and it is not missing the objects. It is providing good separation of white and black pixels. Fig 8. Explains the good detection of different shapes but it is missing many true edges after the extraction. The connectivity of edges is missing.

Algorithm	Speed of execution	Noise removal	Edge detection	Crack detection	Lines or curves	Orientation of pores	Boundary line detection
Sobel	0.2	0.3	0.5	0.2	0.4	0.6	0.3
Laplacian	0.7	0.7	0.9	0.7	0.6	0.9	0.8
Hough Transform	0.5	0.6	0.4	0.3	0.2	0.4	0.7

Table 1. Performance Analysis table

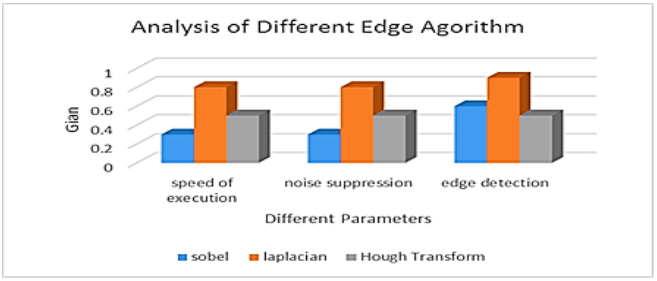

Fig 9. Analysis of Different Edge Detection Algorithm

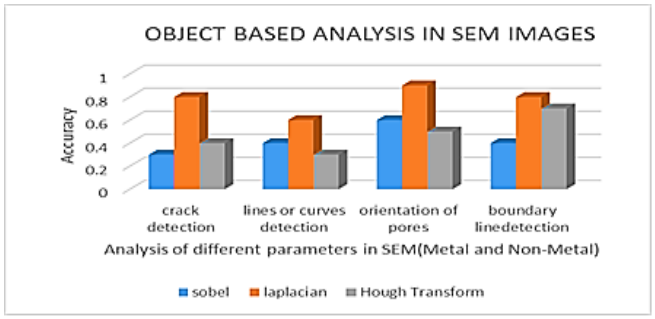

Fig 10. Object based Analysis of SEM images

Fig 9 and 10 explains the complete analysis of different parameters in SEM images. Comparing to Sobel and Hough transform the execution speed is high. The noise removal is good in Laplacian filter it removes the noise very well. It is providing the clear analysis in boundary analysis it is not missing any edges. It helps identify the true and eliminate the false edges but in Hough transform it is missing true edges and boundary analysis is also not done in a very effective manner. The accuracy of edge detection in Laplacian is far better than the other edge detection algorithm it detects the exact shape like circle, ellipse and irregular shape.

CONCLUSION

In SEM image Laplacian edge detection algorithm help in finding the clear edges of voids and cracks on the surface of images by using edge tracking presence to the user and its calculation is identified in fig 7. It provides reliable detection. It set the threshold value properly if the value is low means it will discard the pixels so it provides the clear edge and blurring is avoided. Finally, it is concluded that Laplacian performs good speed execution and noise suppression is better than other method but the edge detection of different shapes of Hough transform technique is quite good. In our future work, we are aiming to develop other edge detection algorithm to find better performance in detecting edges and contour extraction of SEM images both metal and non-metal.

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