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# Multi-technology Integration Based on Low-contrast Microscopic Image Enhancement

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**Abstract:** Microscopic image enhancement is an important issue of image processing technique, which is used to improve the visual quality of image. This paper describes a novel multi resolution image segmentation algorithm for low DOF images. The algorithm is designed to separate a sharply focused object of interest from other foreground or background objects. The algorithm is fully automatic in that all parameters are image in dependent. A multiscale-approach based on high frequency wavelet coefficients and their statistics is used to perform context dependent classification of individual blocks of the image. Compared with the state of the art algorithms, this new algorithm provides better accuracy at higher speed. *Copyright © 2014 IFSA Publishing, S. L.*

**Keywords:** Microscopic image, Sobel operator, LoG operator, Limited adaptive histogram equalization contrast, Image enhancement.

## 1. Introduction

With the development of science and technology, micro-imaging technology continues to improve, have been widely used materials, metallurgy, pharmaceutical, biological, chemical, food and other fields of scientific research and engineering practice, the role of microscopic images increasingly more important, fine structure studies have become an important research direction [1] However, electron microscope images taken of various factors susceptible to the fallout of the decline in image quality, visual effect is not good, so the need for these image enhancement processing.

Thus, the study on enhancement has always been being one of the main contents in image processing field [2]. However, the traditional image enhancement algorithms based on histogram have several shortcomings.

1) The information carried by gray levels is inconsistent with its statistic data in conventional histogram.

2) The conventional histogram equalization has not made full use of the visual sensitive regions in the process of gray level adjustment.

3) The parameters cannot be optimized on and configured adaptively in view of the variability of the image content. To cope with these problems, the relative detailed work can be concluded as follows. First, to overcome the drawback of conventional histogram, a novel histogram construction method has been proposed based on visual attention mechanism. Both the quantity and space distribution are considered in the statistic process of gray levels [3]. The importance of gray levels in different positions can be calculated by using the computational model of visual attention mechanism. Meanwhile, the statistic results are weighted



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according to the importance of every pixel. The new histogram method could reflect the influence of the gray levels on the image information objectively [4].

Second, in order to consider the nonlinear character of visual perception in the process of gray level adjustment fully, it has been raised that different amounts of gray level information are distributed to different visual sensitive regions [5]. The region with high sensitivity should be allocated more information. And the main gray levels are constrained by using the perception ability curve of human eyes, avoiding them occupying large space in the expanding process of histogram.

Digital image processing image enhancement is an important part of technology, which aims to improve image quality, outstanding features of interest, strengthen the image recognition results and to meet some of the special analysis. A wavelet-based image contrast enhancement algorithm is proposed to avoid over-enhancement of noise while enhancing contrast of the image with good visual effect. Commonly used gray-scale image enhancement methods transform, histogram equalization, wavelet transform, homomorphism filtering, Laplacian filtering, and on this basis the various improved algorithms, these methods have their own advantages and disadvantages for some specific images. For some of the simpler image, typically using certain traditional methods can be enhanced to meet the requirement, but the image enhancement for a particular task may require a range of complementary enhancement technology [6]. As an ideal image enhancement technology not only enhance the image of the local contrast, but also enhance the overall image contrast, and not only enhance the image of the edge or contour information, but also highlight the image of the internal details of the overall improvement of visual Many researchers practice shows that the comprehensive use of various image enhancement methods are available to better results, but for low-contrast microscopic image enhancement research is still relatively small, this uses kinds of enhancement techniques for low-contrast microscopic image, image enhancement, for the follow-up research and analysis of microscopic image processes foundation.

In order to manage the large volumes of digital images automatically, various image retrieval techniques, especially image automatically annotation algorithms, draw a lot of attentions in recent years. Aiming at handling the problem of multiple annotations and "semantic gap" of images, this paper investigates how to utilize multiple visual descriptors to improve the performance of automatically image annotation [7].

Scanning electron microscope images often appear in imaging the phenomenon of low image contrast, we propose a multi-technology integration based on the contrast microscopic image enhancement. The method of the image of the high frequency and low frequency components are separated to avoid the increased image noise, while also strengthening, combined with Sobel operator, LoG operator and improved contrast limited adaptive histogram equalization method to realize low contrast microscopic image enhancement [8]. Experimental results and data show that this method is highlighted with the image edges and details, to expand the dynamic grayscale range of the image, increasing image contrast and entropy, with good visual effects, for the follow-up of microscopic image analysis and identification of the foundation.

## 2. Method and Implementation

The traditional image enhancement algorithm in enhancing the image of the image is enhanced while the noise signal, resulting in decrease of information entropy [9]. In order to get better, low-contrast microscopic images of visual effects, highlight the risk profile and details of the information, reduce noise impact, this paper, a variety of complementary image enhancement technology processing target image, that is, the original image morphological gradient transforms Sobel to get edge image p (x, y), then LoG filter on the original image to obtain the high frequency transform image q (x, y), with a median filter to its filtering noise, according to the difference between original image and the high-frequency image value at relatively low frequency image with improved contrast limited adaptive histogram equalization of the low-frequency images are enhanced by low-frequency-enhanced images g (x, y). Finally, after three images processed, such as type 1 show to a certain percentage of the weighted sum of enhanced image F (x, y) (1):

$$F(x,y) = \alpha p(x,y) + \beta q(x,y) + \gamma g(x,y), \quad (1)$$

Then α, β and γ for the linear weighted superposition coefficients, which represent the edge information and the details of the low frequency components in enhancing the proportion of the image. Low-contrast microscopic image enhancement method shown in Fig. 1.

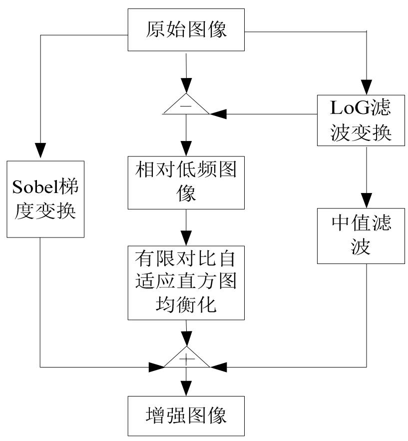



**Fig. 1.** Low-contrast microscopic image enhancement method flow chart.

## 2.1. Sobel Gradient Transformation

Image gradient value shows the significant changes of image gray value, it can be seen as two-dimensional discrete image function, image gradient is in fact the two-dimensional discrete function for the partial derivatives [10]:

$$G(x,y)=\frac{\partial F(x,y)}{\partial x}+\frac{\partial F(x,y)}{\partial y} \tag{2}$$

For digital images, you can use first-order difference instead of first-order differential, discrete approximation of the way is to process continuous pixel differential along lines and columns of the image. Among them, the line gradient defined formula is:

$$G_R(x,y)=F(x,y)-F(x,y-1) \tag{3}$$

Column gradient defined formula is:

$$G_C(x,y)=F(x,y)-F(x+1,y) \tag{4}$$

Demand gradient, the sum of square operation and the square root operation can be the absolute value of the sum of two components of rows and columns, i.e.:

$$G(x,y)=|G_R(x,y)|+|G_C(x,y)| \tag{5}$$

Method of calculating the gradient, Sobel gradient transform results were better able to highlight the good image edge contour information, its horizontal and vertical image space using the template of two directions (as shown in Fig. 2) and the images were adjacent field convolution to complete.

| | | |
|---|---|---|
| -1 | 0 | 1 |
| -2 | 0 | 2 |
| -1 | 0 | 1 |

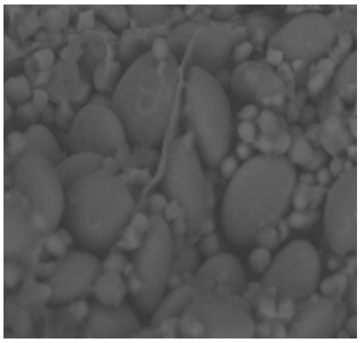
(a) Horizontal gradient template.

| | | |
|---|---|---|
| -1 | -2 | -1 |
| 0 | 0 | 0 |
| 1 | 2 | 1 |

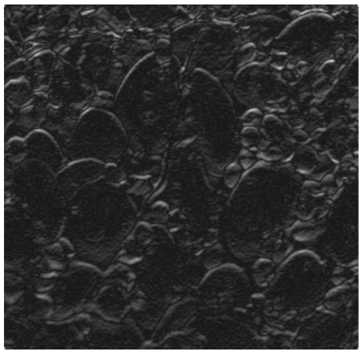
(b) Vertical gradient template.

**Fig. 2.** Sobel operator.

These two directions templates test horizontal and vertical edge, the elements of the template are corresponding to weighting factor for each pixel. Sobel gradient transform calculation is simple and fast, it can get smooth, continuous gradient edge, the microscopic image of the Sobel gradient transform results as shown in Fig. 3.



(a) Microscope image of wheat.



(b) Sobel gradient transformation.

**Fig. 3.** Effect diagram of microscopic image of the Sobel gradient transform.

## 2.2. Laplace Gaussian Filter

Sobel operator to better highlight the edge information, while the LoG operator can be better to highlight the image of the small details [11]. Gauss Laplace (Laplace of Gaussian, LoG) is the result of the image convolution by Laplacian and Gaussian operator, which made by Marr-Hildreth, is the second derivative algorithm which has function of both images smoothness and details enhancement, that is, it smoothed the image to eliminate noise with convolution of two-dimensional Gaussian function firstly and then enhanced image detail with two-dimensional Laplace function which smoothed the image.

Based on the shape of Gaussian function to select the template weights, Gaussian filtering is a linear smoothing filter, the mathematical expression of two-dimensional Gaussian function is [12]

$$G(x,y)=\frac{1}{\sqrt{2\pi\sigma^2}}\exp(-\frac{x^2+y^2}{2\sigma^2}) \tag{6}$$

Among them, σ is a standard deviation of Gaussian function, can be used to adjust the scale filter. Two-dimensional Gaussian function has rotational symmetry, its smoothness in all directions is the same level.

Laplacian is a differential operator ($\nabla^2$), if the image function f (x, y), enhances the image filtered by Gaussian with Laplacian operator, then get image filtered by log. The expression is [13]:

$$\nabla^2 g(x,y) = \nabla^2 (G(x,y) * f(x,y)) = (\nabla^2 G(x,y)) * f(x,y) \tag{7}$$

Among them, LoG filter is the operator.

$$\nabla^2 G(x,y) = \frac{1}{\pi\sigma^4}(1 - \frac{x^2+y^2}{2\sigma^2})\exp(-\frac{x^2+y^2}{2\sigma^2})$$

LoG filter on the microscopic image transformation shown in Fig. 4.

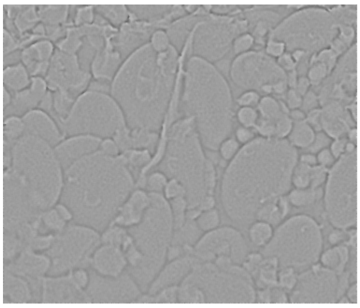


**Fig. 4.** LoG filter transformation effect diagram.

## 2.3. The Low-frequency Image Enhancement

### 2.3.1. Image Frequency

For an image, background region and the gray part of the slow change represent low frequency components of the image, it contains most of the gray scale information, the factor which affect the overall visual effect of the image is the low frequency components of the image generally, while the edge of the image, details and noise represent high frequency of images, if the entire image will be enhanced with the corresponding image noise amplification, so we will deal with the high frequency and low frequency components of the image separately, the value of high-frequency component after median filter overlay with the enhanced low frequency components, it is the purpose to enhance the whole low-contrast SEM images [14].

If the original image is f (x, y), then the low frequency components image $f_l$ (x, y) and the high frequency components image $f_h$ (x, y), the relation of the three can be expressed as [15]:

$$f(x,y) = f_l(x,y) + f_h(x,y) \tag{8}$$

High frequency components image $f_h$ (x, y) obtained by the LoG filter transformation, subtracted high-frequency image from original image and the result is low-frequency image:

$$f_l(x,y) = f(x,y) - Af_h(x,y) \tag{9}$$

Among them, $0 \le A \le 1$, coefficient A can be adjusted according to the image.

### 2.3.2. Contrast Limited Adaptive Histogram Equalization

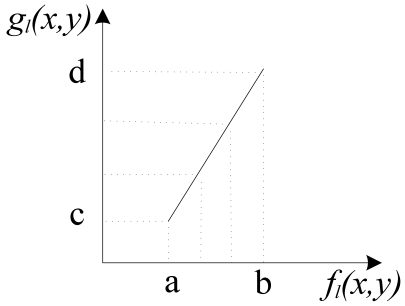
Histogram equalization (HE) is a classic common and effective image enhancement method, based on probability theory, through equalization processing it adjust grayscale distribution to increase image contrast, and improve the visual effects of the image [16]. The main advantage of this algorithm is able to automatically enhance the image contrast, then the disadvantage is that specific enhancement effect is not easy to control, gray might be too much of the merger, the image level is reduced, the image appeared too dark or too light enhancement. Local histogram equalization using a sliding window from left to right, top to bottom, and each window carries on the local histogram equalization, and thus complete the whole image of the grayscale enhancement [17]. Local histogram equalization to achieve a relatively small area of enhancement, is better than histogram equalization, but it considered only the local region of pixels, the computation is big, and is quite sensitive to the noise.

Contrast limited adaptive histogram equalization (CLAHE) is a method between the histogram equalization and local histogram equalization [18]. It is divided into a number of non-overlapping image regions, all regions of the image histogram equalization to do, at last, the difference method using the bilinear combination of adjacent areas to eliminate the artificially created border. The method uses a small window to better highlight the region's local characteristics of the image, to prevent excessive increase of the phenomenon of the image, taking into account the window and the window outside the histogram, and enhance good effects. However, SEM images of low contrast gray value for the general low level is not obvious, limited adaptive histogram equalization contrast to its enhanced effect is not very satisfactory [19]. This paper, a contrast to the limited adaptive histogram equalization method based on improved low-frequency low-contrast image enhancement, the method first used the traditional method of image enhancement CLAHE, then equidistant histogram to adjust grayscale range stretching further.

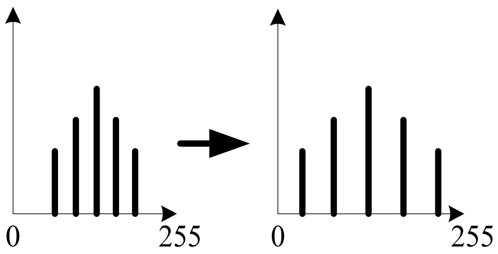
Equidistant histogram stretching is to stretch image contrast with the linear gray scale transform, if the gray scale range of the original image is [a, b], then equidistantly transform it to gray [c, d], the transform relationship expression is [20]:

$$g_l(x,y) = \frac{d-c}{b-a}[f(x,y)-a]+c \qquad (10)$$

According to the expression (10), the images after linear gray-scale transformation can achieved equidistant histogram stretch, as shown in Fig. 5.




(a) Linear gray scale transformation.




(b) Equidistant histogram stretching.

**Fig. 5.** Relationship diagram of equidistant histogram stretching.

The steps of improved contrast limited histogram equalization are:

step 1: the image is divided into n non-overlapping window areas;

step 2: Calculate the histogram of each sub-region, and its doing histogram equalization;

step 3: Combine adjacent area with bilinear difference to get the new gray scale image;

step 4: Calculate the effective gray scale range [a, b] of the histogram;

step 5: According to equation (10) histogram equidistant extending applied to image [21].

## 3. Results and Analysis

Applied to wheat grain cross section of this paper, simulate its low-contrast electron microscope scanning microscope image, implement image enhancement with MATLAB according to the process of Fig. 1, the results compare with histogram equalization, wavelet enhancement, homomorphic filtering and other traditional image enhancement, Fig. 6 shows several enhancement effect comparison diagram and histogram of the low-contrast microscopic image [22].

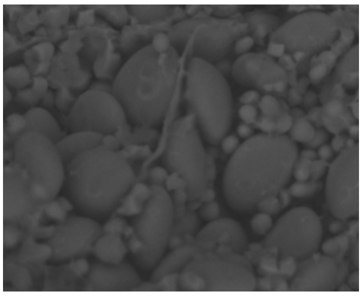
As can be seen from Fig. 6, the original image contrast is low, gray distribution concentrated in a small range over the image histogram equalization method of enhancing the phenomenon occurs, resulting in some fine details. Wavelet filter enhancement and with the state to some extent increase the contrast, but the image is not clear, layering, limited adaptive histogram equalization compared the effect of slightly better than the previous method, the downside is that the image Pianan, contrast yet to be enhanced [23]. Using this approach to get the image clear, moderate brightness, good contrast, highlights the edges and details, to obtain a good enhancement.

In order to objectively evaluate enhancement of the low contrast microscopic image of the enhanced performance, this paper, the image mean, standard deviation, mean contrast and entropy of four performance indicators as an evaluation parameter. Mean is the average of gray, reflecting the overall image brightness situation; mean square that is the image gray value of the mean square error, reflecting the dynamic range of image gray values; the average contrast of the standard deviation, without loss of image information cases, the average contrast ratio the greater the visual effect is better; information entropy describes how much the amount of information contained in images, images, information entropy can reflect the image of details of the capacity.

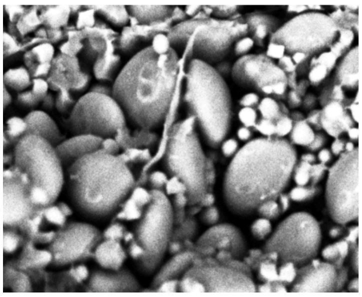
Table 1 shows the original image and Fig. 6, the results of the quantitative data of several enhanced. As can be seen that although the histogram equalization method has greater contrast and dynamic range of gray value, while decreased entropy. Wavelet enhancement, filtering and CLAHE with state SEM images of low contrast enhancement effect of the latter than the former, this method achieved the best results.

## 4. Conclusions

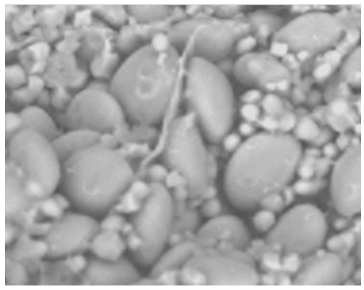
Microscopic images in imaging and other reasons deviation occurs because the edge of focus fuzzy, low-level contrast images obvious problems, the traditional histogram equalization, homomorphic filtering wavelet enhancement and methods of SEM images of low contrast enhancement has some limitations sex. In this paper highlight the edge information Sobel gradient transform, Laplace transform using the Gaussian outstanding image detail, contrast with the improved limited adaptive histogram equalization method is relatively low-frequency image enhancement processing, and finally, the merger of the three treatment images obtained with image enhancement. Experimental results show that the method has good low-contrast microscopic image enhancement effect is conducive to the subsequent image analysis and feature extraction work.



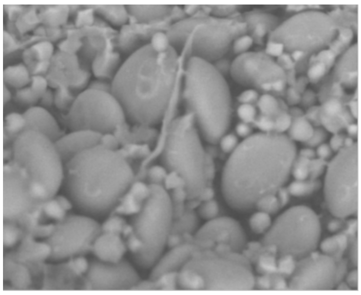
(a) Original image.



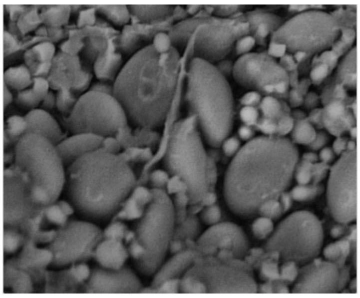
(b) HE.



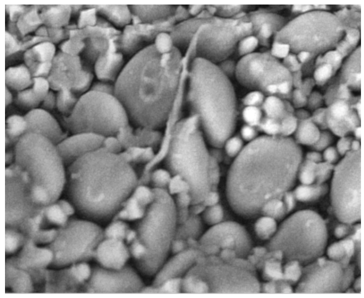
(c) wavelet enhanced.



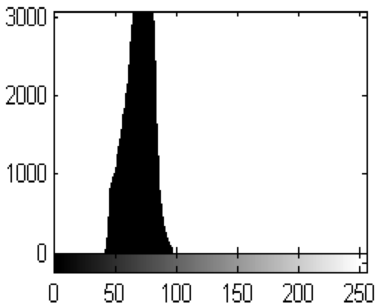
(d) Homomorphic Filtering.



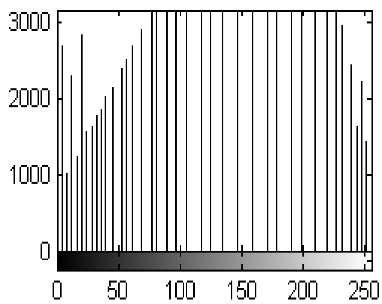
(e) CLAHE.



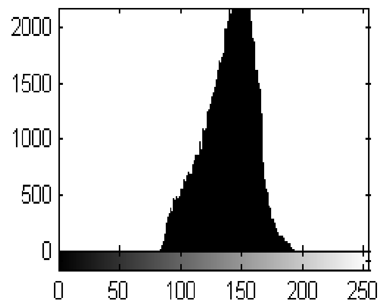
(f) Proposed method.



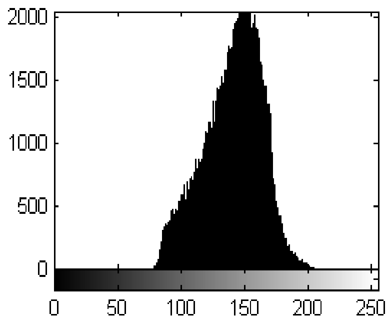

(g) The original image histogram.



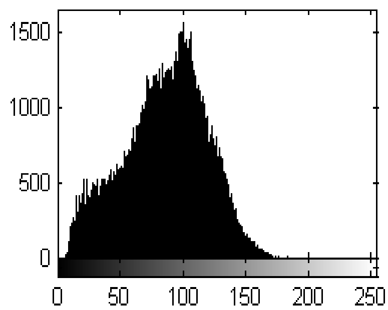

(h) HE histogram.



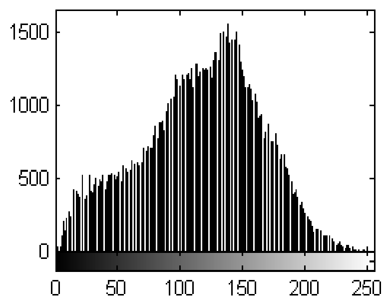

(i) Wavelet enhanced histogram.




(j) Homomorphic filter (k) histogram.




(k) CLAHE histogram.




(l) Histogram of this paper

**Fig. 6.** Several low-contrast microscopic image enhancement comparison chart and histogram.

**Table 1.** Comparison of different algorithms enhanced.

| Index | Artwork | HE | Wavelet enhanced | Homomorphic filtering | CLAHE | This method |
|---|---|---|---|---|---|---|
| Mean | 69.77 | 127.61 | 139.55 | 140.75 | 103.48 | 133.20 |
| MSE | 26.39 | 191.43 | 52.26 | 58.92 | 85.64 | 118.96 |
| Average contrast | 10.35 | 75.07 | 20.49 | 23.11 | 33.59 | 46.65 |
| Entropy | 5.36 | 5.17 | 6.34 | 6.52 | 7.05 | 7.26 |

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