

# Medical Image Enhancement Based on Laplace Transform, Sobel Operator and Histogram Equalization

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**Abstract:** Medical image enhancement is one of the most widely used medical image processing techniques in medical domain. Its purpose is to improve the visual effect of the image and facilitate the analysis and understanding of the image by human or machine. The Laplace transform and the Sobel gradient operator are two common ways of performing edge detection, image sharpening and enabling the image to be enhanced. However, each has limitations when used in isolation. The Laplace operator has a good edge detection effect, but it will make the image noise expand; the Sobel operator has a certain ability to smooth the noise, but the edges of the image obtained after processing are rougher. This paper therefore proposes a method based on both Laplace transform and Sobel operator, and histogram equalization of the transformed image is processed to enhance the image. Using a combination of both filtering methods avoids the disadvantage. This method was found to be effective in improving the quality of lung images and skeletal images through several experiments.

**Keywords:** Medical image enhancement, Laplace transformation, Sobel operator, Histogram equalization

## 1. Introduction

Medical imaging has always been an important auxiliary tool for doctors to diagnose and treat patients. With the continuous development of deep learning technology and the continuous improvement of computer hardware level, medical image assisted diagnosis technology based on computer technology has made significant progress.

According to whether medical image processing is carried out in frequency domain or space domain, medical image enhancement technology can be divided into frequency domain enhancement and space domain enhancement [1] [2].

The frequency domain image enhancement method is to manipulate the spectrum after the Fourier transform of the image, and then achieve the purpose of enhancement by inverse Fourier transform, the method mainly includes low-pass filtering, high-pass filtering, band-pass and band-stop filtering, homomorphic filtering domain [3]. The spatial domain image enhancement method is directly to the image pixel point operation processing, including gray transformation, histogram equalization, image smoothing and sharpening.

At the same time, image enhancement methods based on local transformations such as local histogram equalization, contrast-constrained adaptive histogram equalization, and noise removal methods using local statistical properties have been developed to suit the local characteristics of the image [4].

In 2004, Liping Zhang and Lianqing Huang proposed a fast and simple medical image enhancing method (LHR) based on locally redistributed histograms, which is simple to implement, fast to execute, and can effectively enhance the contrast of medical images [5]. The processed image noise is suppressed, but the clarity is not significantly improved. In 2007, A novel homogeneity measurement was proposed by Guohua Geng to implement enhancement of mammograms which contain many special information. Unlike the histogram equalization method, this method uses both local and global information, enhancing the image without losing too much useful information [6]. In 2009, Peiyu Yan focused on the

characteristics of lung CT images such as wide dynamic range, rich details, relatively small area of interest and low contrast with surrounding areas, improved the Local or Adaptive Histogram Equalization (LAHE) and proposed a CT image contrast enhancement algorithm based on local feature analysis [7]. In 2012, Wu Jun, Jianhua Yang et al. used high-frequency enhanced filtering and histogram equalization mixing method to enhance digital X-ray medical images, and proposed a more effective low-contrast X-ray image enhancement method in clinical operation. [8]. This also indicates that the hybrid method of filtering and histogram equalization has better application in image enhancement.

In this paper, a medical image enhancement method using Laplace transform, Sobel operator and histogram equalization is proposed to process bone images and COVID-19CT images, and good results are obtained. Through filtering and histogram equalization processing, the image contrast is improved while the clarity of details can be enhanced to facilitate the doctor's diagnosis.

## 2. Data Set

The data set used in this study included bone images and lung images. The skeletal images are from MURA, a musculoskeletal medical imaging dataset published by Andrew Ng and ML team at Stanford. Lung imaging images are an open source COVID-19 CT data set published online.

## 3. Methodology

### 3.1. Laplace Transform

The essence of image enhancement by using Laplace transform is to sharpen the image by using the second derivative of it [9]. Sharpening an image by using the second derivative is to improve the contrast by using the neighborhood pixels [10].

The Laplace transform is realized by the Laplacian operator, which is a second-order differential operator. For an image  $f(x, y)$ , its Laplacian operator is as follows:

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} \quad (1)$$

The two second-order partial derivatives in Equation (1) can be expressed by the following formula:

$$\frac{\partial^2 f}{\partial x^2} = f(x+1, y) + f(x-1, y) - 2f(x, y) \quad (2)$$

$$\frac{\partial^2 f}{\partial y^2} = f(x, y+1) + f(x, y-1) - 2f(x, y) \quad (3)$$

We can see from equations (2) and (3) that the Laplace transform is a linear transformation. Therefore, for discrete images, the Laplacian operator can be expressed as:

$$\nabla^2 f = f(x+1, y) + f(x-1, y) + f(x, y+1) + f(x, y-1) - 4f(x, y) \quad (4)$$

The above is the Laplace operator of the mathematical expression, so we can express it as some templates:

0	1	0
1	-4	1
0	1	0

1	1	1
1	-8	1
1	1	1

0	-1	0
-1	4	-1
0	-1	0

-1	-1	-1
-1	8	-1
-1	-1	-1

Figure 1: Laplace operator templates

In this paper, we used the Laplace transform template as shown in Figure 1 for image enhancement.

### 3.2. Sobel Operator

Sobel operator is a discrete difference operator, and the calculated results show the sharpness of the

image at a specified pixel point. Sobel operator can be used to extract the edge of the image and sharpen the image, making the contour details of the image clearer and clearer [11] [12].

The realization method is to use two different convolution kernels to slide on the image, do convolution operation, and detect the horizontal edge and vertical edge of the image respectively. The Sobel convolution kernel is shown in in the following figure:

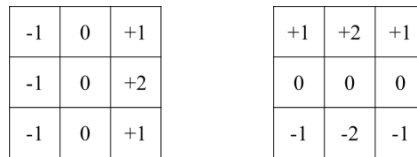


Figure 2: Sobel operator

The operator contains two groups of 3x3 matrices, namely transverse and longitudinal, which can be obtained by convolving them with the image plane. If A represents the original image, Figure 2 represent the gray value of the image detected by transverse and longitudinal edges respectively, the formula is as follows:

$$G(x) = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \times A \tag{5}$$

$$G(y) = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \times A \tag{6}$$

The horizontal and vertical gray values of each pixel of the image are combined with the following formula to calculate the gray size of the point:

$$G = \sqrt{G(x)^2 + G(y)^2} \tag{7}$$

The gradient direction can then be calculated using the following formula:

$$\theta = \arctan \frac{G(y)}{G(x)} \tag{8}$$

The following figure shows an example of using the Sobel operator.

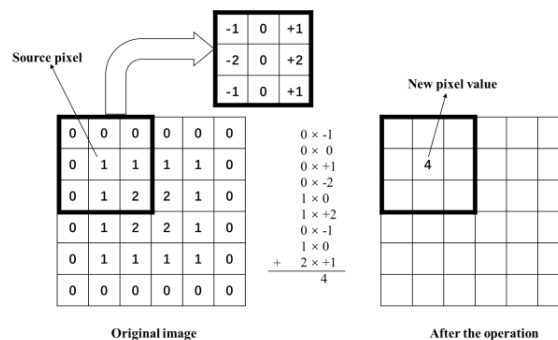


Figure 3: Schematic diagram of Sobel operator

### 3.3. Histogram Equalization

Histogram Equalization is a method to enhance image contrast. Its main idea is to transform the histogram distribution of an image into an approximate uniform distribution, thus enhancing the image contrast [14] [15].

The process of this change is that the original image is mapped to the image with uniform gray distribution through the transformation function. After histogram equalization, the gray cumulative distribution function  $S_k$  is shown as following:

$$s_k = T(r_k) = \sum_{i=0}^k p_r(r_i) = \sum_{i=0}^k \frac{n_i}{n}, (k = 0, 1, 2, \dots, L-1) \quad (9)$$

$r_k$  is the pixel value of the original image.  $T$  is the transformation function.  $s_k$  is the pixel value after histogram equalization transformation.

$n_i$  is the number of pixels with gray level  $r_i$ .  $n$  is the total number of pixels.  $p_r$  is defined as the relative frequency of occurrence of gray level in normalized histogram.

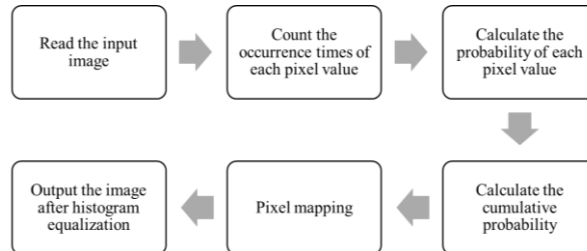


Figure 4: Experimental flow chart

#### 4. Experimental Procedure

##### Step One

The `imfilter()` function of MATLAB is used to perform the Laplace transform of the original image through the filter whose template is `[-1 -1 -1;-1 8 -1;-1 -1 -1]`.

Take a CT image of the lung cross-section of COVID-19 patients as an example. By using the Laplace transform, we can enhance the gray scale mutation area and weaken the gray scale slow change area in the image. The edge information of the image is extracted to form a black and white image with a black background and white foreground as shown in Figure 5.

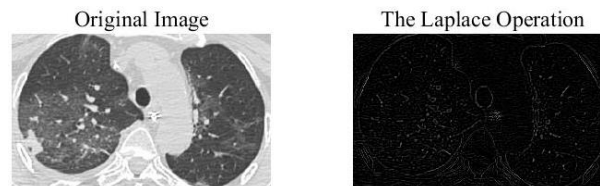


Figure 5: Comparison of the original image with the Laplace transform image

##### Step Two

Add the original image with the Laplace transform of the previous step, that is, sharpen the original image. And you can see that the outline of the image becomes clearer as shown in Figure 6.

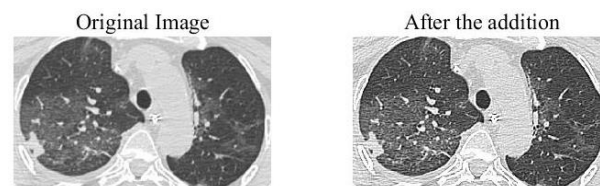


Figure 6: Comparison of the original image with the added image

##### Step Three

Use the Sobel gradient operation on the original image. This operator introduces the operation similar to local average, so it can smooth the noise and eliminate the influence of noise very well. By comparison, it is found that the edges of images processed by Sobel gradient are more coherent and clearer as shown in Figure 7.

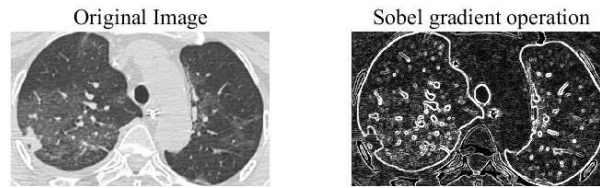


Figure 7: Comparison of the original image with the Sobel gradient transformed image

#### Step Four

The `fspecial()` function of MATLAB was used to create a  $5 \times 5$  mean filter to smooth the image obtained in the previous step. At this point, the color of the image's edge outline lightens and the contrast with the black background increases as shown in Figure 8.

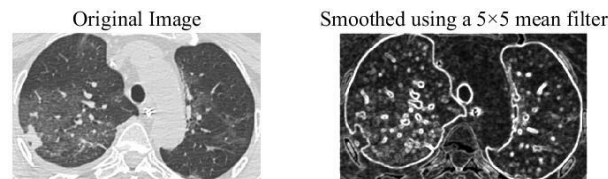


Figure 8: Comparison of the original image with the smoothed image

#### Step Five

The `immultiply()` function of MATLAB is used to dot the smoothed image in the previous step with the image obtained in the second step. The result of dot product operation is shown in Figure 9, and the contrast of the image is further improved.

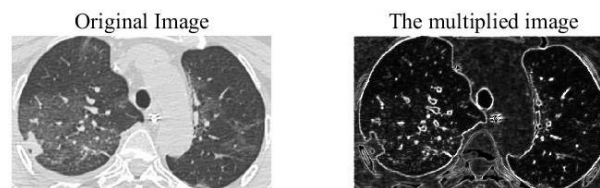


Figure 9: Comparison of the original image with the multiplied image

#### Step Six

The multiplied image is added to the original image to produce the desired sharpening image as shown in Figure 10.

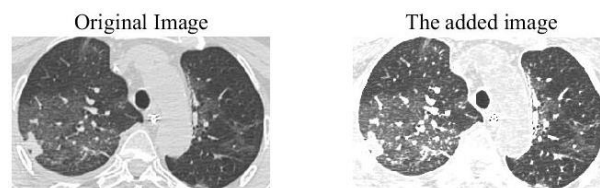


Figure 10: Comparison of the original image with the added image

#### Step Seven

Figure 11 is the final image obtained after histogram equalization using `histeq()` function of MATLAB. Comparing with the original image, it can be seen that the contrast and sharpness of the image after a series of changes are improved, and the edge contour of the image is more obvious.

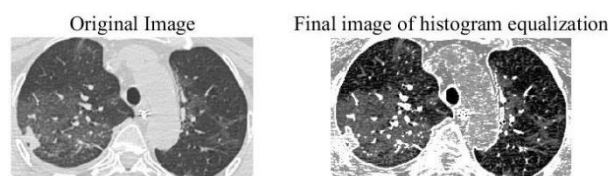


Figure 11: The final image after a series of processing

The following shows the changes of bone images after processing.

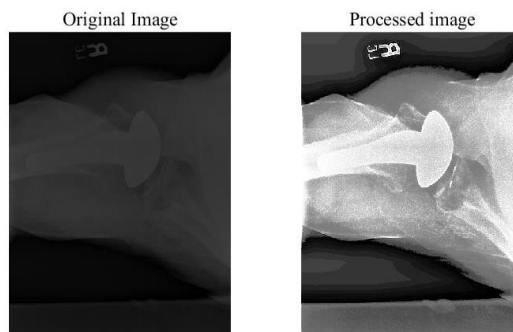


Figure 12: (On the left) Processed image of the skeleton of the right upper limb

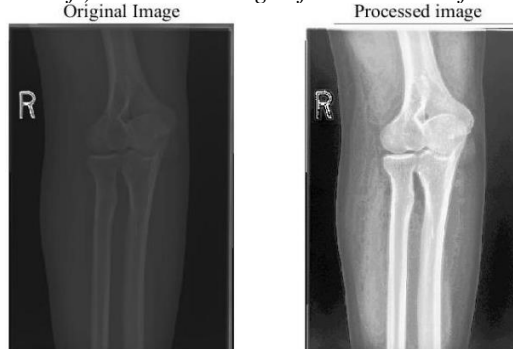


Figure 13: (On the right) Processed image of the skeleton of the right lower limb

Compare the image quality before and after processing by comparing some parameters.

Table 1: Comparison of the parameters before and after processing

Comparison of the parameters before and after processing						
	Lung image		Upper limb image		Lower limb image	
	original	processed	original	processed	original	processed
Average gray value	151.1407	160.6893	32.5328	126.6701	47.8655	125.7901
Contrast	0.2347	0.2841	0.0715	0.2542	0.0324	0.2461

## 5. Conclusion

Laplace is a differential operator that can be applied to enhance areas of sudden changes in grey in an image and attenuate areas of slow changes in grey. It has the disadvantage that there is no more directional information from the edges and it doubly enhances the effect of noise.

The Sobel operator is a first-order differential edge detection operator that introduces a local averaging-like operation and therefore has a smoothing effect on noise, which can be well removed. However, the Sobel operator does not strictly distinguish the subject of the image from the background, so the extracted image contours are sometimes unsatisfactory.

In this paper we combine the two methods, avoiding the disadvantages, and then combine them with histogram equalization for medical image images. According to the images obtained from the experiment, it can be seen that after Laplace transform, Sobel gradient operator processing and histogram equalization, the image quality is significantly improved, the brightness is increased, the contrast is enhanced, and the fine tissues are more easily identified.

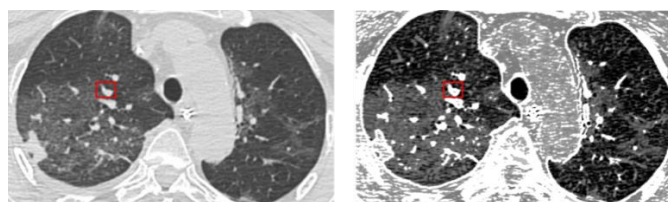


Figure 14: Better edge resolution of microscopic tissues

The processed images have better results in deep learning algorithm processing and clinical differential diagnosis.

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