

COMBINING LAPLACIAN AND SOBEL GRADIENT FOR GREATER SHARPENING

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Abstract

Generally medical images have narrow dynamic range of intensity levels and high noise. One such abdominal x-ray image has been taken for enhancement. This paper enhances the image by sharpening and by lime lighting more, the minute details of the bone structure present in the image. Actually the whole task has been accomplished with Laplacian filter to highlight fine details and with Sobel gradient to emphasize edges. To get the sharpened image, smoothed gradient image is used to mask the Laplacian image. Finally the dynamic range has been increased using gamma transformation.

Keywords:

Noise, Sharpening, Laplacian, Smoothed-gradient, Mask

1. INTRODUCTION

Image enhancement is manipulations on image in order to make it more suitable for certain applications. One way of image enhancement is by increasing dominance of some features over the others and/or by decreasing ambiguity between different portions of the image. Image enhancement process consists of a collection of techniques that seek to improve the visual effects and the clarity of the image, or to make the original image more conducive for computer to process [1]. Image enhancement, which is one of the significant techniques in digital image processing, plays important roles in many fields, such as medical image analysis, remote sensing, high definition television (HDTV), hyper spectral image processing, industrial X-ray image processing, microscopic imaging etc [2]. Image enhancement methods are broadly categorized into spatial domain methods and frequency domain methods. A spatial domain refers to an image plane and the methods directly operate on the pixels. Frequency domain methods are based on adapting one of the different transforms of an image.

Medical images are generally low in dynamic range or contrast as at the time of imaging the radiations have to be kept with lesser energy to avoid damaging of the patient's body [3]. When such images are combined with noise the enhancement task becomes more difficult.

2. BASICS

The experimental image taken is an x-ray image of abdomen. The image is noisy and suffers low dynamic range of intensity levels as generally it is the case with medical images. The idea for enhancement is to highlight those details which are very fine including edges. The basic strategy chosen is to use Laplacian for emphasizing fine details and gradient to highlight edges [4].

Following are the few basics which are needed to be understood for properly understanding the proposed enhancement method.

2.1 SMOOTHING FILTER

Smoothing linear filters are also called averaging filters or low pass filters. At each pixel location the output or response of this filter is simply the average intensity of all the pixels contained within the filter mask. We get the filtered image after convolving (sliding) the filter over the image. In the resultant image every pixel value is replaced by average intensity. The Fig.1 shows a 3×3 smoothing filter.

$$\frac{1}{9} \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Fig.1. A 3×3 smoothing filter

Random noise in an image typically contains sharp transitions in intensity levels. Smoothing filters reduce noise in an image. These filters are also used for blurring which is nothing but eliminating very small details from an image.

2.2 LAPLACIAN FILTER

The Laplacian is a 2D, isotropic, second spatial derivative operator [5]. The Laplacian of an image emphasize regions of intensity discontinuities and is therefore often used for detection of fine details and edges. The Laplacian is very sensitive to noise therefore often applied to a smoothed image. Two commonly used 3×3 kernels are shown in Fig.2. The filters in Fig.2(a) and Fig.2(b) yields isotropic results for rotations in increments of 90° and 45° respectively. In Laplacian image, features involving slow intensity change are de-emphasized. These suppressed features can be brought back into the image by simply adding Laplacian image with the original image.

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix} \quad \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

(a) (b)

Fig.2. Two commonly used Laplacian filters

2.3 SOBEL GRADIENT

Gradient image or Gradient is a nonlinear, first-order derivative sharpening operator. For a function A(x, y) the gradient at coordinates (x, y) is defined as the 2D column vector.

$$\delta A = grad(A) = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial}{\partial x} A(x, y) \\ \frac{\partial}{\partial y} A(x, y) \end{bmatrix} \quad (1)$$

where,

$$G_x = A(x, y) - A(x + 1, y)$$

$$G_y = A(x, y) - A(x, y + 1).$$

The magnitude of vector δA , $M(x, y)$ is given as,

$$M(x, y) = mag(\delta A) = \sqrt{G_x^2 + G_y^2} \quad (2)$$

where, $M(x, y)$ is the Gradient Image and is of the same size as the original image. Or

$$M(x, y) \approx |G_x| + |G_y|. \quad (3)$$

The Sobel operators are shown in Fig.3.

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

(a) G_x

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

(b) G_y

Fig.3. Sobel Operators

The weight value of 2 in the center coefficient is to achieve little smoothing.

2.4 POWER-LAW TRANSFORMATION

The basic expression for Power-Law transformation is given in the form

$$s = cr^\gamma \quad (4)$$

where, c and γ are positive constants and s and r are intensity levels for output and input respectively [6]. Plots for different values of γ are shown in Fig.4. In all cases c is taken as 1. The exponent in the power-law equation is called *gamma*. Intensity levels in an image can be adjusted or corrected by using an appropriate value for gamma. These images are then called gamma corrected images and the process is called *gamma correction* [4].

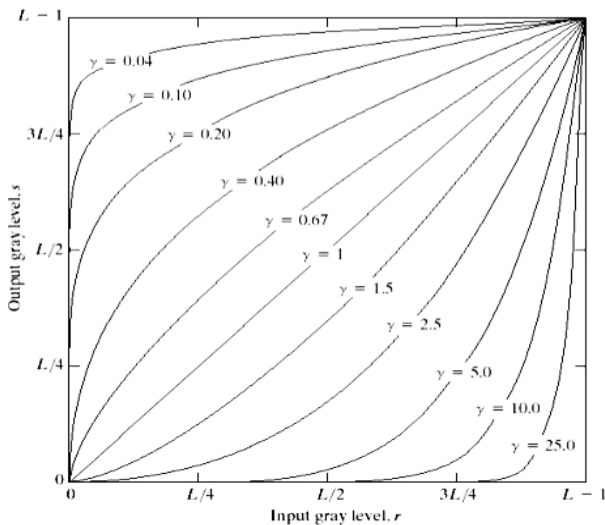


Fig.4. Plots for Power-law transformations

2.5 MASKING

Masking is the process of multiplying a given image by a mask image [4]. Generally the mask image has one or more region(s) of interest (ROI). The ROI has the intensity values as 1s and at other regions the intensity values are 0s. The ROI can be of any arbitrary shape but generally rectangle shape is used.

3. THE PROPOSED METHOD

The stepwise description of the proposed enhancement or sharpening method is given as follows:

1. Original Image taken: The image which is to be enhanced is taken. As discussed earlier it is an Abdominal x-ray image as shown in Fig.5 [7].
2. Laplacian of Original Image: The Laplacian basically highlights rapid intensity discontinuities and de-emphasizes areas with gradual or no intensity change [8]. Because of this a Laplacian image has grayish edges and other discontinuities on a dark featureless background as shown in Fig.6.
3. Sharpened Image: Noisy sharpened image is obtained by adding Laplacian image with the original image. With this addition the overall intensity variations of the image are restored as well as enhanced image is obtained. The resultant image is shown in Fig.7.
4. Sobel gradient of Original image: The gradient of an image enhances prominent edges more than that by Laplacian [9], and this is verified by comparing the resultant image of this step shown in Fig.8 with the image in Fig.7. The resultant image is nothing but Sobel gradient of the original image, obtained using the Eq.(3).
5. Smoothed Sobel Image: Smoothed Sobel gradient is obtained using an averaging filter of size 5x5. The resultant image is shown in Fig.9. Generally gradient of an image has stronger response in areas of high intensity change like step and ramp and lower response in case of noise and fine detail as compared to the responses of Laplacian. To further reduce the noise, Sobel image is filtered with averaging filter.
6. Masking: In this step the resultant image is obtained by treating smoothed gradient image as mask image and multiplying it with the Laplacian image as obtained in step 3. Or in other words this is nothing but masking the Laplacian with smoothed Sobel gradient. The resultant image is shown in Fig.10. Actually Laplacian is a second order derivative operator and hence it gives greater response to fine details and noise than that by gradient. So the product of the two images gives us an image with highlighted fine details and edges both.
7. Final Sharpened image: This image is obtained by adding the masked image (resultant image in step 6) to the original image. The resultant image is shown in Fig.11. This addition is done to make the sharpened features more prominent as well as to keep overall features intact.
8. Gamma Corrected Final Image: If required the dynamic range of the final Sharpened image can be transformed by using any one of the Intensity transformation methods. The

best suited method for dark to very dark image is power-law transformation. After few hits and trials the image is gamma-corrected with $\gamma = 0.75$. The resultant image is shown in Fig.12.



Fig.5. Original Image

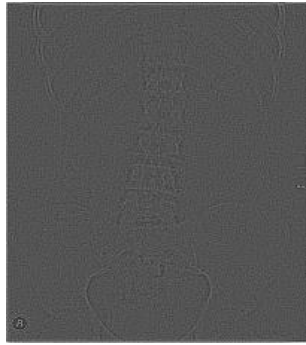


Fig.6. Laplacian Image



Fig.7. Sharpened Image

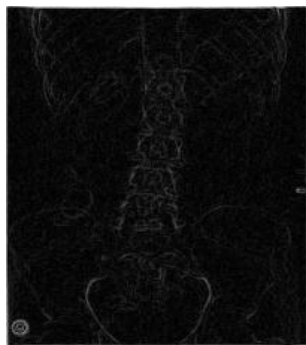


Fig.8. Sobel-gradient Image



Fig.9. Smooth-gradient Image



Fig.10. Masked Image



Fig.11. Final Sharpened Image



Fig.12. Gamma corrected Image

4. DISCUSSION

Laplacian and Gradient both highlights intensity discontinuities but Laplacian is superior in enhancing fine detail and gradient is superior in enhancing edges. Laplacian produces noisier image which can be seen by comparing the image at step 2 with that at step 1. At step 3 a noisy but sharpened image is obtained. One could think of using a median filter for reducing the noise, but doing so may eliminate some important image features. This is not advisable in case of medical images. Therefore Sobel gradient has been used as its response to noise and fine details is low. It can be seen that image at step 4 has lesser noise than the image at step 1. However as expected the edges are very prominent. Multiplying Laplacian with Sobel gradient gives an image whose fine details and edges both are enhanced. Before multiplication if the Sobel gradient is smoothed, noise would be reduced further. That is why smoothed-gradient is multiplied with Laplacian. The image obtained at step 6 contains lesser noise, highlighted features and blur. The presence of blur is due to smoothening done at step 5. Adding the image to the original reduces blur and makes highlighted features more prominent. The edges comprising pelvic brim, different Lumbar vertebrae, ribs etc. are all enhanced.

The other thing which is of importance is that in Laplacian image the noise in smooth areas is predominantly visible and hence objectionable and gradient has the ability to enhance small discontinuities in smooth areas. Therefore masking Laplacian with Sobel gradient gives us an image with preserved details in strong areas and reduced noise in smooth areas. The whole process is shown diagrammatically in Fig.13.

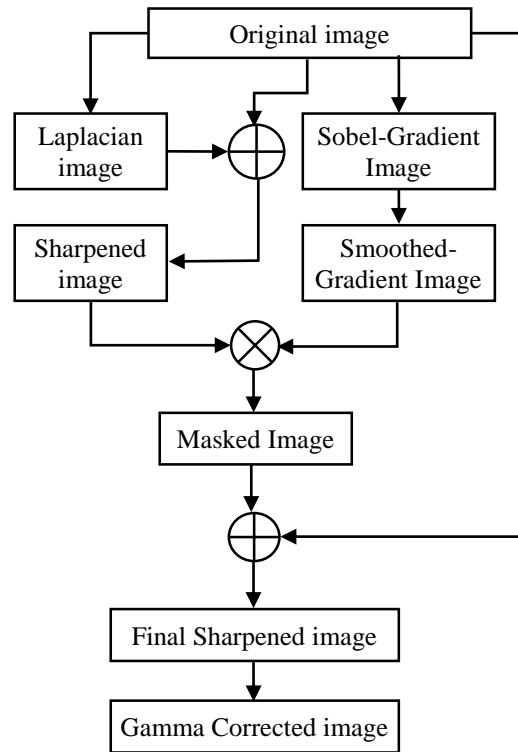


Fig.13. Proposed Method

5. CONCLUSION

The method combines the best features of Laplacian and the gradient to give a better sharpened image which otherwise would not have been possible if anyone is used alone. The method is best suited to images having noise and low dynamic range and from which more details are to be extracted. Quite a good number of medical images are of such type. In the paper the corrupted image is prepared by narrowing down the dynamic range from [0 1] to [0.3 0.7] using the imadjust function of Matlab. Then Gaussian noise is added using imnoise function with mean and variance selected as zero and 0.0002 respectively. Some more images are taken from Internet and the proposed method is implemented. The method is found suitable to these images too as can be made out from Fig.14, Fig.15 and Fig.16. In all the images gamma is taken as 0.75 except in the case of skull image where it is taken as 0.65. This method works very well for images having too much minute details and edges.

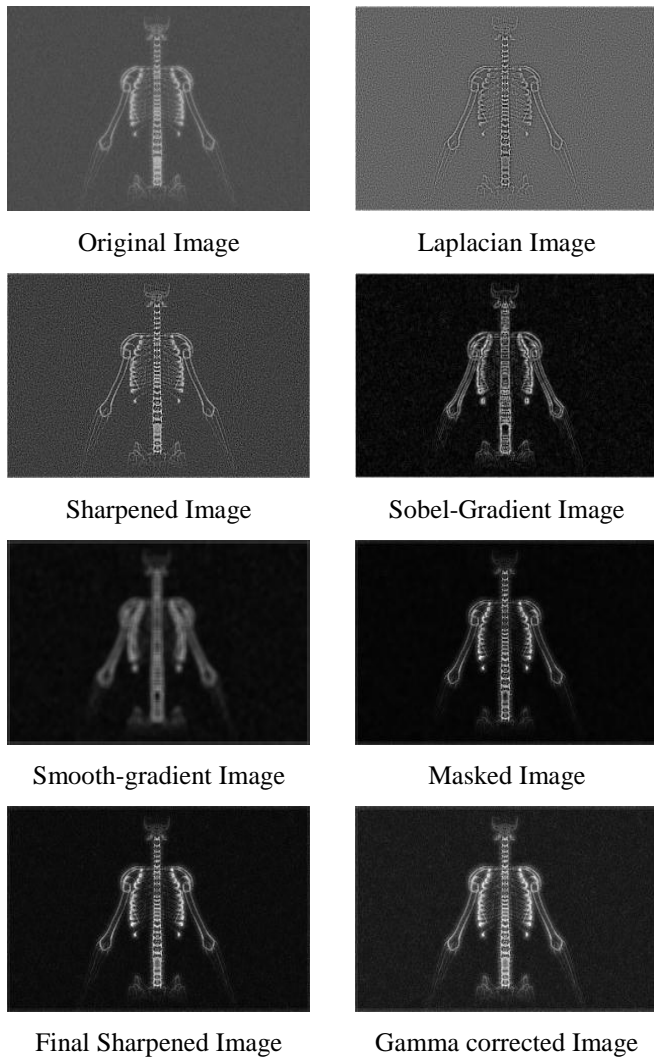


Fig.14. Proposed method implemented on Skeleton Image

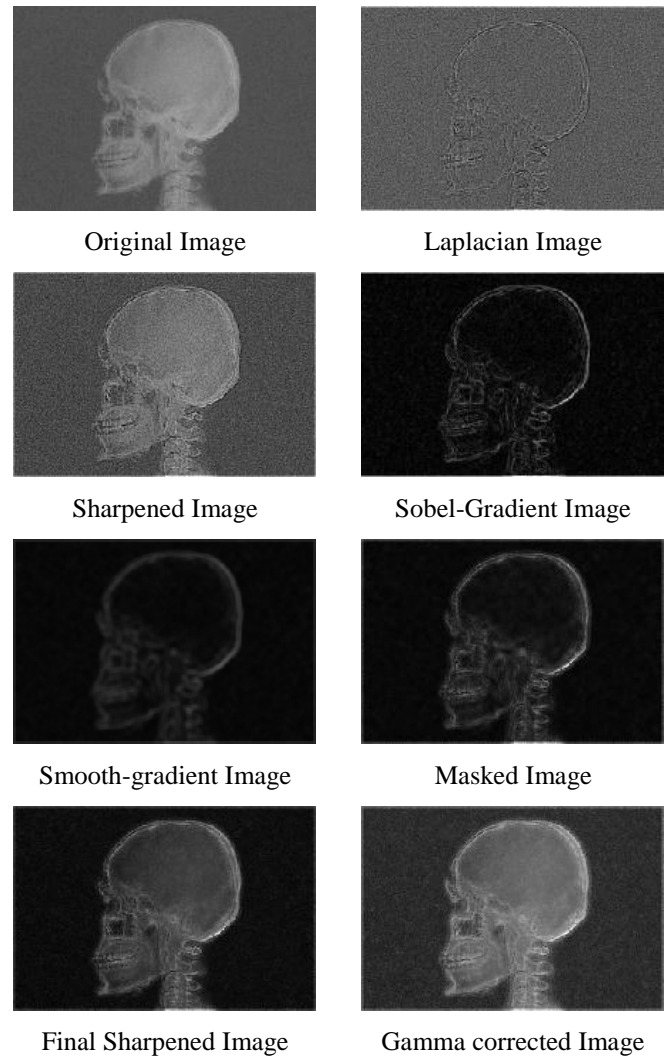
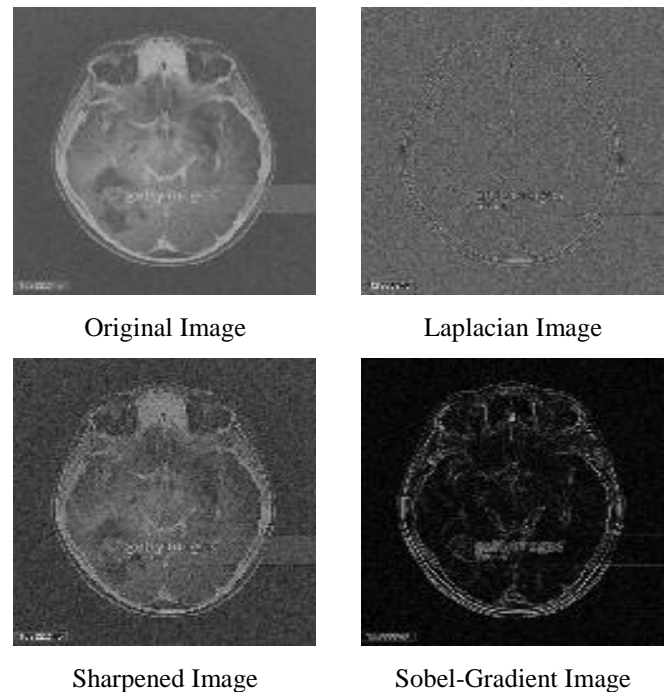


Fig.15. Proposed method implemented on Skull Image



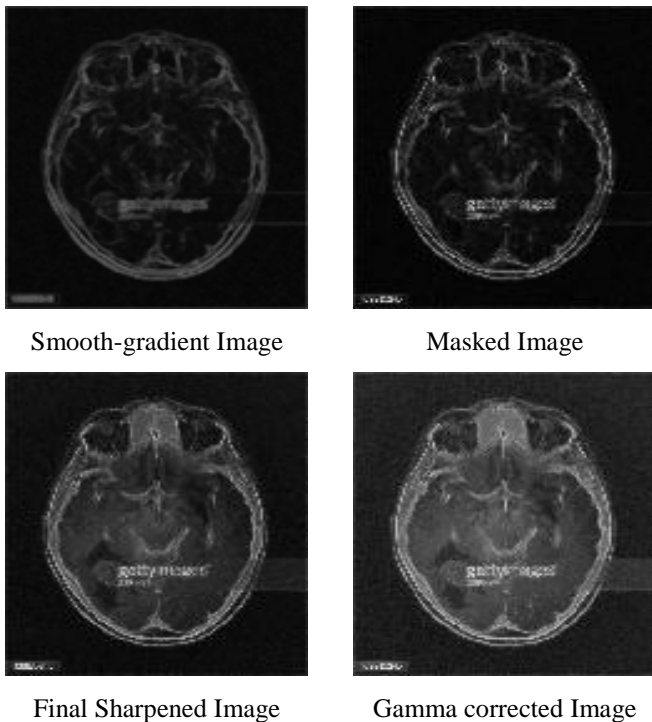


Fig.16. Proposed method implemented on Brain Image

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