2011 8th International Multi-Conference on Systems, Signals & Devices

A DEVELOPED UNSHARP MASKING METHOD FOR IMAGES CONTRAST ENHANCEMENT

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ABSTRACT

In this paper, we propose a developed unsharp masking process for contrast image enhancement. The main idea here is to enhance the dark and bright area in the same way which matches the response of human visual system well. Then in order to reduce the noise effect, a mean weighted high pass filter is used for edge extraction. The proposed method gives satisfactory results for wide range of low contrast images compared with others known approaches.

Index Terms— Contrast image enhancement, mean weighted high pass filter, and unsharp masking

1. INTRODUCTION

Image enhancement is an important topic in many areas of image applications. In literature, a lot of techniques have been used to enhance blurred or imperfectly contrasted images. The unsharp masking technique is the most known method for contrast image enhancement [1]. The edge extraction procedure in the unsharp masking process is usually implemented using Laplacian operator. Although this method is quite effective for enhancing a low contrast images, but it does not discriminate between the feature information and noise [2]. This leads to poor visual perception.

Furthermore, image processing systems must treat the darker regions of an image very carefully because a human observer would perceive any imperfections more easily here than in the brighter regions. Additionally, we can see details more easily in dark regions, whereas the bright regions portions tend to mask details [2]. Also, in bright regions the image is enhanced more because the noise and others noise fluctuations are much less visible, and, in darker regions, the enhancement process is suppressed since it might deteriorate the image quality [3]. To begin, the enhancement process is implemented using linear operator (i.e. Laplacian operator). In order to overcome the drawbacks of the linear systems, quadratic Volterra (QV) filter has been successfully used for edge extraction in the unsharp masking enhancement process. The superiority of the QV filter over linear operator in this area is well demonstrated in [2]. Additionally, the unsharp masking enhancement process has been developed [5] for noise cancellation using the extended Teager algorithm. In other words, a new class of nonlinear filter has been invented for image sharpening, called permutation weighted median (PWM) filter [4]. In [3], QV filter have been extended yielding quadratic weighted median (QWM) filter. This class of filter has been applied for edge enhancement of noisy images by using a new image sharpening process. The advantage of QWM filter over QV filter has been also confirmed in noisy images. In [6] a new nonlinear method for image enhancement is proposed, which matches the response of human visual system well. Others nonlinear approaches have been developed for edge and corner enhancement using anisotropic diffusion [7]. More recently, a method based on local information of the image has been developed for image enhancement [8]. Too a very efficient method for image enhancement has been developed by using curvelet transform [9].

In this paper, we interest in method based on nonlinear operator for image enhancement. As already stated, the main drawbacks of QV filters is the noise amplification due to the sum combinations of the quadratic terms. Also, QV filters extract few features from dark area in the image. For these reasons, the unsharp masking enhancement method is developed in this paper. Firstly, we use the mean weighted high pass filter, in order to reduce the noise amplification in the enhancement process as [5]. Then, the negative operator is used in the enhancement process in order to enhance efficiently the dark area. The developed method is tested for free and noisy images. Simulations gives pleasing enhanced results compared with conventional unsharp masking method and the sharpening method based on WM filter.

The rest of this paper is organized as follows: The next section is devoted to present the general form of QV filters. Section 3 presents the approximate version of QV filters, called mean weighted high pass filter. The next section introduces the developed unsharp masking enhancement process. The last section contains simulations illustrating the advantages of the developed method for free and noisy images.

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2. 2-D QUADRATIC VOLTERRA FILTER

We regard a class of nonlinear filter based on the discrete-time QV series [10]. In this section we present a traditional class of QV filter in 2D framework. A 2D discrete time QV filter is defined by [2]

$$y(m,n) = \sum_{k_1}\sum_{k_2}\sum_{k_3}\sum_{k_4} h_2(k_1,k_2,k_3,k_4) \times x(m-k_1,n-k_2)\,x(m-k_3,n-k_4) \quad (1)$$

This formulation clearly indicates that, although the overall filtering is (quadratic) nonlinear, the filter output is linear with respect to second-order Kernel coefficients and the cross and square terms of the observation samples [2]. In the following, we define a subclass of QV filter approximately equal to product of a local mean estimator and a high pass filter. A thorough theoretical study of some properties of mean weighted high pass filter has been presented in [11].

3. 2-D MEAN WEIGHTED HIGH PASS FILTER

In [12], a special QV filter called Teager's algorithm has been defined. Also, in [5] authors have shown that this filter is approximately equal to local mean multiplied by high pass filter. The characteristics of this class of filter are further studied in [11]. The filter used here for edge extraction gives thinner edges among many others presented in [11]. This filter is applied in the horizontal and vertical direction and also requires a support (3×3) of pixels [11]. It is defined by the input output relationship

$$y(m,n) = 2x^2(m,n) - x(m+1,n)\,x(m-1,n) - x(m,n-1)\,x(m,n+1) \quad (2)$$

According to [5], this class of QV filter can be approximated by mean weighted high pass filter. The system defined by equation 2 has been successfully employed to extract thinner edges from images [2] and to enhance contrast of image [5]. The mean weighted high pass filter is given by the following equation [5].

$$y(m,n) \approx (local - mean) \times \{4x(m,n) - x(m,n-1) - x(m,n+1) - x(m+1,n) - x(m-1,n)\} \quad (3)$$

The local mean adaptive nature of this filter provides us a good reason why the nonlinear filters work very well in image contrast enhancement. According to Weber's law, we can discriminate small differences of brightness in darker regions, but cannot distinguish the same difference in bright areas [5].

4. OVEREVIEW OF THE DEVELOPED METHOD

Unsharp masking enhancement process [1] is one of the most widespread algorithms used for image enhancement. This technique is usually implemented using Laplacian operator. Recently, non linear operator (i.e. QV filter) has been used for image enhancement based on unsharp masking technique [2]. The non linear operator presents an apparent problem appearing in the extraction of features from dark areas. Thus, these areas are not well enhanced as brighter regions. Too, the noise is well amplified due to the sum combination of quadratic terms for QV systems. The developed unsharp masking technique, presented here, is composed by two branches. The first branch extracts the edge from the input image. In the second branch we compute the negative of the input image followed by the extraction of the result. The developed unsharp masking scheme is illustrated by Figure 2.

4.1. The negative operator

The negative transformation is the well known gray level transformation applied to images in spatial domain. The negative of an image with gray level in the range [0, L-1] (with L is equal 256 in our experiments) is obtained by using the negative transformation shown by figure 1. This type of processing is particularly suited for enhancing details embedded in dark regions

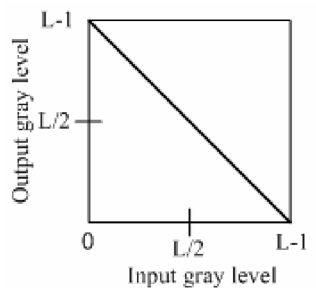

Figure 1. The negative transformation

4.2. The edge extraction

In this paper the edge extraction block in Fig 2 is implemented using mean weighted high pass filter (equation 3) [5]. We choose the filter in order to reduce the noise amplification due to the quadratic terms in equation 2. Also, the filter extracts thinner edges from images. In Fig 2, the top branch of the developed approach the edges of the negative image are extracted. In the down branch, we extract the edge from the input image. In both branches the mean weighted high pass filter is used for edge extraction.

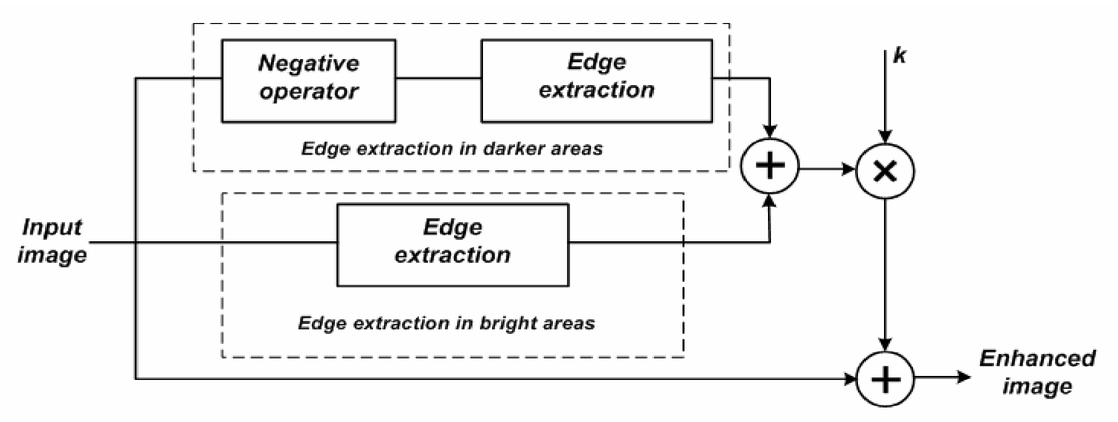

Figure 2. The developed unsharp masking enhancement process

5. EXPERIMENTAL RESULTS

The performance of the developed contrast image enhancement method is evaluated trough simulations presented in this section. In the experiments we regard four images: Test image, zoomed-in version of "Lena" image, boat and house images. The control parameter k is set to 0.1 in our simulations.

The first test image is shown in Fig (3a) and its enhanced version is depicted in Fig (3e). As the second example the zoomed-in version of "Lena" image Fig (3b) is also enhanced using the proposed method. The resulting image is given in Fig (3f). The boat image depicted in Fig (3c) is passed through the developed approach for contrast enhancement. The output of the algorithm is given in Fig (3g). Finally, the house image Fig (3d) is enhanced using the proposed algorithm giving the result in Fig (3h). We remark that the contrast of all images is well enhanced using the developed scheme. The features in the test image (i.e especially the bright regions) are well enhanced. Indeed, in the "Lena" image the hat features are well enhanced. Similarly, in the boat resulting image, could features are enhanced and the improvement of the brightness in darker regions is distinguished.

Figure 4 shows a comparative study of the developed method with others known approaches. The conventional unsharp masking method using quadratic Volterra filter given by equation (2) and the method based on weighted median (WM) filter [4]. This approach has been successfully used for image sharpening. Also, the sharpening operation enhances the negative slope edge and positive slope edge in the same way. The same image sharpening process has been successfully used for noisy images enhancement [3]. The original test, Lena and boat images are depicted in Fig (4a). The resulting enhanced images using weighted median filter are shown in Fig (4b). Also the output of the conventional unsharp masking method is given by Fig (4c) for three images and the result of developed approach is given by Fig (4d). Visually, the proposed method gives more pleasing results than the two others approaches. Indeed, all images are noticeably enhanced and the brightness is well distinguished using our method. In the bright and dark regions, details are enhanced in the same way using the developed approach. Notice also that, for others approaches the images are less enhanced whereas details in bright regions are enhanced more than details in darker areas.

The developed method is also used to enhance “Lena” and “Boat” images corrupted with additive Gaussian noise (SNR = 20dB). The noisy Lena and boat images are given in Fig (5a). The enhanced results using weighted median filter approach are shown in Fig (5b). The output of unsharp masking method is given in Fig (5c) for two noisy images. The enhanced images using proposed method are depicted in Fig (5d). Inspection of the results shows all methods enhance the contrast of images. But, the noise affects are amplified using unsharp masking approach due to the quadratic terms in equation (2). The proposed method exhibit less outliers than others approaches. We remark that the noise is less amplified in our method. In other words, we notice the simplicity of the implementation of the proposed approach over method based on weighted median filter.

In order to evaluate the enhanced result in free noise images, we need a criterion of image sharpness [2]. The mean magnitude of the gradient image (using sobel’s operator) corresponds well with the perceived sharpness. In other words, if two images appear to be equally sharp, their mean gradient magnitude is approximately the same. Table 1 lists the quantitative comparisons of all approaches studied previously. We remark that the mean magnitude of the gradient do not vary significantly for all methods. Consequently, all images are well enhanced using different approaches.

Figure 3. Result of contrast image Enhancement using the proposed approach (a)-(d) are the original images. (e)-(h) the enhanced images using the developed approach with k = 0.1

In order to compare quantitatively the results for noisy images, we use the mean square error (MSE) measure. Which are consistent with the visual results. The enhanced image by conventional unsharp masking method for the noise-free case is taken as the reference image. The MSE calculated for different noise power is summarized in table 2. It should be noted that MSE increase extremely for the unsharp masking approach. But the MSE measure of the method based on weighted median filter are closer to the proposed approach.

Figure 4. Result of contrast image Enhancement using different approaches, (a) original images, (b) Enhanced results using weighted median filter *(L = 0 and T = 15)*, (c) conventional unsharp masking method with k = 0.002 and (d) the proposed approach

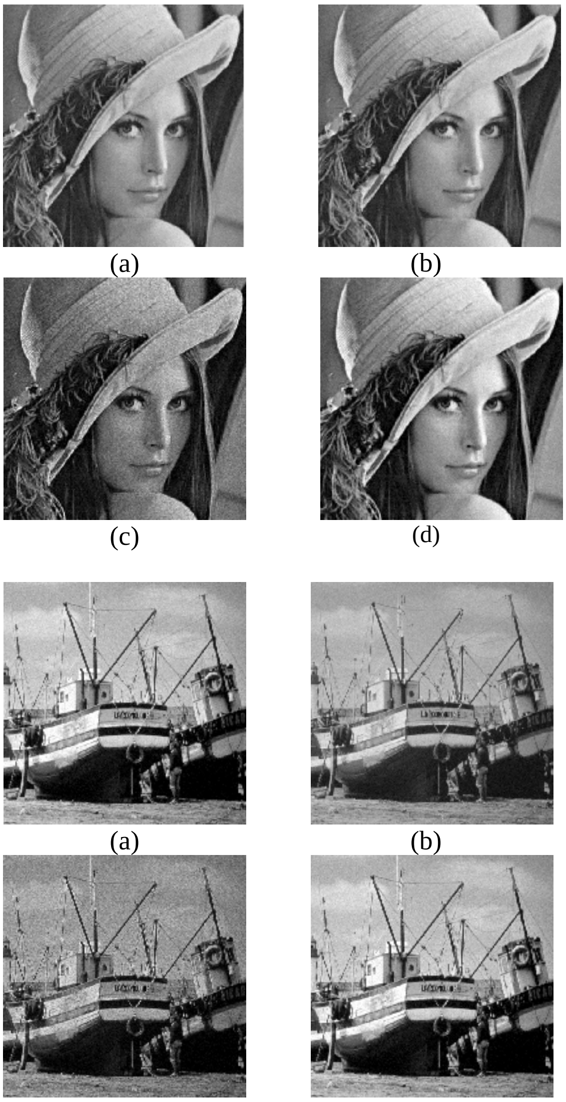

Figure 5. Enhancement of images corrupted with additive Gaussian noise (SNR=20dB). (a) noisy images; (b), the enhanced images using weighted median filter *(L = 0 and T = 15)* ; (c) the enhanced images using conventional unsharp masking method and (d) the enhanced images using proposed approach

Table 1. The mean magnitude of the gradient image $\mu_{\|g\|}$ of the enhanced images for different approaches

	Test image	Lena image	Boat image
Unsharp masking method	25.7	66.78	74.74
WM filter method	24.75	57.95	60.40
The proposed method	**21.74**	**57.77**	**60.31**

Table 2. MSE of the enhanced zoomed-in version of Lena image corrupted with Gaussian noise for different approaches

Noise power	**Unsharp masking**	**WM filter approach**	**Proposed approach**
Noise free	-	23.22	**19.31**
SNR=20dB	134.33	25.17	**24.83**
SNR=16dB	300.91	64.14	**62.91**
SNR=12dB	721.10	169.03	**165.68**
SNR=8dB	1694	402.07	**396**
SNR=5dB	2889	678.15	**668.97**

6. CONCLUSION

In this paper we have presented a developed unsharp masking approach for contrast images enhancement by using mean weighted high pass filter. The developed method gives satisfactory results compared with others known approaches. The contrast of all images is quite enhanced, in the dark area as bright region. Also, the noise affects is well reduced.

7. REFERENCES

[1] A. K. Jain, Fundamentals of Digital Image Processing. Englewood Cliffs, NJ: Prentice-Hall, 1989.

[2] S. Thurnhofer and S. K. Mitra, "A general framework for quadratic Volterra filters for edge enhancement," IEEE Transactions on Image Processing, vol. 5, no. 6, p. 950-963, Jun. 1996.

[3] T. C. Aysal, Kenneth E. Barner, "Quadratic weighted median filter for edge enhancement of noisy images". IEEE Transactions on Image Processing, vol. 15, N. 11, November 2006

[4] M. Fischer, J. L. Paredes, G. R. Arce "Image sharpening using permutation weighted median". In Proc. European Signal Processing Conference (EUSIPCO '00) Tampere, Finland, September 2000

[5] S. K. Mitra, H. Li, I. S. Lin, and T.-H. Yu, "A new class of nonlinear filters for image enhancement," in Proc. IEEE Intl. Conf. on Acoustics, Speech and Signal Processing, (Toronto, Canada), p. 2525 - 2528, 1991.

[6] Wei Zhang, Xuchu Dai, "A New Nonlinear Image Contrast Enhancement Method Matched to Human Visual Perception". Journal of Information and Computational Science, vol. 2, p. 193-198, 2005

[7] M. Nitzberg and T. Shiota. "Nonlinear Image Filtering with Edge and Corner enhancement". IEEE Transactions on Pattern Analysis and Machine Intelligence, vol 14, p. 826-833, 1992

[8] R. Fabrizio "Piecewise Linear Model-Based Image Enhancement". Eurasip Journal on Applied Signal Processing, vol 12, p. 1861-1869, 2004

[9] J. L. Starck, F. Murtagh, E. J. Cands, and D. L. Donoho, "Gray and Color Image Contrast Enhancement by the Curvelet

Transform". IEEE transactions on image processing, vol 12. 2006

[10] G. L. Sicuranza, "Quadratic filters for signal processing," Proc. IEEE, vol. 80, no. 8, p. 1263-1285, Aug. 1992.

[11] S. Thurnhofer, Quadratic Volterra Filters for Edge Enhancement and Their Applications in Image Processing. PhD thesis, University of California, Santa Barbara, 1994

[12] J. F. Kaiser. "On a simple algorithm to calculate the 'energy' of a signal". In Proc. IEEE Intl. Conf. on Acoustics, Speech and Signal Processing Albuquerque, NM, 1990