Unsharp Masking-Based Approach for Color Image Processing

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ABSTRACT

In this paper, we present an unsharp masking-based approach for noise smoothing and edge enhancing. And apply it to color image processing. The proposed structure is similar to the conventional unsharp masking structure, however, a nonlinear function is added to control the behavior of the operator. The proposed scheme enhances the true details, limits the overshoot near sharp edges and attenuates the noise in flat areas. Moreover the use of the control function eliminates the need for the subjective coefficient λ used in the conventional unsharp masking technique.
Simulations show that the processed image presents sharp edges which makes it more pleasant to the human eye. Moreover, the amount of noise in the image is clearly reduced.

1 Introduction

Image segmentation and edge detection are basic operations in computer vision applications. Moreover, they are becoming key operations due to the growing interest in object-oriented video coding and content-based indexing and retrieval in image and video database systems. These two operations are extremely sensitive to noise and blur in the image. Therefore, it is common to apply a preprocessing operator to attenuate the noise and sharpen the edges of objects prior to segmentation or edge detection.

The multichannel nature of the color images adds another degree of complexity to the enhancement problem; due to the inherent correlation that exists between the different components.

A number of linear and especially nonlinear techniques have been proposed in the literature to deal with color images to achieve various tasks, such as restoration, noise filtering and interpolation. Among the nonlinear methods, one can mention the Vector median filter [1] and the Vector directional filter [2].

Recently, a new class of nonlinear filters called the vector rational filters (VRF) for color image interpolation was introduced in [3]. Rational filters, as the name indicates, consist of ratios of two polynomials and were introduced by Leung and Haykin [4] based on the work of Walsh [5] for signal detection and estimation and was later applied by Ramponi for different image processing tasks, such as, interpolation [6], enhancement [6], and filtering [7].

In the following, we extend the class of vector rational filters [3] to deal with color images. Specifically, we propose a rational operator to control the unsharp masking behavior, in order to attenuate the background noise and enhance the edges of objects in color images. We show that this new operator has good performances in noise attenuation and edge enhancement.

2 Unsharp Masking

In the unsharp masking (UM) approach for image enhancement, a fraction of the high-pass filtered image is added to the original one to form the enhanced image [8].

The input/output relation for the unsharp masking filter can be written as follows:

$$x' = x + \lambda z \qquad (1)$$

where x, x' are the input and output images and $\lambda > 0$ controls the fraction of the high-pass filtered image z to be added; see Fig. 1.

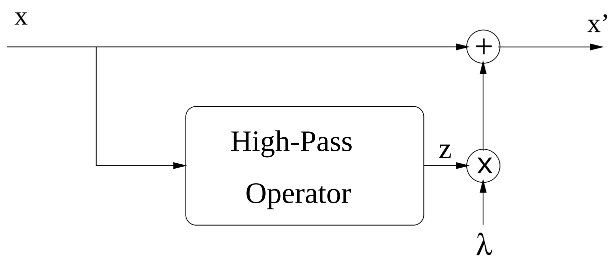

Figure 1: The unsharp masking structure.

This is a simple method, but it has two major drawbacks. First it enhances the noise present in the image. Second, it enhances too much the sharp transitions which leads to excessive overshoot on sharp edges.

Several modifications of the linear UM technique were presented in the literature, [6], [9], [10], trying to reduce the noise amplification. In some of these modifications the Laplacian was replaced by an operator which is less sensitive to noise and in the others adaptive control of the fraction of details added to the image is used.

3 Proposed algorithm

In this paper we propose a method which uses the Laplacian as high-pass filter and controls the amount of enhancement based on the output of a second stage: detail sensing stage, Fig. 2.

The input/output relation of our algorithm can be written as:

$$x' = x + z, \tag{2}$$

where $z = L \times f$ in which L is the Laplacian and f is the control function.

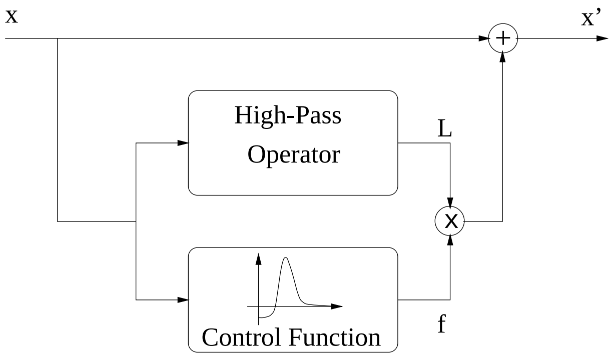

Figure 2: Structure of the proposed scheme.

3.1 Condition imposed on the control function

The control function f has to be simple and obey to several restrictions, in order to enhance true details and reduce the noise.

i) It has to attenuate signal variations which are smaller than a certain threshold D. This will allow us to smooth selectively the signal variations which are attributed to noise corruption.

Let d be the value of the edge sensing operator, it will be specified in the following what is d for one-dimensional single channel and two-dimensional multi-channel signals; and let $\Delta = \frac{d}{D}$.

$$\Delta \leq 1, \quad f(\Delta) \leq 0, \tag{3}$$

ii) The mid-range details which are the signal transitions having magnitude larger than D must be enhanced:

$$1 < \Delta < +\infty, \quad f(\Delta) > 0, \tag{4}$$

iii) To avoid the excessive overshoot over sharp edges:

$$\lim_{\Delta \to +\infty} f(\Delta) = 0, \tag{5}$$

Thus the ideal control function has to have the shape shown in Fig.3.

A simple function verifying all these conditions can be formulated as a rational function which is the ratio of two polynomial functions. Like polynomial functions, a rational function is a universal approximator [4]. Moreover, it can achieve a desirable level of accuracy with a lower complexity and possesses better extrapolation capabilities than polynomial functions.

The proposed control function is:

$$f(\Delta) = \frac{\Delta^m - a}{b\Delta^n + c}, \tag{6}$$

where, Δ is the thresholded output of the edge sensing operator.

By properly choosing $\{a, b, c, m, n\} \in R_+^*$; we can make this function verify all the previous conditions:

i)

$$f(\Delta) \leq 0, \quad \text{for } \Delta \leq 1 \Rightarrow a = 1, \tag{7}$$

ii)

$$f(\Delta) > 0, \text{ for } \Delta > 1, \tag{8}$$

iii)

$$\lim_{\Delta \to +\infty} f(\Delta) = 0 \Rightarrow n > m, \tag{9}$$

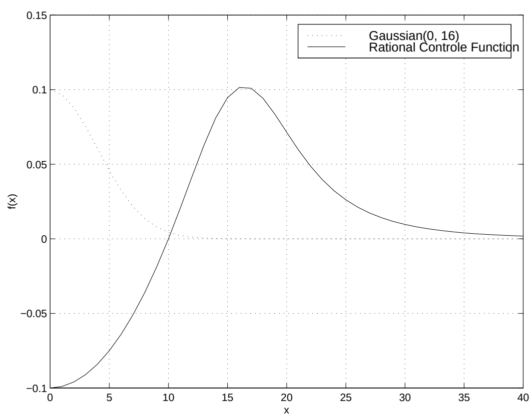

Figure 3: Plot of the control function.

Fig.3 shows a plot of the controle function with parameters: $m = 2$, $n = 4$, $D = 10$.

Fig. 4, compares the action of the proposed operator on one-dimensional ideal steps of different amplitude to those of the linear UM and the mean filter. The enhancement threshold here is $D = 25$. Thus the first step is clearly attenuated and the second which is considered as a true detail is enhanced. Whereas, the mean filter attenuates both steps and the linear UM enhances both of them. The gradient is used as the edge sensing term.

The same operator is applied to enhance a one-dimensional step of amplitude 50 corrupted with zero-mean Gaussian noise of variance 1, see Fig.5.

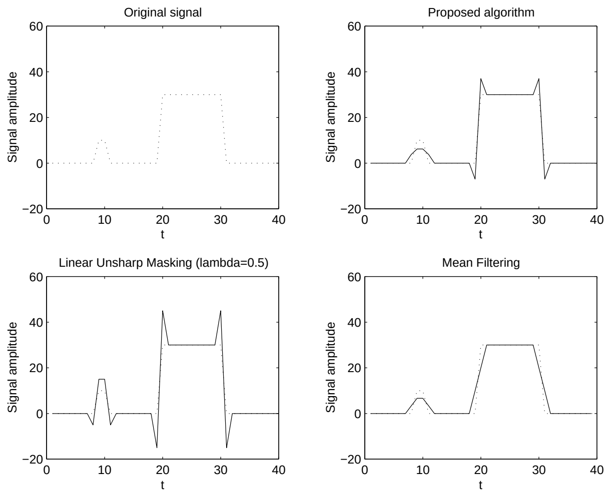

Figure 4: Comparison of the action of different algorithms on step signals of different amplitude.

3.2 The two-dimensional operator

A rational function for image enhancement was introduced by Ramponi in [6], where two operators were proposed for gray scale image enhancement. The first, privileges low-variance details, while the second, puts more emphasis to mid-variance details and should be more convenient in presence of noise. In both operator the Laplacian and Gradient were applied on the vertical and horizontal directions separately.

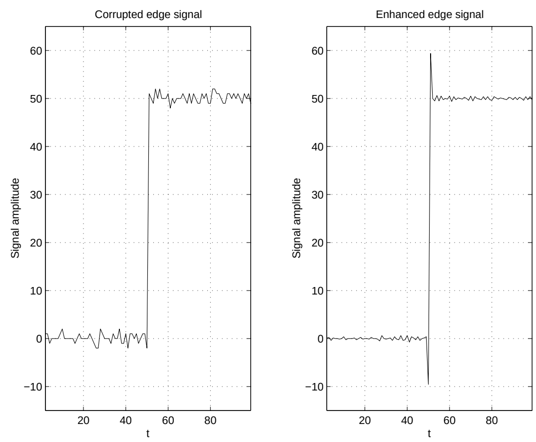

Figure 5: Noisy One-dimensional step edge and its processed version with the proposed operator.

For color image processing the problem of edge sensing is more delicate due to the multichannel nature of the image data. Nevertheless, several measures can be used as similarity measures between the color of neighboring pixels, such as the L_1, L_2 norms [1], the angles between the vectors directions [2] or the gradient operator presented in [11]. In the rest of this paper we adopt the L_2 norm. The computed distances give an indication of the presence of edges in that direction "edge

#	MSE	MAE
Noisy Image	534.95	30.43
Proposed	**314.56**	**21.08**
MF	348.03	20.64
VMF	349.02	22.64
GVDF	327.58	21.46

Table 1: Quantitative measures of the noise attenuation performances of the MF, the VMF, the GVDF and the proposed algorithm.

sensing factor".

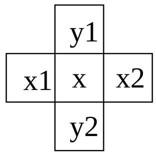

Figure 6: Mask used by the edge sensing operator.

Using the kernel in Fig.6 and considering the pixels of the color image as 3-component vectors in the color space. we can write the fraction of details to be added to the original image as:

$$z = \frac{L_x(\Delta_x^m - 1)}{b\Delta_x^n + c} + \frac{L_y(\Delta_y^m - 1)}{b\Delta_y^n + c}. \tag{10}$$

where $L_x = 2x - x_1 - x_2$, $L_y = 2x - y_1 - y_2$ are the Laplacian applied on the horizontal and vertical directions, respectively; see Fig.6. $\Delta_x = \frac{||x1-x2||_2}{D}$ and $\Delta_y = \frac{||y1-y2||_2}{D}$ are the edge sensing operators applied on the horizontal and vertical directions.

4 Experimental results

To assess the performance of our algorithm, the color image Lenna of size 480x512 is blurred by a 5x5 moving average filter and a zero-mean Gaussian noise with variance 100 is added to it.

MAE and MSE criteria are used to quantitatively assess the capabilities of our scheme in terms of noise attenuation, see Table 1, and to compare them to those of several well known noise smoothing techniques such as the mean filter (MF), the vector median filter (VMF) and the generalized vector directional filter (GVDF)[1].

A magnified region of the processed images using the new algorithm and the conventional unsharp masking method are presented for visual evaluation. It can be clearly seen that the image processed by our algorithm presents sharper edges and smoother flat areas. While the noise is enhanced by the linear UM scheme.

[1]Here, the GVDF uses the α-trimmed mean filter for magnitude processing.

5 Conclusions

A new approach for noise smoothing and edge enhancing, was presented in this paper. And applied to color images. Simulations show that the processed image presents sharp edges which makes it more pleasant to the human eye. Moreover, the amount of noise in the image is clearly reduced.

Current work is focusing on using other measures for the edge sensing term such as the extension of the gradient operator to multivalued images [11], and on robust selection of the control function parameters based on the local statistics of the image.

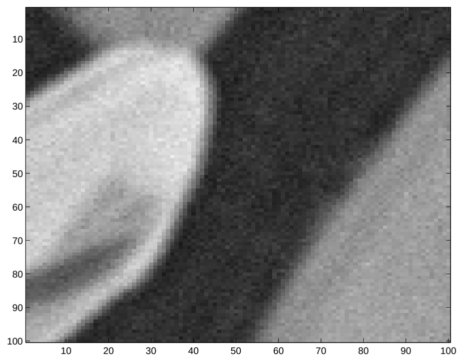

Figure 7: Corrupted Image.

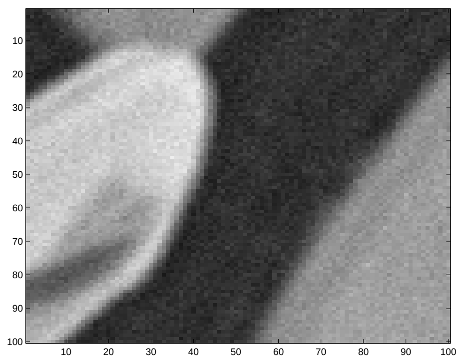

Figure 8: Processed image with the proposed algorithm.

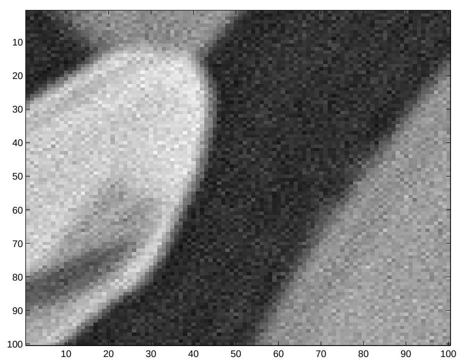

Figure 9: Processed image with the linear UM.

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