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Research Article
Edge-Detected Guided Morphological Filter for Image Sharpening

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A new edge-guided morphological filter is proposed to sharpen digital images. This is done by detecting the positions of the edges and then applying a class of morphological filtering. Motivated by the success of threshold decomposition, gradient-based operators are used to detect the locations of the edges. A morphological filter is used to sharpen these detected edges. Experimental results demonstrate that the performance of these detected edge deblurring filters is superior to that of other sharpener-type filters.

1. INTRODUCTION

Pictures or images play an important role as a mass communication medium. The tremendous volume of optical information and the need for its processing and transmission have paved the way to image processing by digital computers [1].

Image sharpening has played an important role in image processing since the beginning of the digital image revolution [2]. Thus, many well-known techniques for image sharpening exist today and are readily available in most commercial software packages. Moreover, sharpening of images is becoming increasingly important as closed-circuit television performance. This means that the edges can stop and start sporadically. In this new approach, the problem of edge detection is regarded as a classification problem in pattern recognition. Sharpening only at these locations gives unpredictable results. A better approach, taken in this paper, is to enhance the image at edges more closely associated with the grayscale intensity values. This new concept is

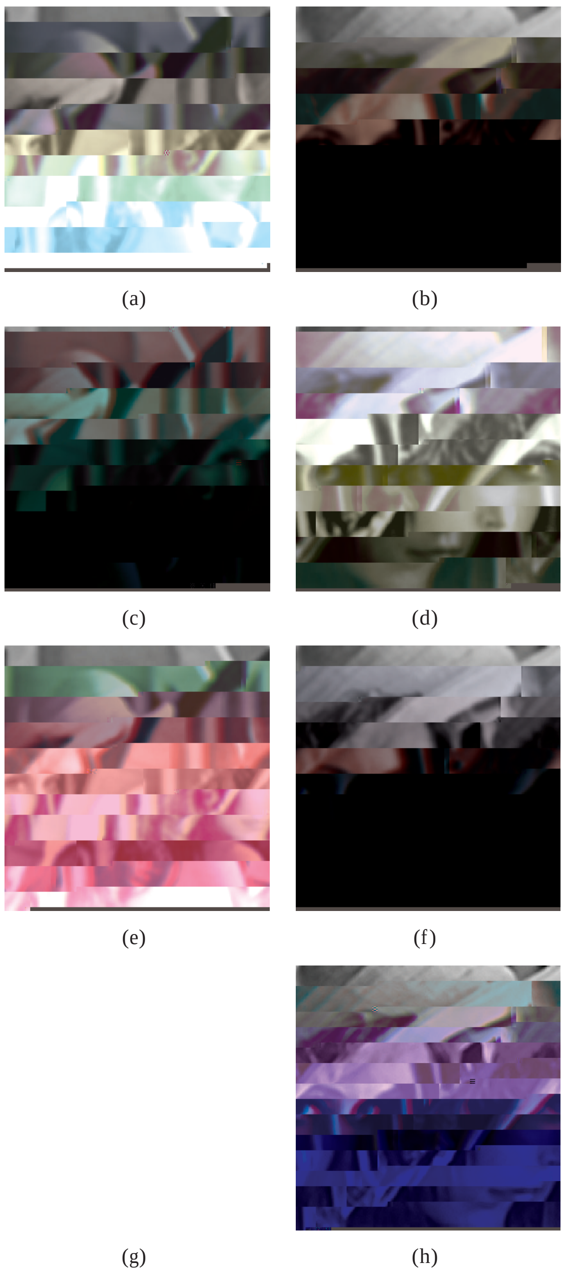


Figure 4: (a) Lenna image corrupted by 10% grain noise and blurred by a Gaussian filter and zoomed-in version in (b). The result of the modified high-pass, QWM, and the proposed edge-detected flat structuring element morphological filter are given in (c), (e), and (g) along with their zoomed-in versions in (d), (f), and (h), respectively.

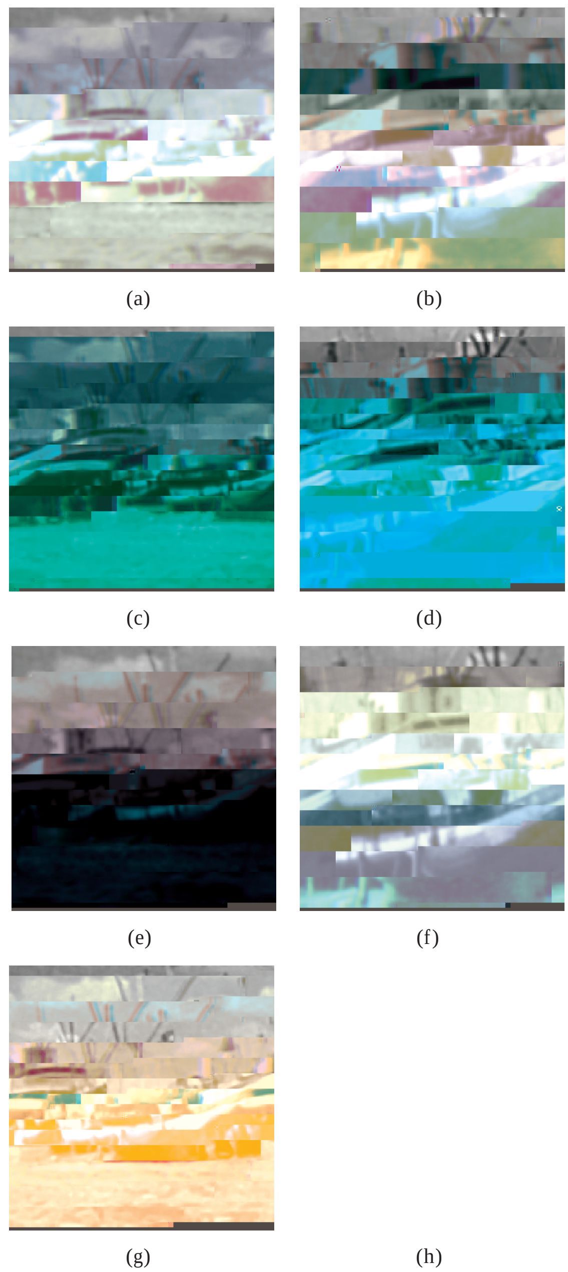


Figure 5: (a) Sailboat image corrupted by 10% grain noise and blurred by a Gaussian filter and zoomed-in version in (b). The result of the modified high-pass, QWM, and the proposed edge-detected flat structuring element morphological filter are given in (c), (e), and (g) along with their zoomed-in versions in (d), (f), and (h), respectively.

In mathematical morphology [18], the transformation which replaces the gray-level value at a pixel by the maximum of the gray-level value in its neighborhood is known as the grayscale dilation operator and is defined by (5) as follows:

$$(f \oplus g)(x) = \max_{\mu \in R^2} \left\{ f(\mu) + g(x - \mu) \right\}, \quad (5)$$

in which function $f(x)$, $f : x \in R^2 \rightarrow f(x) \in R$ is the original image, and $g(x), g : x \in R^2 \rightarrow g(x) \in R$ is the structuring element implicitly defining the weighted neighborhood.

Similarly, the transformation which replaces the gray-level value at a pixel by the minimum of the gray-level

Note that the dilation operator is extensive: $(f \oplus g)(x) \geq f(x)$, and the erosion operator is antiextensive: $(f \Theta g)(x) \leq f(x)$.

3.2. *Contrast enhancement*

Consider a grayscale signal $f(x)$ and a structuring element g containing the origin, Kramer and Bruckner [16] and then redefined by Schavemaker et al. [19] used the following discrete nonlinear filter to enhance the local contrast of $f(x)$ by increasing its gradient as shown in (7):

$$\psi(f(x)) = \begin{cases} (f \oplus g)(x) & \text{if } f(x) \geq \dfrac{(f \oplus g)(x) + (f \Theta g)(x)}{2}, \\ (f \Theta g)(x) & \text{if } f(x) < \dfrac{(f \oplus g)(x) + (f \Theta g)(x)}{2}. \end{cases} \quad (7)$$

According to (7), the output of the filter depends on the relative magnitude of the original signal $f(x)$ as compared to the average of its eroded and dilated versions. If the original signal $f(x)$ is greater than or equal to this average, then the output of the filter ψ follows the dilation of $f(x)$, and if it is lower, then ψ follows its erosion. The dilation is carried out by a flat or concave structuring element and tends to be larger than the original signal close to the gradient. On the other hand, the erosion is lower than the original signal.

Figure 1 shows that the output value of this filter switches between the value of the dilation of $f(x)$ by $g(x)$ and the value of its erosion by $g(x)$. This switch causes the gradient of the signal to increase, which leads to a contrast enhancement [20].

This paper will focus on two types of structuring element in order to sharpen a grayscale image. Firstly, Kramer and Bruckner in [

Table 1: NMSE, SSIM, and ESSIM for different sharpener-type filters. For each image, the value in bold indicates the best filter with the *lowest* NMSE, the *highest* SSIM as well as the *highest* ESSIM.

Sharpener filter	Bridge			Baboon		
	NMSE	SSIM	ESSIM	NMSE	SSIM	ESSIM
Blur image	0.0238	0.6450	0.5152	0.0160	0.6559	0.5046
High-pass sharpener	0.0236	0.5254	0.3451	0.0158	0.5615	0.3408
Modified high-pass sharpener	0.0224	0.5629	0.3689	0.0148	0.6129	0.3930
LUM sharpener	0.0187	0.5979	0.4159	0.0139	0.6228	0.4543
QV	0.0227	0.5565	0.3769	0.0150	0.6123	0.4045
QWM	0.0228	0.5419	0.3636	0.0152	0.5864	0.3748
Bi-LOG	0.0402	0.6564	0.5285	0.0460	0.5857	0.4768
Sharpener filter proposed in [16]	0.0234	0.6537	0.5183	0.0158	0.6556	0.5160
Sharpener filter proposed in [18]	0.0219	0.6573	0.5013	0.0154	0.6578	0.5084
Prewitt edge detection with filter in [16]	0.0236	0.6524	0.5147	0.0157	0.6531	0.5121
Proposed concave structuring element	0.0149	**0.6751**	0.5298	0.0113	**0.7186**	**0.5347**
Proposed flat structuring element	**0.0146**	0.6745	**0.5312**	**0.0112**	0.7167	0.5307

Table 2: NMSE, SSIM, and ESSIM for different sharpener-type filters. For each image, the value in bold indicates the best filter with the *lowest* NMSE, the *highest* SSIM as well as the *highest* ESSIM.

Sharpener filter	Lenna			Sailboat		
	NMSE	SSIM	ESSIM	NMSE	SSIM	ESSIM
Blur image	0.0132	0.7222	0.6026	0.0145	0.6544	0.4742
Modified high-pass sharpener	0.0094	0.7716	0.6525	0.0110	0.7170	0.5502
QWM	0.0128	0.7309	0.6217	0.0138	0.6704	0.4981
Proposed EDMOG fiter	**0.0082**	**0.7848**	**0.6789**	**0.0100**	**0.7368**	**0.5759**

Contrast comparison is defined by

$$c(i, j) = \frac{2\sigma_{ij}}{}$$

Table 1 shows the NMSE, SSIM, and ESSIM as quantitative comparisons between the above-mentioned sharpening techniques. The output of each filter is evaluated by comparing its estimate to the original image.

5. EDGE DETECTION MORPHOLOGICAL OF GAUSSIAN AND EXPERIMENTAL RESULTS

In this section, the edge-detected guided morphological filter will be modified to sharpen degraded images having blurred edges and noisy surfaces. In this sharpening category, the proposed edge-detected guided morphological filter is combined with Gaussian smoothing. Consider (15),

$$G\left(r_g\right) = -e^{-r_g^2/2\sigma_g^2}, \tag{15}$$

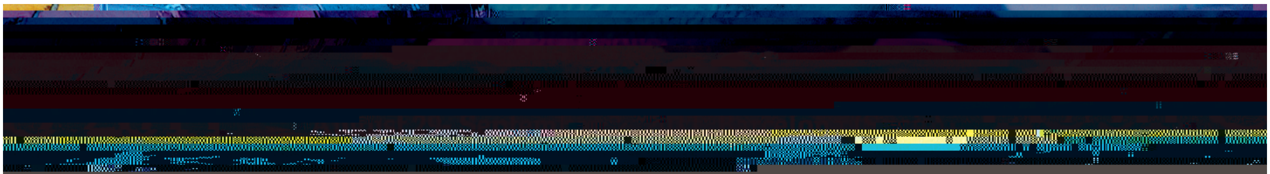
where r_g is the Gaussian blur radius, and σ_g is the Gaussian standard deviation.

Convolving this function with an image results in image blur. Applying the proposed edge-detected guided morphological filter leads to a method referred to as the *edge detection morphological of a Gaussian* (EDMOG) filter.

The performance of the proposed EDMOG filter is compared with a number of sharpener-type filters including modified high-pass sharpener proposed in [22], and QWM proposed in [24].

As test images, the well-known *Lenna* and *Sailboat* images were used. Figures 4 and 5(a) are the test images

[16] H. P. Kramer and J. B. Bruckner, “Iterations of a non-linear transformation for enhancement of digital images,” *Pattern Recognition*, vol. 7, no. 1-2, pp. 53–58, 1975.



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