APPLICATION OF SELF-QUOTIENT ε- FILTER TO IMPULSE NOISE CORRUPTED IMAGE

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Abstract: This paper introduces an application of self-quotient ε-filter (SQEF) to impulse noise corrupted images. SQEF is an improved self-quotient filter (SQF) to extract the image feature from noise corrupted image. Although SQF is a simple nonlinear filter to extract the feature from the image, it cannot extract the feature from the noise corrupted image. On the other hand, SQEF can extract the feature not only when it is applied to the clear image but also when it is applied to the noise corrupted image. In this paper, we especially focus on feature extraction from impulse noise corrupted image, and investigate the effectiveness of self-quotient ε-filter to impulse noise corrupted images.

1 INTRODUCTION

Self-quotient filter (SQF) is a simple nonlinear filter to extract the feature from an image (Wang et al., 2004). It needs only an image, and can extract intrinsic lighting invariant property of an image while removing extrinsic factor corresponding to the lighting. Feature extraction by SQF is simpler than that based on multi-scale smoothing (Gooch et al., 2004). SQF can extract the outline of the objects independent of shadow region. However, as it assumes that the image does not include noise, it can not extract the shape and texture when the noise damages the image. The noise influence becomes large due to the self-quotient effect of SQF.

To solve the problem, we have introduced an advanced self-quotient filter labeled self-quotient ε-filter (SQEF) (Matsumoto, 2010). The proposed filter is based on the idea of SQF and ε-filter (Arakawa et al., 2002). ε-filter is a simple edge-preserving nonlinear filter. Although many studies have been reported to reduce the small amplitude noise while preserving the edge (Himayat and Kassam, 1993; Tomasi and Manduchi, 1998), it is considered that ε-filter is a promising approach due to its simple design. It does not need to have the signal and noise models in advance. It is easy to be designed and the calculation cost is small because it requires only switching and linear operation. We can extract the feature from noisy facial images clearly by defining SQEF as the ratio of two different ε-filters. This paper focuses on the application of SQEF to impulse noise corrupted images.

In next section, we describe the algorithm and the feature of SQEF. Experimental results are shown to clarify the effectiveness of the proposed method for impulse noise corrupted image in Sec.3. Conclusions are given in Sec.4.

2 SELF-QUOTIENT ε- FILTER

Let us define $x(i_1,i_2)$ as the image intensity at the point $\mathbf{i}=(i_1,i_2)$ in the image. The aim of self-quotient filter is to separate the intrinsic property and the extrinsic factor, and to remove the extrinsic factor. To solve the problem, self-quotient filter assumes that a smoothed version of an image has approximately the same illumination as the original one. In self-quotient filter, we first calculate the following equation:

$$z(i_1,i_2)=\frac{x(i_1,i_2)}{F[x(i_1,i_2)]}, \tag{1}$$

where $x(i_1,i_2)$ is the original image and F is the smoothing function. $z(i_1,i_2)$ is then binarized to ex-

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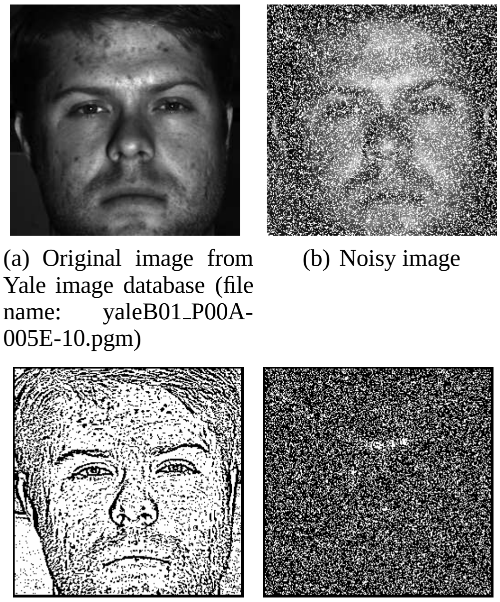


(a) Original image from Yale image database (file name: yaleB01_P00A-005E-10.pgm)

(b) Noisy image

(c) Filter output when we used original image

(d) Filter output when we used noisy image

Figure 1: Self-quotient image from original image and impulse noise corrupted image.

tract face features from the images. When the quantization bit of the image is 8 bits, $z(i_1,i_2)$ is binarized as follows:

$$Q(i_1,i_2) = \begin{cases} 255 \text{ (if } z(i_1,i_2) > Th) \\ 0 \text{ (if } z(i_1,i_2) \leq Th) \end{cases}, \tag{2}$$

where Th represents a threshold value.

Due to the process of Eq.1, the texture and edge can be extracted because the original image is divided by the smoothed image. However, self-quotient filter assumes that the image does not include the noise. When we consider the noise corrupted image, the noise is reduced in the smoothed images $F[x(i_1,i_2)]$, while the original image $x(i_1,i_2)$ includes the noise. As a result, the influence from the noise in SQF is emphasized very much due to the self-quotient effect of SQF in Eq.1.

We show some examples to clarify the handling problem. Figure 1 shows the filter outputs of SQF when we used the original image and noisy image. Figures 1(a) and 1(b) show the original image and noisy image with 30% impulsive noise, respectively. The original image is cut from Yale face image database (file name: yaleB01_P00A-005E-10.pgm) (Georghiades et al., 2001). Figures 1(c) and 1(d) show the filter outputs of the original image and noisy image, respectively. As shown in Fig.1, SQF works well if the image is not damaged with noise. However, it cannot extract the feature from the image clearly when the image is damaged with noise. Our aim is to propose an improved SQF to handle the image including noise.

A simple idea to solve the noise influence in self-quotient filter is to use two smoothed filters instead of original image as follows:

$$z(i_1,i_2) = \frac{F_1[x(i_1,i_2)]}{F_2[x(i_1,i_2)]}. \tag{3}$$

F_1 and F_2 should be different because the output always becomes 1 if F_1 and F_2 are the same smoothed filter.

However, even if we design SQF by using two different smoothed filters, not only the noise is smoothed but also the texture and shape are blurred. As the blur level of one smoothed filter is different from the other, it is also difficult to handle impulsive noise. Hence, we need to employ alternative filters, which can reduce the small amplitude noise effectively, while preserving the texture and shape information instead of simple smoothed filter. The alternative filters should be simple to keep the simplicity of self-quotient filter.

Based on the above prospects, SQEF is designed as follows:

$$z(i_1,i_2) = \frac{\Phi_{\varepsilon_1}[x(i_1,i_2)]}{\Phi_{\varepsilon_2}[x(i_1,i_2)]}, \tag{4}$$

where Φ_ε represents ε-filter described as follows:

$$\begin{aligned} & y(i_1,i_2) = \\ & \Phi_\varepsilon[x(i_1,i_2)] = x(i_1,i_2) + \\ & \sum_{j_1=-K}^{K} \sum_{j_2=-K}^{K} a(j_1,j_2) F(x(i_1+j_1,i_2+j_2) - x(i_1,i_2)), \end{aligned} \tag{5}$$

where $a(j_1,j_2)$ represents the filter coefficient. $a(j_1,j_2)$ is usually constrained as follows:

$$\sum_{j_1=-K}^{K} \sum_{j_2=-K}^{K} a(j_1,j_2) = 1. \tag{6}$$

$F(x)$ is the nonlinear function described as follows:

$$|F(x)| \leq \varepsilon : -\infty \leq x \leq \infty, \tag{7}$$

where ε is a constant number constrained as follows.

$$0 \leq \varepsilon. \tag{8}$$

It should be noted that calculation cost of ε-filter is small because it requires only switching and linear operation. See Refs.(Arakawa et al., 2002; Arakawa and Okada, 2005) if the reader would like to know the details about ε-filter.

$z(i_1,i_2)$ is then binarized as follows:

$$Q(i_1,i_2) = \begin{cases} 255 \text{ (if } z(i_1,i_2) > Th) \\ 0 \text{ (if } z(i_1,i_2) \leq Th) \end{cases}, \tag{9}$$

where Th represents a threshold value.

In ε-filter, ε is an essential parameter to reduce the noise appropriately. If ε is set to an excessively large value, the ε-filter becomes the same as linear filter. On the other hand, if ε is set to 0, it does nothing to reduce the noise anymore, that is, the filter output becomes the input image itself. Hence, SQF is a subset of SQEF. When we take into account the design of SQF, numerator in Eq.4 should become similar to the original image, while denominator in Eq.4 should become an smoothed image.

By setting ε adequately, we can effectively reduce small amplitude noise while preserving shape and texture information. Hence, the optimized ε value is utilized as numerator in Eq.4. It should be noted that the optimized ε can be obtained automatically by using signal-noise decorrelation criterion (Matsumoto and Hashimoto, 2009). On the other hand, a sufficient large ε should be used as the denominator in Eq.4 to emphasize the feature of the image.

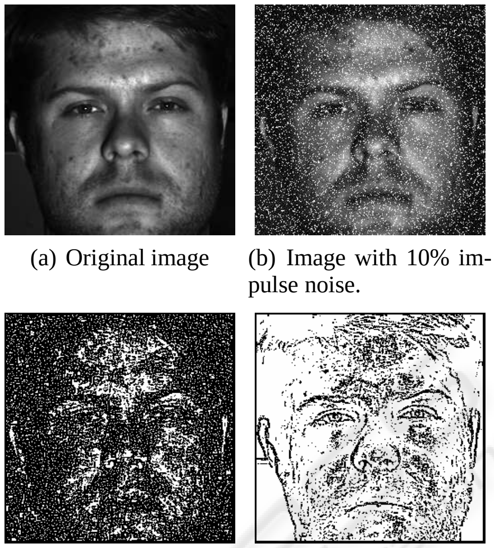
When we apply SQEF to impulse noise corrupted image, it is considered that both ε-filters in SQEF keep the impulse noise in the image unlike when two smoothed filters are employed. Hence, when one filter output in SQEF is divided by the other filter in SQEF, the impulse noise effect is reduced by the self-quotient effects.

3 EXPERIMENTS

To evaluate the filter characteristics of SQEF, we conducted the evaluation experiments using various types of facial images. Some facial images are selected from Yale image database (Georghiades et al., 2001) and facial parts are cut from them. The image size is 256 pixels × 256 pixels. We added 10%, 20% and 30% impulse noise to images, respectively. Throughout the experiments, the filter coefficient a_i is set to $1/(2K+1)^2$ to make it uniform weight. To test the robustness of the the proposed method concerning the window size, the window size was changed from 3×3 to 9×9. We show the results when the window size was set to 5×5 as examples. Similar results could be obtained throughout all the experiments regardless of the window size.

Figures 2, 3, and 4 show the experimental results when we used the image with impulse noise whose percentage was 10%, 20% and 30%, respectively. Figures 2(a), 3(a) and 4(a) show the original image for comparison.

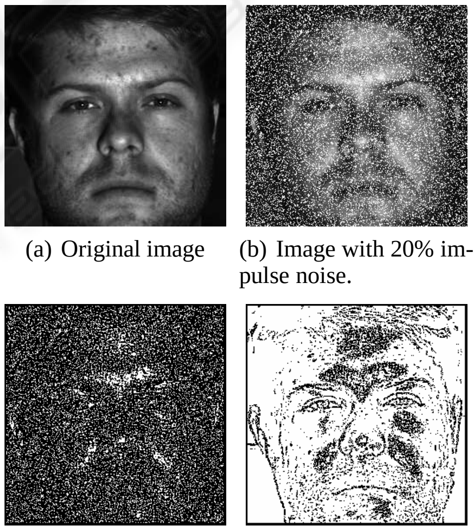
Figs.2(b), 3(b) and 4(b) show the input image with impulse noise whose percentage is 10%, 20% and 30%, respectively. Figs. 2(c), 3(c), and 4(c) show the



(a) Original image (b) Image with 10% impulse noise.

(c) Filter outputs when SQF was used. (d) Filter outputs when SQEF was used.

Figure 2: Experimental results when 10% impulse noise is added.



(a) Original image (b) Image with 20% impulse noise.

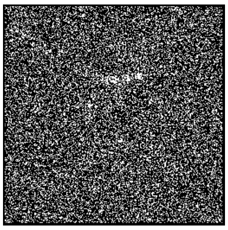
(c) Filter outputs when SQF was used. (d) Filter outputs when SQEF was used.

Figure 3: Experimental results when 20% impulse noise is added.

filter outputs of SQF when we used the input image with noise whose percentage is 10%, 20% and 30%, respectively. Figs. 2(d), 3(d), and 4(d) show the filter outputs of SQEF when we used the input image with noise whose percentage is 10%, 20% and 30%, respectively. As shown in Figs.2, 3 and 4, SQEF can extract the shape and texture information with reducing the noise, while SQF can not extract the feature clearly.

(a) Original image

(b) Image with 30% impulse noise.



(c) Filter outputs when SQF was used.

(d) Filter outputs when SQEF was used.

Figure 4: Experimental results when 30% impulse noise is added.

4 CONCLUSIONS

In this paper, we introduced the applications of a self-quotient ε-filter to impulse noise corrupted image. We showed some experimental results and confirmed the effectiveness of the proposed method. The algorithm is simple and calculation cost is small. It can extract face features from face images with impulse noise. Future works include application of the proposed method to face recognition. We also would like to apply it to medical images to extract disease site.

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