Image denoising method used in earthquake ruin scene based on multi-scale mathematical morphology

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A modified method of image denoising based on multi-scale mathematical morphology is proposed to be used in the earthquake ruin scene. A new morphological arithmetic operator is desiged according to the basic operations in the mathematical morphology, then the multi-scale operation filter is used based on new operator to realize image denoising. Compared with the other methods, this new method can reduce noise of earthquake ruin scene effectively and has a good practicability.

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Visual detection technology is widely applied to get the earthquake ruin environment in earthquake relief work, which can be used by the rescue team to observe the victim under the collapsed buildings or in the narrow spaces directly to make the rescuing plan rapidly and accurately. However, due to the rescue scene environment after earthquake is very complex, the acquisition image of the rescue scene is low signal-to-noise ratio (SNR) and low contrast, it is hard to the rescue personnel to judge the position and orientation of the rescued. Therefore, how to obtain the images with high SNR, and improve the quality of the images is the essential research during the earthquake rescuing. Image denoising[1−3] is a key step to get high image quality, so a modified method of image denoising method based on multi-scale mathematical morphology is proposed to obtain the high quality, high SNR images of earthquake ruin scene.

Mathematical morphology[4,5] is a nonlinear filtering method, which is used to process gray-scale image. Its basic idea is using a certain structuring element to measure and extract the corresponding shape in the image, remove the irrelevant structures to analyse the image. Using the morphology in image processing can simplify image data, and it is easy to be implemented with parallel processing in hardware environment[6,7]. Its basic operation includes dilate, erode, open operation, and close operation. Set the input image $f(x,y)$, $b(x,y)$ is structure element, wherein (x,y) is a coordinate point, f is gray value of point (x,y), b is structure function of point (x,y), D_f and D_b are the definition domain of function f and b respectively. For a gray-scale image, dilate and erode are defined by the maximum value and the minimum value of a neighborhood pixel. $BD_b(f)$ is the dilate of f using the structural function b, defined as

$$BD_b(f) = (f \oplus b)(x,y) = \max\{f(x - x, y - y') + b(x', y')|(x', y') \in D_b\}. \quad (1)$$

Erode is the inverse operation of the dilate, recorded as $BE_b(f)$, defined as

$$BE_b(f) = (f \Theta b)(x,y) = \max\{f(x + x', y + y') - b(x', y')|(x', y') \in D_b\}. \quad (2)$$

Dilate operation is the process that merge the background points contacting the object into the object, which can fill the cavity and form a connected domain in the image, and fill the concave part on the image boundary. Erode operation can eliminate the bright region that is smaller than the structure element, thereby it can remove the isolate noise point and the convex part on the boundary effectively.

The open operation and close operation of the gray image can be express cascading the dilate and erode operation. The open operation of f with b is defined as $BO_b(f)$:

$$BO_b(f) = f \circ b = (f \Theta b) \oplus b. \quad (3)$$

The close operation of f with b is defined as $BC_b(f)$:

$$BC_b(f) = f \bullet b = (f \oplus b) \Theta b. \quad (4)$$

In open operation, erode operation is the first step, then dilate operation is processed, which can remove the isolated area and burr in the processed image. Therefore, using open operation can eliminate the positive peak whose shape is less than the structure element. And the background noise can be eliminated if we choose the appropriate structure element according to the noise characteristics. The sequence of close operation is operating the dilate operation at first, then processing the erode operation, which can fill the small holes in the objects, connect the adjacent objects, and smooth the boundary of the objects.

According to the above instruction, we can see that dilate operations can enhance the energy of the target image, erode operation can remove the isolate noise point and the convex part on the boundary effectively, at the same time, the erode operation increases the concave part on the image boundary, which lead to that the image is not smooth. Open operation and close operation to the gray-scale image can smooth the image effectively, but in this process, the boundary of the object is fuzzy, which reduce the sharpness of the image.

In order to combine the advantages of different operations, the basic operators are improved in this letter, the following operator is defined as

$$MBC_{b_{i,j}}(f) = BO_{b_i}(BE_{b_j}(BD_{b_j}(BC_{b_i}(f)))). \quad (5)$$

Here, the structure elements b_i and b_j can be same or different.

From Eq. (5), the image is processed with $BC_{b_i}(f)$ operation to fill the small holes in the objects, and then $BD_{bj}(f)$ is used to enhance the image to improve the definition of the image. In the following operation, $BE_{b_j}(f)$ and $BO_{b_i}(f)$ are used to reduce the noise in the image and smooth the image. So $MBC_{b_{i,j}}(f)$ has strong filtering function because of the cascade operation of $BC_{b_i}(f)$, $BE_{bj}(f)$, and $BO_{b_i}(f)$, at the same time, this operator not only can smooth the image using the cascade operation of $BC_{b_i}(f)$ and $BO_{b_i}(f)$, but also can protect the energy of the image object to improve the definition of the image using $BD_{bj}(f)$.

In the gray-scale morphology, choosing different structure element will affect the result of the image processing, therefore, the multi-scale operation is used in this letter to improve the stability of the operator.

The multi-scale structure element is defined as

$$b_i = i \cdot b = b \oplus b \oplus b \oplus \cdots \oplus b, \quad i = 1, 2, \cdots, n. \quad (6)$$

Here, the small scale structure element is dilated, so that the structure element size is increased gradually, and its shape is similar.

n scale operation of the improved operator is

$$\mathrm{MMB}^n(f) = MBC_{b_{i+1,j+1}}(MBC_{b_{i,j}}(f)),$$
$$i = 1, 2, \cdots, n; j = 1, 2, \cdots, n. \quad (7)$$

Equation (7) shows that the final image processing result is got by fusing the processing results with the improved operator under different scales.

A gray-scale image of earthquake ruin scene added the Gauss noise (0, 0.01) is used to verify the validity of the proposed method.

Single scale morphology filter operator chooses three structure elements respectively, 2×2 ball structure element, 3×3 ball structure element, and 6×6 ball structure. Multi-scale operator (MMB operator) selects scale value $i = j = 1$, structure element b 3×3 ball. The experimental results are shown in Fig. 1.

From the image results, we can know that MMB filter method can filter the noise better than the single scale morphological filter method, and the clarity of the image can be improved.

To verify the effectiveness of processing results with MMB operator and single scale morphology filter objectively, we use peak SNR (PSNR) as evaluation criterion (Table 1).

In order to verify the image processing effect, we compare the image processing results with the mean filter, median filter, wavelet filter, and the algorithm mentioned in this letter. We use Fig. 1(a) added Gaussian noise as the processed images, processing the results as shown in Table 2.

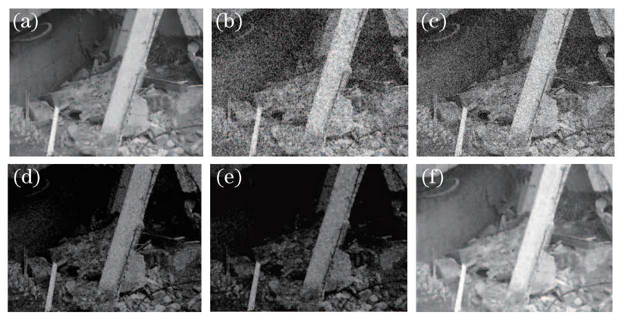

Fig. 1. Multi-scale and single scale processing results. (a) Processed image, (b) the image added the Gaussian noise (0, 0.01), the processed image results with single scale morphology filtered image ((c) 2×2, (d) 3×3, and (e) 6×6 ball structure elements), and (f) the processed image result with MMB filter.

Table 1. PSNR of the Filtered Image with Single Scale Morphology Filter and Multi-Scale Filter

Noise	Morphology Filter (ball(2×2))	Morphology Filter (ball(3×3))	Morphology Filter (ball(6×6))	MMB (i=1)
(0, 0.005)	29.57	24.23	24.13	59.88
(0, 0.01)	28.75	24.12	24.09	56.32
(0, 0.03)	27.99	24.07	24.06	48.85
(0, 0.05)	27.77	24.06	24.06	45.67

Table 2. PSNR of the Filtered Image with Different Filter Method

Noise	Mean Filter Result	Median Filter Result	Wavelet Filter Result	MMB (i=3)
(0, 0.005)	34.11	32.89	47.04	59.88
(0, 0.01)	33.49	31.30	41.84	56.32
(0, 0.03)	32.02	29.47	35.92	48.85
(0, 0.05)	31.23	28.87	34.01	45.67

Comparing the PSNR of the filtered image with different filter methods, it is found that MMB filter operator proposed in this letter can filter the noise in the image effectively, and its effect is better than the processed results by mean filter, median filter, and wavelet filter.

In conclusion, we propose an improved image denoising method based on multi-scale mathematical morphology for earthquake ruin scene. Through the simulation, it can be verify that the proposed method can filter the noise more effectively compared with the traditional filter method.

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