An Image Filtering Method Based on Morphological Gradient Operator

Juan Tang[1,2]
[1]*College of mechanical and electrical engineering, Hebei Agricultural University, Baoding 071000, Hebei, China*
[2]*Key Laboratory of Broiler Chicken Breeding Facilities, Ministry of Agriculture, Baoding 071000, Hebei, China*

Wendi Wang
College of mechanical and electrical engineering, Hebei Agricultural University, Baoding 071000, Hebei, China

Lihua Li[1, 2]*
[1] *College of mechanical and electrical engineering, Hebei Agricultural University, Baoding 071000, Hebei, China*
[2]*Key Laboratory of Broiler Chicken Breeding Facilities, Ministry of Agriculture, Baoding 071000, Hebei, China*
**Corresponding author(E-mail: 974707364@qq.com)*

Abstract
The purpose of image filtering is to reduce as much impact noises play on image quality as possible so as to improve the visual effect of the image and restore it to the clear state approximate to the original image. In the image analysis, it is usually assumed that the image objects with the same gray-level are the regions, so the boundaries or edges of objects are located in where drastic changes occur in gray-level and gradient operation highlights these changes. The filter based on mathematical morphology can resort to geometric feature information, use morphological operators to filter noises effectively and reserve original information of the image. Therefore, this paper proposes an image filtering method based on morphological gradient operator. The structural elements output by erosion and dilation can be used to define the maximum and minimum values of every pixel in the neighborhood. These operations can enhance the changes. The use of morphological gradient operator combined by erosion and dilation can replace and separate the minimum noises. The opening and closing operations in morphology can remove the dark details with smaller dimensions than structural elements and protect the overall gray-level value of the image and bigger dark regions from being affected. The simulation experiment proves the effectiveness of the method of this paper.

Key words: Image Filtering, Morphological Gradient Operator, Structural Elements.

1. INTRODUCTION

Filter processing will directly affect the effectiveness and reliability of the subsequent image processing and analysis. Through image filtering, the impact of noises can be reduced and the definition of the image can be strengthened. In digital image signals, noises are usually the maximum or minimum values, which, through addition and subtraction, disturb the gray-level value of pixels in real image and cause some bright and dark speckle in the image. These speckles will degrade the overall quality of the image and affect the restoration and segmentation of object image as well as feature extraction and recognition. Though the conventional filtering methods can eliminate noises to a certain degree, it is quite limited when it comes to the protection of image feature information (Fan and Wang et al., 2015). Therefore, scholars have tried to construct a smoothing method, which can automatically judge the edges, effectively differentiate different regions and adopt corresponding filtering mechanisms based on specific characteristics in order to better protect edge information while suppressing noises The mathematical morphology method has distinct advantages compared with other spatial- or frequency-domain image processing and analysis. Erosion and dilation can both achieve the fundamental low-pass filtering function. Various new operations suitable for practical applications can be derived from erosion and dilation operations, which, in turn, can construct morphology algorithms with different characteristics and functions. Open-close operation is to remove noises from the image and achieve the purpose of smoothing the image. Its functions are similar to those of low-pass filter(Zhao and Gui et al., 2006).

By reference to the statistical features of image noises, distribution characteristics of pixel points and distribution law of image spectrum, scholars have studied various filtering methods starting from different application demands based on different theories. Image filtering, according to different domains it is located, can be divided into spatial-domain filtering, frequency-domain filtering and wavelet-domain filtering. The denoising processing performed with spatial-domain template is referred to as spatial-domain filtering. As it involves complicated domain transformation, frequency-domain filtering will take more resources and time in hardware(Do and Vetterli, 2005). The following are relatively simple frequency-domain filtering methods: ideal low-pass filter, Butterworth filter and Wiener filter. The application of wavelet transform in image filtering is the process to use the prior knowledge of the image and noises to be processed and design proper method according to the principle that the wavelet coefficients of image and noises are different under different resolutions so as to revise the wavelet coefficient of noisy image(Buades and Coll et al., 2005). While effectively suppressing noises, the traditional filtering algorithms usually blur the image edges, making it impossible to identify the contour of the details. In order to overcome this defect, some new image filtering methods have come into being in recent years. These methods have made excellent achievements in image filtering, but their algorithms are too complicated and they are not ideal to the images with many noises, especially Gaussian noises in terms of filtering result. The main algorithms of gray-level morphology include grey-level morphological gradient, morphological smoothing and texture segmentation. Starting from mathematical morphology, this paper uses the noise separation algorithm based on mathematical morphology to improve the filtering effect(Goldstein and Reed et al., 1998; Mukhopadhyay and Chanda, 2002).

This paper firstly introduces the basic operations of binary morphology and gray-level morphology, i.e. erosion, dilation, open and close operations and some characteristics. A series of practical algorithms of binary morphology and gray-level morphology can be obtained through combinations of these operations. Secondly, it confirms that the filtering effect of morphology is related to the combinations of its fundamental operations, the shapes and sizes of the structural elements. The construction of different filter can affect filtering effect. Based on its characteristics, it constructs a weighted morphological filter for multi-dimensional structural elements. Thirdly, the simulation experiment shows that the algorithm of this paper is effective.

2. IMAGE EROSION AND DILATION

The basic operations of mathematical morphology include dilation, erosion, opening and closing operations. Among them, erosion and dilation are two mutually dual operations. Erosion is to shrink the graphs of objects, while dilation to enlarge them.

2.1. Erosion of Binary Image

Strictly, mathematical morphology is based on geometry and the most fundamental algorithms are erosion and dilation. As a kind of boundary point to remove connected domain, erosion makes the boundary shrink inwards. It can be used to eliminate small and meaningless objects. If there is a tiny connection between two objects, sufficiently big structural elements can be selected to erode the connection. Erosion can separate different objects connected together and remove the small granular noises(Gady, 1999). The formula of erosion is as follows.

$$E(X) = X \Theta B = \{x \mid B + x \subseteq X\} \tag{1}$$

Make a translation of a on the structural element B and obtain B_a. If B_a is included in X, mark down this a point. The set composed by all a points that meet the above-mentioned points is called as the erosion result of X by B.

2.2. Erosion of Gray-level Image

Similar to the erosion of binary image, the erosion of gray-level image is equal to the track drawn by the center of a circle when the semi-circle structural element "slides" beneath the eroded function. However, the structural element must translate under the curve of the function and the semi-circle structural element filters the function from underneath(Liu and Liu, 2012; Portilla and Strela et al, 2003). The steps of erosion are classified as follows.

(1) Scan the original image and find the 1st object point with a pixel value of 1.

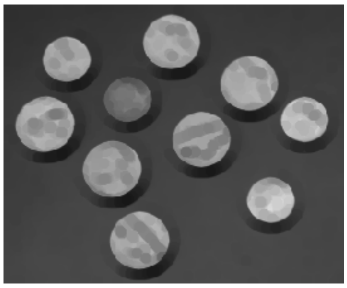
(2) Move the original point of the structural element with preset shape and position of original point to this point.

(3) Judge whether the pixel value covered by the said structural element is all 1. If yes, the pixel value of the same position in the eroded image is 1; if not, it is 0.

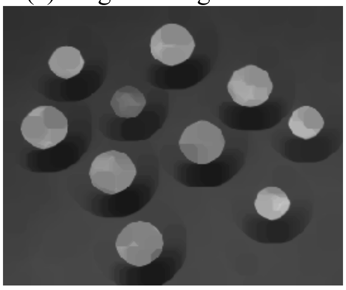
(4) Repeat Step (2) and Step (3) until all pixels of the original image have been completely processed.

Fig.1 below is the erosion results of Coins by flat disklike structural elements with a radius of 5, 10 and 20 respectively.

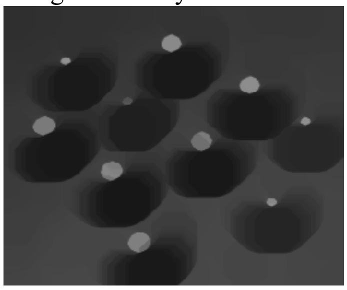
(a) Original image of Coins



(b) Image eroded by structure disk (5)



(c) Image eroded by structure disk (10)



(d) Image eroded by structure disk (20)

Figure 1. Erosion operation of Coins

It can be known from the results of Fig.1 that for image erosion, if the value of structural elements is positive, the output image will be darker than the input image; if the dimensions of bright details in the input image is smaller than the structural element, its impact will be weakened, which depends on the surrounding gray-level value of these bright details as well as the shape and magnitude of structural elements.

2.3. Dilation of Binary Image

Dilation refers to the processing which combines the background points of object region into the object in order to expand the boundaries. Dilation can be used to fill in certain blankness and remove the small granular noises in the object region. Dilation can be seen as the dual operation of erosion. It is defined as follows: make a translation of a on structural element B and obtain B_a. If B_a hits X, record down this a point. The set that includes all a points that satisfy the above conditions is named as the dilation result of X by B. Dilation is usually defined as follows.

$$X \oplus B = \{x \mid B + xUx \neq \varnothing\} \tag{2}$$

It can be seen from Formula (2) that if the original point of structural element B translates to (x, y), its intersection with X is non-empty. The set of all these points (x, y) is the dilation result (Decker and Francois et al., 2011).

2.4. Dilation of Gray-level Image

Gray-level dilation can be achieved by translating the original point of structural element until it overlaps with the signal and then seeking the maximum value of structural element on every point in the signal. Dilation adds pixels to the edges of the objects in the image while erosion deletes the edge pixel. The number of pixels added or deleted is related to the size and shape of the structural elements used in image processing(Elad and Aharon, 2006). The steps of dilation are shown as follows.

(1) Scan the original image and find the 1st background point with a pixel value of 0.

(2) Move the original point of the structural element with preset shape and position to this point.

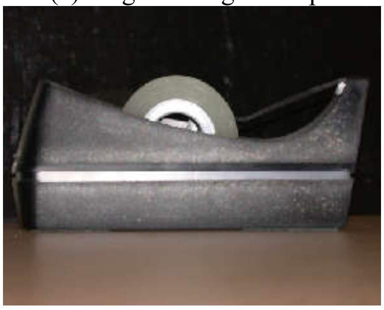
(3) Judge whether there is any object points with a pixel value of 1 contained by that structural element. If yes, the pixel value of the same position of dilated image is 1, if not, it is 0.

(4) Repeat Step(2) and Step (3) until the processing of all pixels in the original image is completed.

Fig.2 shows the dilation results of Tape with the structural elements of 5-order unit matrix.

(a) Original image of Tape

(b) Image after one dilation with structural element



(c) Image after two dilations with structural element

(d) Image after three dilations with structural element

Figure 2. Dilation operation of Tape

It can be known from Fig.2 that as for the dilation operation of image, if the value of structural elements is all positive, the output image will be brighter than the input image and they will be reduced or removed in the dilation according to the relationship between the gray-level value, shapes of dark details in input image and the structural elements.

3. IMAGE FILTERING METHOD WITH ALTERNATIVE OPENING AND CLOSING OPERATIONS

3.1. Opening Operation

Opening operation makes the contour of the image smooth, disconnect the narrow interruption and eliminate the tiny protrusions. Use structural element B to perform opening operation on Set A. Firstly, use B to erode A and then dilate the result with B. It is defined as follows.

$$A \circ B = (A \odot B) \oplus B \tag{3}$$

For binary image, opening operation can delete the object regions that do not contain the template shape, smoothen the object contour, disconnect the narrow interruption and remove the tiny protrusions.

3.2. Closing Operation of Binary Image

Closing operation can also make the image contour smooth, but as opposed to opening operation, it can eliminate the narrow interruption and slender gap, remove small holes, and fill up the cracks in the contour. The use of structural element B performing closing operation on Set A is defined as follows.

$$A \circ B = (A \oplus B) \odot B \tag{4}$$

Closing operation can smooth the image contour, connect the narrow loopholes into slender bend and fill up the hopes smaller than the neighborhood in the template. Closing operation is defined as follows.

3.3. Steps of Algorithm of This Paper

Assume image $I(x, y), 0 \le x, y \le N-1$ and the template $T(i, j), 0 \le i, j \le m$, the erosion calculation formula is

$$E(x, y) = (I \Theta T)(x, y) = \min_{0 \le i, j \le m-1} \left[I(x+i, y+j) - T(i, j) \right] \tag{5}$$

The dilation calculation formula is

$$D(x,y)=(I\oplus T)(x,y)=\max_{0\le i,j\le m-1}\left[I(x+i,y+j)+T(i,j)\right] \tag{6}$$

The granularity distribution function is

$$f(\lambda)=\frac{A(X_{\lambda B})-A(X_{(\lambda+1)B})}{B(\lambda B)}\ge 0 \tag{7}$$

Here, B refers to the structural elements with a radius of 1, λB the structural elements with a radius of λ, $X_{\lambda B}=open(X,\lambda B)$ the granularity after removing those with a radius $<\lambda B$ and $A(X_{\lambda B})$ the area (i.e. the number of points).

Morphological gradient can improve the intensity of pixels in the neighborhood determined by the structural elements and the structural elements output by erosion and dilation can define the maximum and minimum value of each pixel in the neighborhood; therefore, these most fundamental operations can be used to strengthen the changes in the following three combinations.

$$G_d(x,y)=f(x,y)\oplus B(x,y)-f(x,y) \tag{8}$$

$$G_d(x,y)=f(x,y)-f(x,y)\Theta B(x,y) \tag{9}$$

$$G_d(x,y)=f(x,y)\oplus B(x,y)-f(x,y)\Theta B(x,y) \tag{10}$$

Formula (8) is referred to as dilation gradient and Formula (9) as erosion gradient. Seek the sum of Formula (8) and Formula (9) and obtain morphological gradient (10). The algorithm as follows.

(1) Assume that the structural element B is spherical, it becomes a circle when projected to x and $f(x)$, provide a cross-section $f(x)$ of image $f(x,y)$ when y is a constant.

(2) Perform opening operation on f with B, it can be seen as that B falls down from one end to the other along the lower edge of f.

(3) When B falls down along the lower edge of f, the parts of f that don't contact B will be compressed to contact B. In practical, opening operation is frequently used to eliminate the dark details with smaller sizes compared with structural elements while protecting the overall gray-level value and big bright regions of the image from being affected.

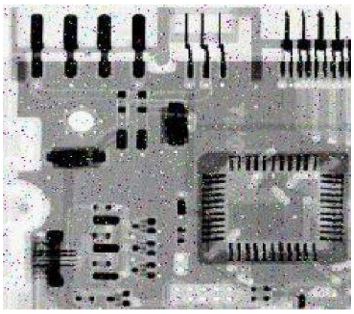
(4) Perform closing operation on f with B, It can be seen as that B falls down from one end to the other along the upper edge of f.

(5) When B moves along the upper edge of f, the parts of f that don't contact with B will be filled up to contact B.

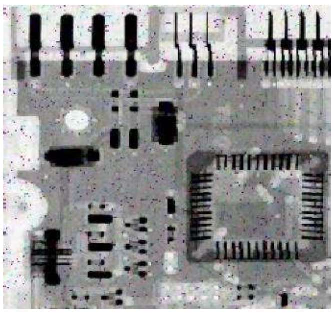
(6) If using a 5×5 all "1" structural element, an edge with a width of two or three pixels can be obtained. When the original point of Set B is in the boundary of the set, some of structural elements will be located outside the set. The common processing under this condition is to assume that the value outside the boundary is 0.

4. EXPERIMENTAL TEST AND ANALYSIS

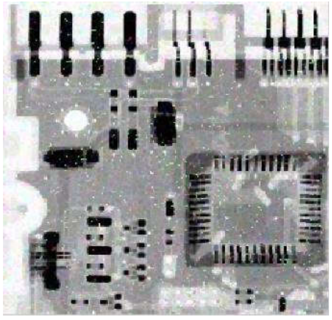
The software platform used in the experiment of this paper is MATLAB 2014a and this paper uses the image filtering method with alternative opening and closing operations to perform image de-noising. Perform opening and closing operations on the gray-level image shown in Fig.3(a). (b) is the result of opening operation with the structural element of 5-order unit matrix, (c) is the result of closing operation with the structural element of 5-order unit matrix, (d) is the result of opening operation with the flat rhombus structural element with a distance between the original point to the peak point of 3 and (e) is the result of closing operation with the flat rhombus structural element with a distance between the original point to the peak point of 3.



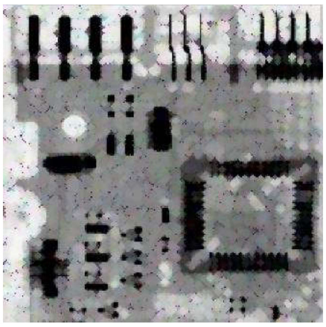
(a) Noisy image



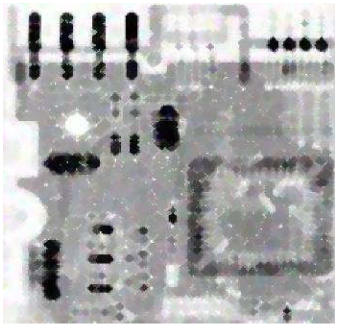
(b) Opening operation with the structural element of 5-order unit matrix



(c) Closing operation with the structural element of 5-order unit matrix



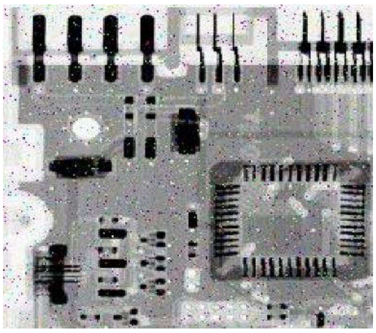
(d) Opening operation with the flat rhombus structural element



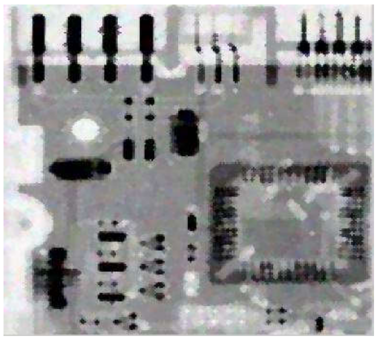
(e) Closing operation with the flat rhombus structural element

Figure 3. Opening and closing operations

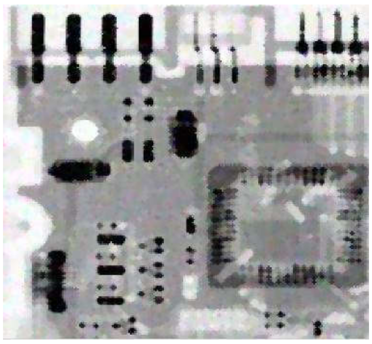
Closing operation fills or moves the disk along the exterior edge of the image. If the structural element B is a disk, its rotation will not have any impact on the operation result. Apparently, when closing operation filters the outside of the image, it only smoothens the sharp angle protruding into the interior of the image. in Fig.4, opening-closing operation result is shown as (b), closing-opening operation result as (c) and the result of alternative filtering as (d).



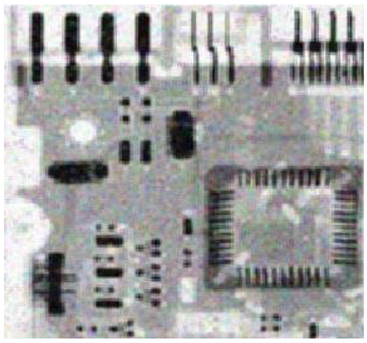
(a) Noisy image



(b) Opening-closing operation



(c) Closing-opening operation



(d) Alternative filtering

Figure 4. Image filtering with alternative opening-closing operations

Opening operation can smooth certain tiny connections, burrs on edge and isolated speckles of the image and can be obtained by translating the structural elements that can be filled into the image through calculation. This is also the result of "erosion first, dilation second". If opening operation uses a disk to firstly erode and then dilate a rectangle, the disk will perform opening operation on the rectangle, which will make the interior angle rounded. Such rounding result can be obtained by sliding the disk within the rectangle and calculate the intersection which can be filled into. While maintaining the size and morphology of original object, closing operation fills up the concave regions, bridges the holes or cracks and fills the holes, concave regions and the disconnected objects. It can maintain the object size unchangeable.

5. CONCLUSIONS

Mathematical morphology can simplify image data, preserve their basic shapes and eliminate the irrelevant structures. In image analysis, it is normally assumed that the image objects with the same gray-level are regions. Under this circumstance, object boundaries or edges are usually located in the places where the gray-level changes drastically and gradient operation stresses these changes, the noise separation method based on morphological gradient operations in this paper can effectively extract the principal components and improve the rate of contribution. Use the structural elements with certain morphology to measure and extract the corresponding shapes in the image so as to achieve the purpose of image filtering, suggesting that mathematical morphology has certain practical significance in its applications to image filtering.

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REFERENCES

Buades A, Coll B, Morel J M. (2005) "A Review of Image Denoising Algorithms with A New One Multiscale", *Modeling and Simulation*, 4(2), pp.490-530.

Decker A De, Francois D, Verleysen M, Lee J A. (2011) "Mode Estimation in High-Dimensional Spaces with Flat-Top Kernels: Application to Image Denoising", *Neurocomputing*, 74(9), pp.1402–1410.

Do M N, Vetterli M. (2005) "The Contourlet Transform: An Efficient Directional Multiresolution Image Representation", *IEEE Transactions on Image Processing*, 14(12), pp.2091- 2106.

Elad M, Aharon M., (2006) "Image Denoising via Sparse and Redundant Representations over Learned Dictionaries", *IEEE Trans Image Process*, 15(2), pp.3736-3745.

Fan W, Wang K, Cayre F, et al. (2015) "Median Filtered Image Quality Enhancement and Anti-Forensics via Variational Deconvolution", *IEEE Transactions on Information Forensics and Security*, 10(5), pp.1076-1091.

Gady Agam. (1999) "Regulated Morphological Operations", *Pattern Recognition*, 32, pp.133-134.

Goldstein J S, Reed I S, Scharf L L. (1998) "A Multistage Representation of The Wiener Filter Based on Orthogonal Projections", *Information Theory IEEE Transactions*, 44(7), pp.2943-2959.

Liu F, Liu J. (2012) "Anisotropic Diffusion for Image Denoising Based on Diffusion Tensors", *Image Represent*, 23(3), pp.516–521.

Mukhopadhyay S, Chanda B. (2002) "An Edge Preserving Noise Smoohting Technique Using Multiscale Moprhology". *Signal Poreessing*, 82(4), pp.527-544.

Portilla J, Strela V, Wainwright M J, Simoncelli E P. (2003) "Image Denoising Using Scale Mixtures of Gaussians in the Wavelet Domain", *IEEE Trans. Image Process*, 12 (11), pp.1338–1351.

Zhao Yu-qian, Gui Wei-hua, Chen Zhen-cheng, et al. (2006) "Edge Detection of Brain Magnetic Resonance Image by Multiscale Morphology". *International Journal of Tomography & Statistics*, 4(W06), pp.33-43.