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A method of generating scratched look calligraphy characters using mathematical morphology

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Abstract

We propose a method to generate scratched look calligraphy characters by mathematical morphology, and it can decide on the number of times of thinning computation and the structuring element and also can know whether the sizes of generated calligraphy characters are same as the original one in theory. By different changed structuring elements, we can get various scratched look calligraphy characters.

Keywords: Mathematical morphology; Binary image; Skeleton; Structuring element; Scratched look calligraphy characters

1. Introduction

Mathematical morphology is a theory successfully used in image analysis and image processing, characteristic extraction, pattern recognition and filtering of image. Since this theory consists of set operations, it becomes possible to process an image by parallel computing.

As we already know calligraphy fonts have been used in our computer till now and it does not have the natural scratched and blurred look, and [3] gave a method to show that scratched or blurred look calligraphy characters can be generated by using mathematical morphology. In this method one is not sure how many times the thinning computation should be carried out and by what condition the structuring element should be selected.

In this paper, we propose a method to generate scratched look calligraphy characters by mathematical morphology. By this method, we can decide on number of times of the thinning computation

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and structuring element, and can also know whether the sizes of generated calligraphy characters are same as the original one in theory.

The basic operations of mathematical morphology are introduced in Section 2, and Section 3 describe the method of generating an image skeleton first and next the method of generating scratched look calligraphy characters from the skeleton.

2. Basic operations of mathematical morphology

In this paper, the binary image is considered, which means the image has black and white pixels only. Mathematical morphology consists of set operations. Sets in mathematical morphology represent the shapes of binary image.

Let A and B be sets in two-dimensional Euclidean space $\boldsymbol{Z}^2$ with elements a and b. Binary morphological operations of dilation, erosion, opening and closing on the sets are introduced as follows [1,2,4,7].

(1) *Dilation*: Dilation is the operation which combines two sets using vector addition of set elements. The dilation of A by B is defined by

$$A \oplus B = \{c \in \boldsymbol{Z}^2 | c = a + b \text{ for some } a \in A \text{ and } b \in B\}. \tag{2.1}$$

Dilation as a set theoretical operation was proposed by Minkowski, and is often used as an image operator for shape extraction and estimation of image.

Usually, A is considered as the image undergoing analysis, while B is referred to as the structuring element.

The dilation of A by B can be computed as the union of translation of A by the element b of B:

$$A \oplus B = \bigcup_{b \in B} (A)_b, \tag{2.2}$$

where the translation of A by b is defined by

$$(A)_b = \{z \in \boldsymbol{Z}^2 | a + b, a \in A\}. \tag{2.3}$$

(2) *Erosion*: Erosion is the operation which combines two sets using vector subtraction of set elements. The erosion of A by B is defined by

$$A \ominus B = \{x \in \boldsymbol{Z}^2 | x + b \in A \text{ for every } b \in B\}. \tag{2.4}$$

The erosion of A by B is the intersection of all translations of A by the element $-b$, where $b \in B$:

$$A \ominus B = \bigcap_{b \in B} (A)_{-b}. \tag{2.5}$$

Erosion is often used as a method for the shrinking of the original image.

(3) *Opening*: In practice, dilation and erosion are usually used as a pair. Since the result of iteratively applying dilations and erosions is an elimination of specific image detail smaller than the structuring element without the global geometric distortion, the operations of opening and closing are defined as follows:

The opening of X by B is defined by

$$X \circ B = (X \ominus B) \oplus B. \tag{2.6}$$

(4) *Closing*: The closing of X by B is defined as follows:

$$X \bullet B = (X \oplus B) \ominus B. \tag{2.7}$$

3. The generation of calligraphy characters with scratched look by mathematical morphology

3.1. Generating the skeleton of an image

For image X, let $SK(X)$ be its skeleton. In [5], a definition of the skeleton of an image in two-dimensional continuity space has been given. In practice, since digital images are processed, [4,6] gave a definition of skeleton in two-dimensional discrete space:

$$SK(X) = \bigcup_{n=0}^{N} S_n(X), \tag{3.1}$$

where N is the number of times of the thinning computation and

$$S_n(X) = (X \ominus nB) - (X \ominus nB) \circ B, \tag{3.2}$$

where B is a smallest disk structuring element which contains the origin, and

$$nB = B \oplus B \oplus \cdots \oplus B.$$

Usually, for radii 1 and 2, the smallest disk discrete symmetric structuring elements are called SQUARE and CIRCLE, which is shown in Figs. 1 and 2.

Since (3.2) can be changed into

$$\begin{aligned} S_n &= (X \ominus nB) - (X \ominus nB) \circ B \\ &= (X \ominus nB) - (X \ominus nB) \ominus B \oplus B \\ &= (X \ominus nB) - (X \ominus (n+1)B) \oplus B, \end{aligned} \tag{3.3}$$

a fast algorithm for computing the skeleton can be obtained as follows.

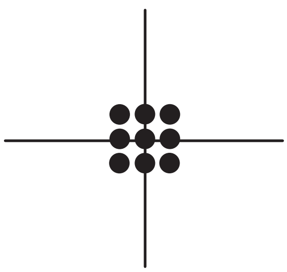

Fig. 1. Structuring element SQUARE.

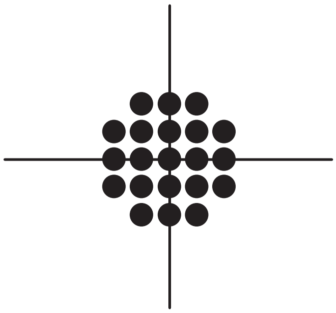

Fig. 2. Structuring element CIRCLE.

Fig. 3. Original image.

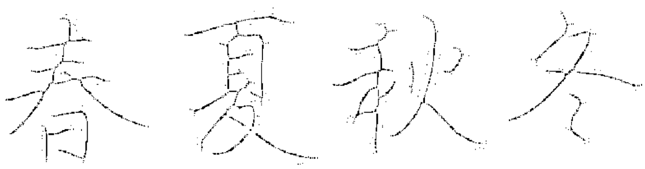

Fig. 4. The skeleton of the image by SQUARE, $N = 11$.

Algorithm 1.

1. $n = 0$, $\text{Erosion} = X \ominus B$, $S_n = X - \text{Erosion} \oplus B$.
2. While $\text{Erosion} \neq \phi$, do
   (a) $n = n + 1$.
   (b) $S_n = \text{Erosion} - \text{Erosion} \ominus B \oplus B$.
   (c) $\text{Erosion} = \text{Erosion} \ominus B$.

As an example, the original image of calligraphy characters is given in Fig. 3. Using the structuring element SQUARE, its skeleton can be obtained by Algorithm 1 as shown in Fig. 4. Here, when computing the skeleton of Fig. 3, the number of times of the thinning computation N can be obtained and $N = 11$.

From Fig. 4, we can see some errors in the skeleton which are caused by the discrete disk structuring element [8].

3.2. Generating the scratched look of calligraphy characters

In [4], from the skeleton of an image, the image can be regenerated by

$$X = \bigcup_{n=0}^{N} [S_n(X) \oplus nB]. \tag{3.4}$$

Since (3.4) can be written as

$$\begin{aligned}
X &= \bigcup_{n=0}^{N} [S_n(X) \oplus nB] \\
&= S_N(X) \oplus NB \cup S_{N-1}(X) \oplus (N-1)B \cup \cdots \cup S_1 \oplus B \cup S_0(X) \\
&= [S_N(X) \oplus (N-1)B \cup S_{N-1}(X) \oplus (N-2)B \cup \cdots \\
&\quad \cup S_1(X)] \oplus B \cup S_0(X) \\
&= [[S_N(X) \oplus (N-2)B \cup S_{N-1}(X) \oplus (N-3)B \cup \cdots \\
&\quad \cup S_2(X)] \oplus B \cup S_1(X)] \oplus B \cup S_0(X) \\
&\ \ \vdots \\
&= [\cdots [[[S_N(X) \oplus B \cup S_{N-1}(X)] \oplus B] \cup S_{N-2}(X)] \cdots] \oplus B \cup S_0(X),
\end{aligned} \tag{3.5}$$

a fast algorithm from (3.5) can be obtained as follows.

Algorithm 2.

1. $n = N$, Dilation $= S_n(X) \oplus B$, $X =$ Dilation $\cup S_{n-1}(X)$
2. For $n = N-1, \ldots, 0$, do
   (a) Dilation $= X \oplus B$.
   (b) $X =$ Dilation $\cup S_n(X)$.

As we know, a method in [3] has shown that scratched or blurred look calligraphy characters can be generated by using mathematic morphology. We consider that if we change some black elements of the structuring element into white pixels (notice: some boundary elements can be changed but not all), from (3.4) and (3.5) we can get scratched look calligraphy characters which have the same size as the original ones in theory. By modifying the structuring element, we can get different types of scratched look calligraphy characters.

As an example, changing some elements of the structuring element CIRCLE shown in Fig. 5, scratched look calligraphy characters can be obtained as shown in Fig. 6.

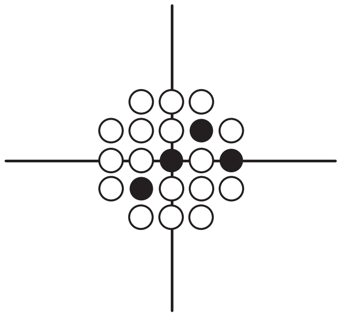

Fig. 5. The changed CIRCLE.

Fig. 6. The scratched look calligraphy characters of Fig. 2 by changed CIRCLE.

4. Conclusions

By using mathematical morphology, we proposed a method to generate scratched look calligraphy characters. The number of times the thinning computation for skeleton computing had been carried out is obtained and we know which structuring element has to be selected. By differently changing the structuring element, we can get different scratched look calligraphy characters.

As we see in Fig. 4, since there are some errors in the skeletons generated by using discrete disk structuring elements, the sizes of generated calligraphy characters were not the same as the original ones and how to reduce errors is the next problem we will address in the future.

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