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Proposals of Co-occurrence Frequency Image based Filters

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Abstract

We have discussed that the co-occurrence frequency image (CFI) defined based on the co-occurrence frequency histogram of the gray value of an image has a potential to introduce a new scheme for image feature extraction. This paper proposes a couple of filters for image enhancements of such as sharpening and smoothing filters. These filters are very similar to but quite different from those which have been used so far. Thus we could show a possibility for introducing a new paradigm for basic image enhancement filters based on CFI.

1 Introduction

Co-occurrence matrix [1-3] was proposed for the texture analysis as one of the methods of image processing. These basic methods were investigated mainly from the view point of the texture discrimination [3-5] in the image analysis. Though the co-occurrence matrix has a promising potential due to the 2 dimensional statistics of the image, further discussions beyond the texture discrimination have not been sufficiently proposed so far. These technological backgrounds are originated by the facts: that one dimensional statistic (histogram) is stable and powerful tool in image analysis, that the co-occurrence matrix was proposed exclusively for texture analysis [1, 3], and that the co-occurrence matrix needs large computation costs.

Image processing is generally constructed based on the gray information such as 1 dimensional statistical gray histogram, co-occurrence histogram, gradient, texture, etc [6]. However, no practical image processing method based on the co-occurrence histogram had been proposed excepting the texture identification [3-5]. Since the gray histogram is the most influential for extracting the global image properties, image processing methods have been always expected to be improved or extended. From this view point, it was notable that Kashiwagi and Oe have proposed a paradigm of feature extraction called Frequency Image [7, 8].

The co-occurrence histogram or co-occurrence matrix is also such influential basic image feature especially for the texture feature analysis. We have proposed a paradigm of the feature called "Co-occurrence Frequency Image (CFI) [9]" as a complete extension of the gray histogram and frequency image, and we try to investigate the method for feature extraction of the image by using CFI [10].

This paper proposes a couple of filters for image enhancements such as sharpening filters and smoothing filters based on Co-occurrence Frequency Image. In section 2, Co-occurrence Frequency Image is summarized, and in section 3, the extraction method by using Band-Pass filter is introduced. In section 4, some proposals of the filter and its experimental results are presented.

2 General Idea of CFI

2.1 Histogram and Co-occurrence Histogram

Here we have an image f_{ij} where the respective size is M in horizontal and N in vertical and the number of gray levels is 256. Let the gray histogram $h(f_{ij})$ be prepared from the image. Frequency image (FI) [7, 8] is expressed as in eq. (1) based on the histogram $h(f_{ij})$.

$$FI = P = (pk)\,,\quad pk = h(f_{ij})\,,$$

$(k = 0, 1, 2, ..., 255)$ (1)

Here k denotes the gray level number of the pixel. FI is an image of which value represents the gray frequency characterized by the gray histogram of a given image.

From this point of view, it is notable that Haralick, Shanmugam and Dinstein [1] proposed so-called co-occurrence matrix $C(i, j; d, \alpha)$ where d denotes an arbitrary distance between a pair of pixels and a denotes an angle of 0, 45, 90 and 135, with 14 different features for texture discrimination. In order to extend the paradigm of FI given above, anonymous [9] used the co-occurrence histogram (CH) or co-occurrence Frequency (CF) that is generally defined based on a pair of pixels f_{ij} and $f_{i+K\ j+L}$ in the image as shown in eq. (2). Parameters K and L are for describing the relationship between a pair of pixels. Fig. 1 shows the framework of CH.

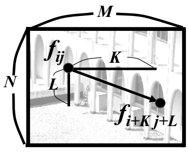
$$CH = hh(f_{ij}, f_{i+K\ j+L}) \tag{2}$$

2.2 Co-occurrence Frequency Image

Let CH or CF be the co-occurrence frequency value of a given image (Fig. 2; Building). And, based on CF, let us introduce Co-occurrence Frequency Image of which each pixel consists of an address of the CF (Fig. 3) of the input image. Fig. 4 shows an example of *CFI*. These images are computed by eq. (3).

$$CFI = Q = (q_{kl}),\ \ q_{kl} = *(hh(f_{ij}, f_{i+K,\, j+L})) \quad (3)$$

, where *hh* is the co-occurrence frequency and $K = 0, 1, ..., 255$, $L = 0, 1, ..., 255$.



f_{ij} \ f_{i+kj+l}	0	1	2	3	4	5	6	7		255
0	0	0	0	0	0	0	0	0	...	0
1	0	0	0	0	0	0	0	0	...	10
2	0	0	0	0	0	0	0	3	...	10
3	0	0	0	0	0	10	10	0	...	10
4	0	0	0	0	0	0	10	10	...	10
5	0	0	0	10	0	10	10	10	...	34
6	0	0	0	10	10	10	7	28	...	10
7	0	0	3	0	10	10	28	10	...	10
	...	...	...	...	...	...	...	...		...
255	0	10	10	10	10	34	10	10	...	86

Fig. 1 Framework of Co-occurrence histogram

Fig. 2 Input image (Building) (*M*x*N*)

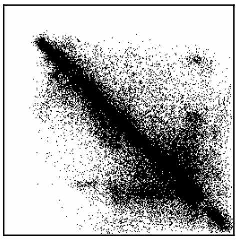


Fig. 3 Co-occurrence Histogram (256x256)

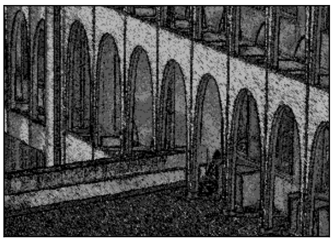


Fig. 4 Co-occurrence Frequency Image (*M*x*N*)

3 Feature Extraction based on CFI

3.1 Feature extraction by CFI-based Band-Pass filter

The distribution of frequency value in CFI expresses the basic feature of the image more complicatedly than FI. We propose a scheme of feature extraction based on CFI-based band-pass filter as given by eq. (4).

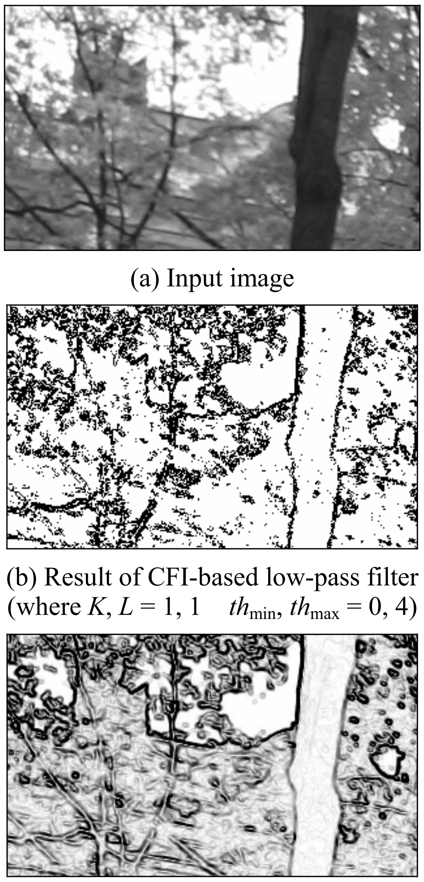
$$W = (w_{ij})$$

$$w_{ij} = \begin{cases} f_{ij} & th_{\min} \le CFI_{ij} \le th_{\max} \\ 0 & otherwise \end{cases} \quad (4)$$

Here $th_{\min}$ and $th_{\max}$ are the thresholding parameters of the frequency value.

3.2 Edge detection by CFI-based low-pass filter

This CFI-based filter for edge detection designed by setting $th_{\min}$ and $th_{\max}$ be lower is similar to but not coincident with any well known edge detectors such as Sobel gradient. Fig. 5 shows an example of a set of CFI's together with an example of Sobel edge extraction. Comparing CFI edge given in Fig. 5b with Sobel edge given in Fig. 5c, it is known that these are approximately similar but the details are exactly different. The value of CH could be generally lower in case of the edge detection, because the number of the pairs of pixels (f_{ij}, $f_{i+K\,j+L}$) consisting edge is very small. Our method can be used not only for detecting the co-occurrence features of the given image but also for providing a new paradigm to design such filters that could generate several functions such as edge detection by combining the input image and its CFI.



(a) Input image

(b) Result of CFI-based low-pass filter (where $K, L = 1, 1$ $th_{\min}, th_{\max} = 0, 4$)

(c) Result of Sobel filter (3x3)

Fig. 5 Edge detection

4 Designing New Filters based on CFI

4.1 A sharpening filter based on CFI

By using the binary image of the edge given in Fig. 5b, a simple edge enhancement could be realized. This fact encourages us to extend this idea of CFI-based filter designing more.

A shaping filter is designed by combining the original image and the result of edge detection by means of the low-pass filter defined by eq. (5).

$$E_{ij} = f_{ij} + \xi(CFI_{ij}) \cdot (f_{ij} - f_{i+K,\, j+L})$$

$$\xi(CFI_{ij}) = \begin{cases} 1 & CFI_{ij} \le th_{\max} \\ 0 & otherwise \end{cases} \qquad (5)$$

, where $\zeta(CFI_{ij})$ denotes the weight function specified based on the value of CFI. Therefore, when let $\zeta(CFI_{ij})$ be 1 in the experiment, an output image becomes the direct combination of the original image and the gradient of the pair of pixels.

A few experimental results are shown in Fig. 6 and Fig.7. Fig. 6b (CFI-based method) and Fig. 6c (Laplacian method) shows the results of shaping, and these edges are sharpened in the respective way. But in the latter case, the texture especially in the region of trunk is apparently sharpened and therefore noisy. Thus this experiment demonstrated that the CFI-based method can surely select nothing but the edge region, that the Laplacian method is generally weak in noise as shown in Fig. 7c. CFI-based method could be selected the edge region without noise, and mask the texture in the region of the trunk.

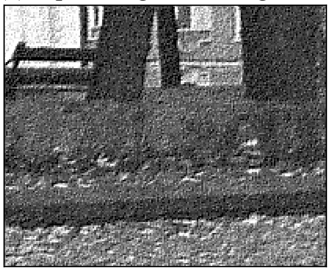
(a) Input image

(b) The result of shaping based on CFI (where K, L = 1, 1, $th_{\max}$ = 6)

(c) The result of shaping by Laplacian filter

Fig. 6 The results of shaping

(a) Input image including noise



(b) The result of shaping based on CFI (where K, L = 1, 1, $th_{\max}$ = 6)

(c) The result of shaping by Laplacian filter

Fig. 7 The results of shaping applied to an image with random noise

4.2 A smoothing filter based on CFI

In order to reduce the typical side effect of the smoothing such as the edge blur, we propose a smart smoothing method based on CFI as follows.

Basic idea is to apply smoothing operation selectively to the flat region and we implemented this idea by eq. (6).

$$S_{ij} = \psi(CFI_{ij}) \frac{1}{M} \sum_{m=-N}^{N} \sum_{n=-N}^{N} f_{i+m,\, j+n} \,,$$

$$\psi(CFI_{ij}) = \begin{cases} 1 & th_{\min} \le CFI_{ij} \\ 0 & otherwise \end{cases} \qquad (6)$$

, where $\psi(CFI_{ij})$ denotes the weight function based on the value of CFI.

The experimental results when $\psi(CFI_{ij})$ = 1 and the size of the filter is 5x5 are shown in Fig. 8 and Fig. 9. As clearly known from these results, CFI-based smoothing filter could be an edge preserving characteristic. CFI-based method could be selected the flatness texture without noise, and realize an edge preserving characteristic.

(a) Input image

(b) The result of smoothing based on CFI (where K, L = 1, 1, th_{min}= 8)

(c) The result of smoothing filter (5x5)

Fig. 8 The results of smoothing

(a) Input image including noise

(b) The result of smoothing based on CFI (where K, L = 1, 1, th_{min}= 8)

(c) The result of smoothing filter (5x5)

Fig. 9 The results of smoothing applied to an image with random noise

5 Conclusion

We have proposed a new image feature of co-occurrence frequency image, and we proposed a couple of new band-pass filters based on CFI. For example, CFI could provide new feature extractions such as edge and the flatness regions. Though these filters are generally applicable to the whole region of the image, we could introduce new methods of sharpening filter and of edge preserving smoothing filter.

As the future subjects, this method requires the more detailed investigations for choosing and customizing the parameters K, L, th_{min} and th_{max} of CFI. Moreover an introduction of new CH which is independent to the direction and/or the distance between a pair of pixels is strongly expected, and the further CFI-based filters are now being under investigated.

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