Variance filter for edge detection and edge-based image segmentation

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Variance Filter for Edge Detection and Edge-Based Image Segmentation

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Abstract - **In this paper problem of edge-based image segmentation is considered. Specifically, a new approach to edge detection is introduced. The proposed method utilizes variance filter to determine edge position. Results of edge detection using the new approach on synthetic and real images are presented and compared with results provided by the traditional i.e. image-derivative based approaches. Results of the comparison are analyzed and discussed.**
Keywords - **Edge detection, Image segmentation, Variance filter.**

I. Introduction

The accuracy of edge detection is crucial in many applications of vision systems. It's because edges define shape and location of objects being investigated [1]. Edge-based approaches are often used for image segmentation as they provide necessary information for image analysis and pattern recognition performed during high level image processing.

Edge detection is challenging problem especially in case of low contrast, blurred and noisy images. Therefore it was widely discussed by the researches over the years [2][3]. Although variety of methods for edge detection has already been proposed mostly they can be qualified into image derivative based methods or moment based methods.

Image derivative based approaches approximate image derivatives using special masks [1]. Specifically, gradient methods (such as Sobel operator or Canny edge detector) utilize image first derivative [4][5], while zero-crossing methods (such as LoG [6]) use image second derivative. In case of gradient methods edge position is defined by local extremes of image first derivative. Zero-crossing approaches locate edges based on zero-crossing in image second derivative. Image derivative based methods are fast in locating edges. However their accuracy is low as provide wide edges, specifically in case of blurred images. Moreover they fail when detecting edges in low contrast images.

Moment-based approaches to edge detection utilize image intensity moments [7] or spatial moments to determine edge position [8-10]. Specifically, moments are expressed in terms of edge parameters (i.e. edge location, edge direction, background intensity, edge contrast) and then solved to determine edge position. Geometrical moments [8], Zernike moments [9] or orthogonal Fourier-Mellin moments [10] are utilized by the most popular moment-based approaches to edge detection. Moment based approaches are computationally complex but they are characterized by high precision of edge location. However, they often fail in case of significantly blurred edges.

In this paper simple and efficient approach to edge detection is introduced. The method uses variance filter and is dedicated to significantly blurred or low-contrast edges.

The remaining part of this paper is organized as follows. Firstly, in Section 2 description of the proposed method is given. It is followed in Section 3 by the analysis of algorithm performance. In Section 4 results of edge detection using the proposed method are compared with results of well-established approaches. Finally, Section 5 concludes the paper.

II. The Proposed Method

2.1. Variance filter

The proposed approach to edge detection uses variance filter defined by Equation (1).

$$u_{\mathrm{var}}(\mathbf{x}) = \sigma^2\{u(\mathbf{x}-\mathbf{q}) \mid \mathbf{q} \in W\} \qquad (1)$$

where: $u(\mathbf{x})$ is image intensity at the location $\mathbf{x}(x_1, x_2)$, $W = \{\mathbf{q} \mid -(W_D - 1)/2 \le q_{i=1,2,\ldots,m} \le (W_D - 1)/2\}$, W_D is size of a filtering window and Equations (2) and (3) are fulfilled.

$$\sigma^2 = \frac{1}{n}\sum_{i=1}^{W_D^2}(u_i - \bar{u})^2 \qquad (2)$$

$$\bar{u} = \frac{1}{n}\sum_{i=1}^{W_D^2} u_i \qquad (3)$$

2.2. Method description

The proposed method works in three main stages.

In the first step variance filter defined in the previous section is applied. The output of the filter is next normalized to fit the available intensity levels. This can be expressed by Equation (4).

$$u'(\mathbf{x}) = round\left(N \frac{u_{\mathrm{var}}(\mathbf{x})}{\max(u_{\mathrm{var}})}\right) \qquad (4)$$

where: $\max(u_{var})$ is maximum output of the variance filter determined for the whole image and N is number of intensity levels available in the image and *round* function rounds its argument to the closest integer.

High variance corresponds with edges where intensity changes sharply, while low variance is assigned to mostly uniform non-edge areas. There in the second step of edge detection output of the variance filter is clustered into two classes: *edge pixels* and *non-edge pixels*. K-means clustering algorithm [11] is applied in this step. As a result a wide edge is obtained

Finally, image skeletonization algorithm is applied in order to define one-pixel width edge. In this step basic skeletonization algorithm as proposed in [1] is applied.

The successive steps of edge detection in exemplary image using the proposed method are presented in Figure 1. Specifically Figure 1a presents exemplary synthetic image. Figure 1b presents result of variance filtering. In Figure 1c wider edges obtained by K-means clustering are shown. Finally, Figure 1d shows final edges obtained by applying skeletonization algorithm to image from Figure 1c. In order to increase readability of the results in Figures 1b-1d negatives are shown.

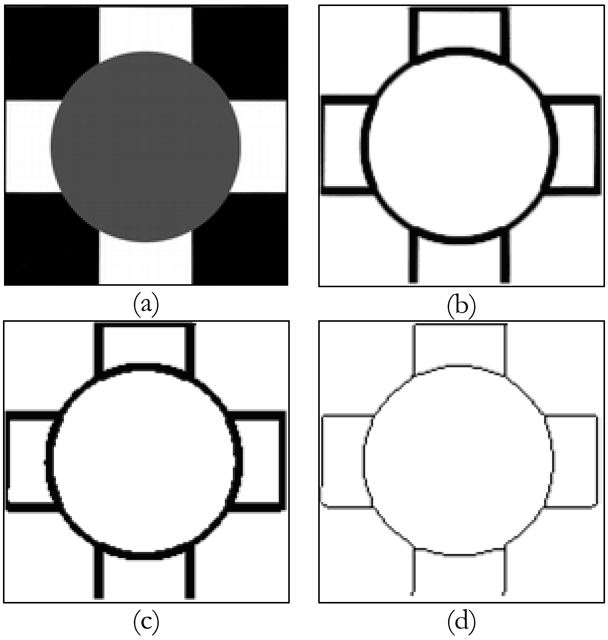
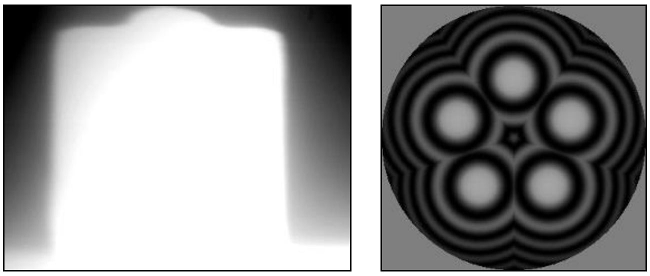


Fig.1. Successive steps of edge detection using the proposed method; (a) original image; (b) result of variance filtering; (c) binary image of wide edges; (d) final edges obtained using the proposed method.

III. MASK SIZE INFLUENCE

The main parameter of the proposed algorithm is size of the window W_D used by the variance filter. This size significantly influences results of edge detection using the proposed method and should be selected depending on size of the object and the width of the gradient slope. This issue is explained on exemplary images shown in Figure 2.The images represent different classes of images. In Figure 2a heat-emitting specimen of steel is shown. The image presents one object with significantly blurred edges. Image contains no details. Figure 2b presents synthetic image with blurred edges and containing large number of details. The influence of mask size on edges determined by the proposed method is shown in Tables 1 and 2. Specifically, Table 1 refers to image from Figure 2a and Table 2 refers to image from Figure 2b. In each table first row presents results of variance filtering. In the second row wider edges obtained by K-means clustering are shown. One pixel width edges are presented in the third row and compared with the original image in the last row. Mask size is indicated in the column caption. In order to increase readability of the results images after processing are shown in negatives.

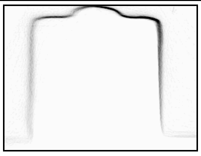
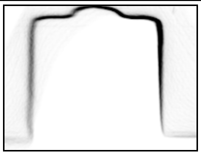
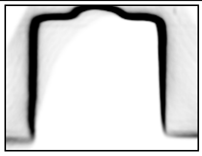
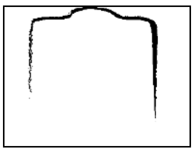
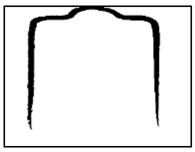
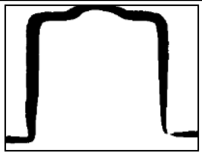
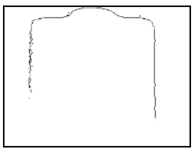
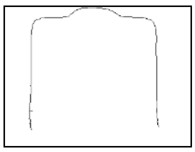
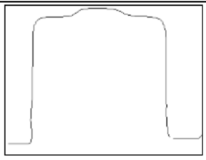
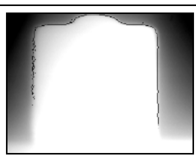
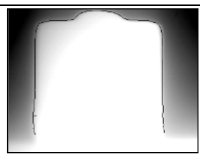
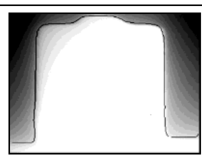


(a) (b)

Fig. 2. Exemplary images; (a) heat emitting specimen of steel; (b) synthetic image with large number of details.

TABLE 1

THE INFLUENCE OF THE FILTERING WINDOW SIZE ON THE DETERMINED EDGES

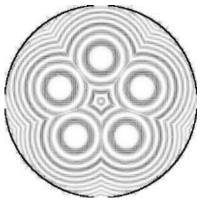
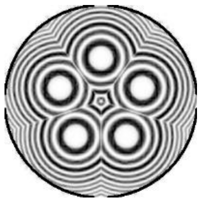
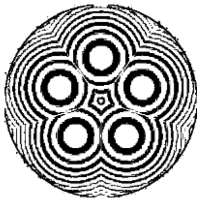
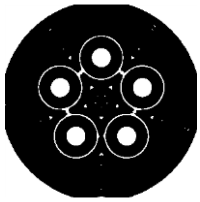
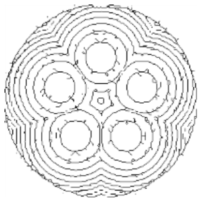
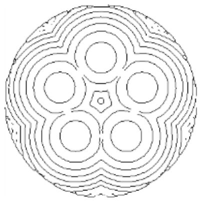
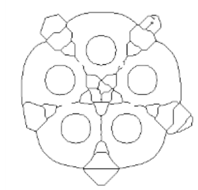
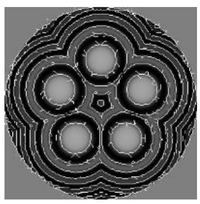
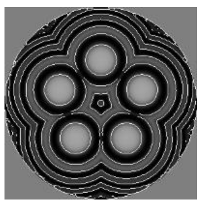
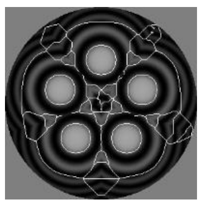
W_D=3	W_D=5	W_D=9
		
		
		
		

Results presented in Table 1 show clearly that in case of images containing small number of details but presenting objects with significantly blurred edges bigger filtering windows provide better results. In case of the exemplary image shown in Table 1 it was not possible to extract complete edge using 3x3 pixel window. However, result obtained after applying 9x9 pixel window is satisfying. The resulting edge is complete, smooth and precisely matches the shape of the object.

In case of images containing large number of small details better results are obtained after application of smaller filtering windows (see Table 2). Windows bigger than the dimensions of the details removes them from the output image and produces edges which do not match shape of the objects in the input image.

TABLE 2

THE INFLUENCE OF THE FILTERING WINDOW SIZE ON THE DETERMINED EDGES

W_D=3	W_D=5	W_D=9
		
		
		
		

IV. RESULTS AND COMPARISON WITH OTHER METHODS

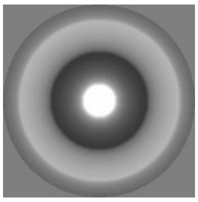
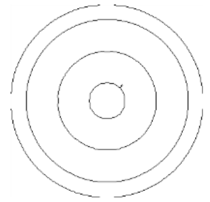
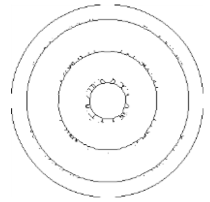
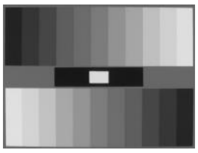
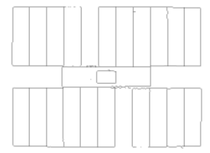
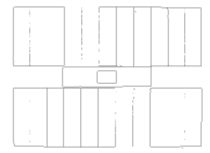
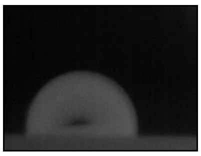
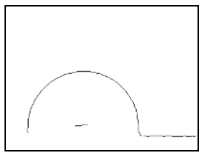
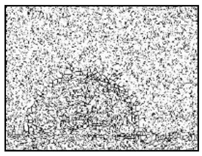
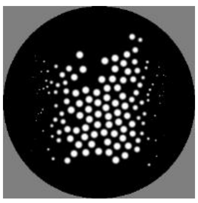
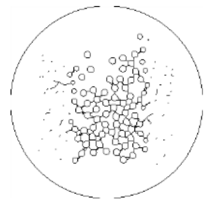
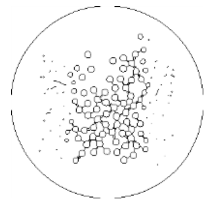
In this section results of edge detection using the proposed method are presented and compared with results obtained using Sobel edge detector. Synthetic and real images are considered. In order to extract Sobel edges the gradient image (obtained by convolving the input image with the Sobel gradient masks) was firstly binarized using K-means algorithm; next skeletonization was performed on the binary image.

The comparison of the results is given in the Table 3. Specifically, in the first column the original images are presented. The second column shows results of the introduced method. Finally, in the third column edges obtained using Sobel edge detector are shown.

In order to increase the readability of the results negatives of the processed images are shown.

TABLE 3

THE COMPARISON OF EDGE DETECTION RESULTS

ORIGINAL IMAGE	THE PROPOSED METHOD	SOBEL
		
		
		
		

Results shown in Table 3 reveal that in case of images with significantly blurred edges the proposed method outperforms Sobel gradient edge detector. Edges provided by the variance filter based method are significantly smoother and more regular in such case. The proposed method is also more robust in detecting low contrast edges. In case of images presenting large number of small details both considered methods provide edges of similar quality.

V. CONCLUSION

In this paper a new approach to edge detection was introduced. It is based on the variance filter. The method is simple and is characterized by low computational complexity. The extensive simulations on different classes of images proved that in case of low contrast and significantly blurred edges the introduced method outperforms traditional gradient based approaches to edge detection.

The main weakness of the introduced edge detector is its low resistance to noise. Both the impulse and the Gaussian noise significantly decreases quality of edge detection using the proposed approach. However, irrespective of this fact the method is potentially useful in a wide spectrum of applications.

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Synthetic images used in this work were downloaded from *Texture Synthesis Diary* [12].

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