ISSN No: 2348-4845
International Journal & Magazine of Engineering,
Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design and Application of Novel Morphological Filter Used In Vehicle Detection

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Abstract

In this paper we represent our proposed novel morphological filter developed under the scope of Taiwan-Mongolian co-project. We applied the implemented filter in vehicle detection from CCTV video signal. Our goal was to develop a filter that can reduce the noise in background subtracted binary image, which created by camera shake, and unnecessary moving objects such as wave of the tree etc. We compared our filter performance with morphological open, close, erosion, dilation, and median filters. PSNR (Peak Signal to Noise Ratio) is employed for evaluating the performance of the filters; our filter's PSNR was relatively higher than the other method. Furthermore, we used our filter for vehicle detection, and detection rate was 100%as the other methods. Thus, we conclude the new filter is sufficient for denoising binary image, and suitable for vehicle detection. We can classify the vehicles based on their sizes.

I. INTRODUCTION

Computer vision has always been widely accepted in application to extract information from video source. However, removing noises in a frame of the video was a difficult task, and a lot of filtering algorithms were developed in last decades. Mathematical morphology has been used as a powerful tool for filtering noises, while preserving the important geometrical features.

Furthermore, morphological methods use structuring elements (SE) such as rectangle, ellipse and cross, and size of the SE can be adjusted to get better results. The SE of the morphological filter is similar to the window or mask function. In actual applications, there is quite a difference of morphological features among the vibration signals because of operating environment and processing parameters of the mechanical equipment. At present, morphological opening, morphological closing and their combinations (open and close) are widely used in image processing. Also omni directional methods of morphology were introduced. Moreover it is said that close-opening and open closing filter.

Median filters and order-statistic filters are a class of nonlinear and translation-invariant discrete filters that have become popular in digital speech and image processing, and also in statistical or economic time series analysis.

These filters are easy to implement and can suppress impulse noises, which blur edges. Furthermore median blur method blurs the frame according to the kernel size which is deficient for proper usage.

We found out that aforementioned filters could not remove noise from binary image as we desired. Thus, we intended to develop a better filter that could remove more noise while keeping the geometrical structure of the moving vehicles.

And we classify the vehicles also based on their size

Class 1 - Light vehicles:

Light vehicles are motor vehicles, other than heavy vehicles as defined below, with or without a trailer,

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
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and include motorcycles, motor tricycles and motor cars.

Class 2 - Medium heavy vehicles:
Medium heavy vehicles are heavy vehicles, as defined below, with two axles.

Class 3 - Large heavy vehicles:
Large heavy vehicles are heavy vehicles, as defined below, with three or four axles.

Class 4 - Extra large heavy vehicles:
Extra large heavy vehicles are heavy vehicles, as defined below, with five or more axles.

II. METHOD
The main difference between our method andmorphological filter is we calculate the surrounding pixels of asuspicious pixel, however morphological methods check thepixels in structuring element. In binary morphology, thedilation (1) and erosion (2) are respectively defined as below:

$$(G\oplus B)(x,y) = \max\{G(x-i, y-i) + B(i,j)(i,j) \in D_B\} \quad (1)$$

$$(G\ominus B)(x,y) = \min\{G(x-i, y-j) - B(i,j)(i,j) \in D_B\} \quad (2)$$

Where $\oplus$, and $\ominus$ denotes, respectively, dilation operator anderosion operator, $G(x,y)$ is binary image, and $B(x, y)$ is structureelement.

Opening (3) and closing (4) operation of binary image aredefined as

$$G \circ B = (G\ominus B) \oplus B \quad (3)$$

$$G \bullet B = (G\oplus B)\ominus B \quad (4)$$

where $\circ$, and $\bullet$ denotes, respectively, opening operator andclosing operator.

The filter window can be 2D square, rectangle, cross, andellipse in default morphological filters, but in our case, we useda square window. Window size can be resizable to improve theresult of the filter. Our method is similar to the filters in a waythat it treats the pixels one by one to decide whether it's noiseor not. Following is a pseudocode of our method.

Algorithm's pseudo code
1. Run till the end of frame

1.1. if $x(1,1)$=1, suspicious pixel is white

1.1.1. Calculate S, number of white pixels inside the window

1.1.2. if $S < n2/2$, number of white pixels is less than a half of total pixels inside the window

1.1.2.1. set $x(1,1)$=0

1.1.3. end if

1.2. end if

2. end frame.

We assume the window as a 2-D square matrix size of n×n. We also assumed binary image's white pixel has a value of 1, and black pixel has a value of 0. Our suspicious pixel $x(1,1)$ is at 1st row and 1st column of the window. This window will slide from top left corner to the bottom right corner checking all the frame pixels. If the white pixel occurs while searching, we calculate the S which is the total number of white pixels inside the window, at the moment. If $S < n2$, S is less than a half of the number of all pixels inside the window, the algorithm decides the suspicious pixel is a noise, then the algorithm changes the suspicious pixel to a black pixel. On the other hand, if $S > n2$, S is greater than a half of the number of all pixels, we leave the suspicious pixel as it is assuming the pixel was a part of a vehicle. Equation of S, and suspicious pixel $x(1,1)$ are defined as below:

$$S = \sum_{i,j}^{i+n} x(i,j) \quad (5)$$

$$x(1,1) = \begin{cases} 1, S > \frac{n^2}{2} \\ 0, otherwise \end{cases} \quad (6)$$

Where, S is a number of white pixels in the window, x(i,j)is a pixel, at row i and column j, inside the window, n is a sizeof the window.

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III. EXPERIMENTS AND RESULTS

We tested the new method in video which is provided byTraffic Control Center of Ulaanbaatar, the video was recordedin Nov. 2015. A sample frame from the video is shown in Fig.1, size of the frame was 622×441, and format was png. We didbackground subtraction to separate the moving objects fromstationary background (Fig. 2). We intentionally chose thisframe due to its high noise presence in order to show the qualityof the new filter. We also added Gaussian noise (Fig. 3).Control image (Fig. 3) was created manually by removing allthe noise from Fig. 2. We intended to get the best result whichis as close as the control image. The result of the new methodis shown in Fig. 5. Results of morphological open, close, andmedian filters are shown in, respectively, Fig. 6, 7, 8. All theseresults were the best results that we manually chose from manydifferent cases.

We employed *PSNR* (Peak Signal to Noise Ratio) forcomparisons of filter quality. In order to calculate PSNR, firstwe found *MSE* (Mean Squared Error). The definition of the*MSE* is shown below:

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(Y_{i,j} - S_{i,j})^2 \qquad (7)$$

Where, M, N are size of the frame, Y and S are frames to becompared, i and j are the coordinates of the pixel.

PSNR is defined as:

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) dB \qquad (6)$$

Fig. 1. Original image from the video.

Fig. 2. Image after background subtraction.

Fig. 3. Gaussion noise added on Fig. 2.

Fig. 4. The control image, noises were manually removed from Fig.2.

Fig. 5. Filtered result of Figure 3 by the new method, window size is 8×8.

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Fig. 7. Filtered result of Figure 3 by morphological close, ellipse type, size is 2×2.

Fig. 8. Filtered result of Figure 3 by median filter.

PSNR values of all methods are shown in Fig. 9, results ofmorphological erosion and dilation methods are included eventhough their filtered images are not present in the paper. Amongthe results, *PSNR* of the new method was 21.39, which is thehighest one among the others, meaning closest to the controlimage. Second best method was morphological erosion, and theworst method was morphological dilation.

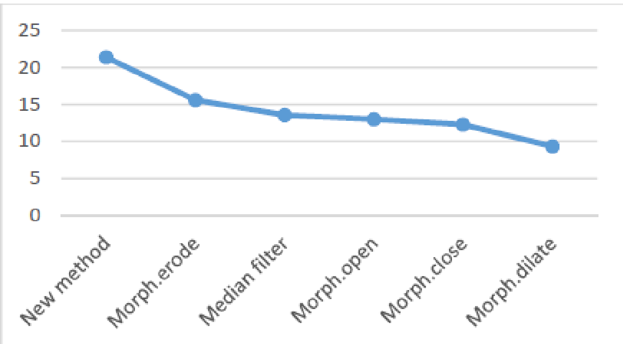

Fig. 9. Comparison between PSNRs.

Histogram of the white and black pixels of all methods are represented in Table 1. We can see the new method removed more amount of white pixels among the others. However, removing excessive white pixels is not good when those white pixels were part of vehicle, in our case, we can easily recognize the vehicles from the filtered image with naked-eyes. Besides, automatic vehicle detection, using blob detection method, rate was 100% when our filter was used.

TABLE I. COMPARISON BETWEEN WHITE AND BLACK PIXELS HISTOGRAM

	Number of white pixels	Number of black pixels	Sum of the pixels
Image Threshold	17525	256777	274302
Control Image	4474	269828	274302
Noised Image Threshold	39398	234904	274302
New method	5587	268715	274302
Morph. dilate	111333	162969	274302
Morph. erode	7798	266504	274302
Morph. open	16199	258103	274302
Morph. close	45690	228612	274302
Median filter	20681	253621	274302

Calculation costs of the methods are shown in Table 2. Inthis experiment, we used laptop with Intel Core i7 processor2.4GHz (8CPUs), 8GB of RAM, Windows 10 OS, and thewindow size was 8x8 so the calculation cost of our function wasmore than other methods. However the calculation cost couldbe decreased by 2-4 times after improvement of the algorithm.

TABLE II. CALCULATION COSTS OF THE METHODS

Function	microsecond
New method	6560
Morph. dilate	363
Morph. erode	336
Morph. open	1293
Morph. close	739
Median filter	393

IV. CONCLUSION

New morphological filter is developed, and evaluationexperiments are performed in this study. According to theexperiment results, PSNR of the new filter was relatively higherthan the other filters.

Furthermore, vehicle detection rate was100% as the other filters provided when the new filter is employed. Thus we conclude our filter is suitable for denoisingbinary image and for vehicle detection application. In thefuture, we will improve the algorithm so the calculation costcould be decreased by 3-4 times.

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