The Vehicle Edge Detection Based on Homomorphism Filtering and Fuzzy Enhancement in Night-time Environments

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Abstract—**This article presents a novel vehicle edge detection algorithm based on Canny operator in nighttime environment. Firstly, spatial homomorphism filtering is used to eliminate the illuminating influence; then an improved self-adaptive fuzzy enhancement Canny operator is used to enhance the vehicle edge; lastly the maximum classification square error method is used to calculate the dual threshold, performing the vehicle edge detection. Experiments indicate that this method eliminates the interference from the auto lamps, well applicable for the vehicle edge detection in the night-time environment.**

Keywords- vehicle edge detection; spatial homomorphism filtering; fuzzy enhancement; Canny operator; maximum classification square error method

I. INTRODUCTION

In recent years intelligence traffic system based on computer vision technology is developing dramatically, amongst the accuracy and algorithm complexity of the video vehicle detection affect the overall efficiency and final outcome of the intelligence traffic system, which acts as the premise of such technologies as vehicle tracking, video speed measurement, and vehicle detecting. Low light illumination at nighttime and great variance of light intensity is the major problem in the video vehicle detection. Even with the installation of expensive infrared cameras for night-time road images, it is only effective in detecting pedestrians and the results will still be influenced by the strong light of auto headlight, surface reflected light and ambient light in detecting vehicles at night.

Therefore, such references [1-4] perform by detecting the prominent characteristics of the vehicles in nighttime like headlight and taillight, while these methods are of low robustness and with limited traffic parameters, still influenced by strong light. To solve the nighttime light influence, this paper advances a vehicle detection method in nighttime environment: Firstly, spatial homomorphism filtering is used to eliminate the illuminating influence; then an improved self-adaptive fuzzy enhancement Canny operator is used to enhance the vehicle edge; lastly the maximum classification square error method is used to calculate the dual threshold, performing the vehicle edge detection. Experiments indicate that this method eliminates the interference from the road images irradiated by auto lamps, well applicable for the vehicle detection in the night-time environment.

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II. OPTIMIZED ALGORITHMS IN SPATIAL HOMOMORPHISM FILTERING

The grey level image can be described by the product of the incident and the reflected light component, and the incident light is determined by the light source, distributing uniformly in low-frequency part of the frequency domain, representing the background image. And the reflected light represents the image details, distributing in high-frequency part. The reflected light depends on the object's internal nature, and landscape brightness feature depends on reflected light. Therefore, the homomorphism filtering gains the goal to compensate imbalanced illuminating in the uneven brightness image by suppressing the low frequency and amplifying the high frequency part of image at the same time.

The traditional homomorphism filtering algorithm is done in the frequency domain, however, frequency homomorphism filtering algorithm has drawbacks such as lack of the access of local contrast enhancement, occupying large spaces, time-consuming calculation that it is not suitable for the real-time detection system. The reference [5] processed the homomorphism filtering algorithm in the spatial domain, whose fundamental concept is to perform the low-pass filter on the image at first, and then use the original image to subtract the low-pass filtered image, thus the results can reflect the effect of suppressing the low frequency and amplifying the high frequency. This paper adopts the concept of reference [5] to eliminate the impact of light using homomorphism filtering on the night-time traffic images.

The illumination model of the spatial homomorphism filtering image $im(x,y)$ is $im(x,y)=i_0\cdot i(x,y)\cdot r(x,y)$, $i(x,y)$ is the incident light component, $r(x,y)$ is the reflected light component and i_0 is the incident light constant.

The steps of optimized spatial homomorphism filtering algorithm are as follows:

Carry out the logarithmic arithmetic on the image, separate the incidence light sum reflected light component:

$$g(x,y) = \ln im(x,y) = \ln i_0 + \ln i(x,y) + \ln r(x,y)$$

Carry out the low-pass filtering on $g(x,y)$, filter away the reflected light component:

$$g'(x,y) = LPF\{g(x,y)\} \approx \ln i_0 + \ln i(x,y)$$

Use the original image to subtract the low-pass filtered image and plus $\ln i_0$ reserving certain low frequency component to obtain the high frequency enhanced image $h(x,y)$:

$$h(x,y) = g(x,y) - g'(x,y) + \ln i_0 \approx \ln i_0 + \ln r(x,y)$$

Carry out the antilog arithmetic on $h(x,y)$, get final outcomes of homomorphism filtering:

$$f(x,y) = \exp\left(h(x,y)\right) \approx i_0 \cdot r(x,y).$$

Even multiplied by the incident light constant i_0, the images processed by spatial homomorphism filtering algorithm lose certain low frequency information distorting the original images to some extent but the high frequency information has been enhanced. Therefore, the spatial homomorphism filtering is more suitable for the detection of goal edge.

III. Canny Edge Detection Based on Self-adaptive Fuzzy Enhancement

The usual edge detection algorithms include Roberts operator, Prewitt operator, Sobel operator, Laplace operator and so on, and these operators are apt to implement, but more sensitive to image noise. By contrast, the Canny operator based on the optimized algorithm is widely used owing to its high signal-to-noise ratio and detecting accuracy. However, the filter in the traditional Canny algorithm is a Gauss function, and the improper choice of smooth parameters will easily cause the loss of slowly changing edges or the fake edge phenomenon and increase calculation, so it is not suitable for the high demanding real-time intelligent traffic system. The reference [6] advanced a edge detection method using fuzzy enhancement algorithm instead of classical Gaussian filtering in Canny edge detection method to achieve quite satisfactory results of edge detection, but the fast fuzzy enhancement algorithm parameters need to be manually set in reference [6] and the diagonal direction has not be considered in Canny operator and the gradient direction has not be considered in non-maxima suppression, as a result, this method could gain ideal enhancement effect and is sensitive to noise without high accuracy of edge positioning. Therefore, this paper presents an improved self-adaptive fuzzy enhancement Canny operator edge detection algorithm based on the concept of reference [6]: firstly carry out the bilinear generalized fuzzy enhancement edge algorithm on the homomorphism filtered images[7]; then replace the Gaussian smoothing by fuzzy enhancement algorithm in the Canny algorithm and calculate the gradient value and direction of each pixel, conducting the non-maxima suppression in the gradient direction; finally, solve the dual-threshold value [8] by the maximum classification square error method to detect the edge of vehicles.

A. *Bilinear Generalized Fuzzy Self-adaptive Enhancement*

The reference [7] provided a Linear Generalized Fuzzy Operator(LGFO) to enhance the image contrast and advanced a novel nondestructive bilinear boundary detection algorithm based on GFS(generalized fuzzy sets): firstly transform the gray space of the grey image into the for the generalized fuzzy sets by using linear left semi-trapezoid fuzzy distribution function and conduct the contrast enhancement on the generalized fuzzy sets using LGFO; then transform the enhanced generalized fuzzy sets into generalized fuzzy sets and transform the generalized fuzzy sets into the gray space of the image. This algorithm enhances the image edge with high speed and great effect, but it has not considered the setting of adjustable parameter *r* in the Linear Generalized Fuzzy Operator. Different *r* will conduct enhancement on different grey level area. Therefore, the vehicles grey level area belong to are different after the homomorphism filtering as for the traffic images of different night illumination, so using fixed transformation parameters clearly affect the fuzzy enhancement, thereby affecting the results of vehicle edge detection. Considering this problem, this paper presents a method choosing the grey level threshold of homomorphism filtered image as the self-adaptive adjustable parameter *r* automatically to enhance the accuracy of fuzzy enhancement based on the suppressing low-frequency and enhancing high-frequency characteristics of homomorphism filtering. The steps are as follows:

1) Transform the image from gray space $F = (f_{xy} \mid f_{xy} \in [0,255])$ into generalized fuzzy sets $P = (p_{xy} \mid p_{xy} \in [-1,1])$ using formula (1), then transform the generalized fuzzy sets P into the normal fuzzy sets $P' = (p'_{xy} \mid p'_{xy} \in [0,1])$. This process conducts the fuzzy enhancement on the area contrast.

$$p_{xy} = LT(f_{xy}) = {(f_{xy}-D)}\big/{(f_{\max}-D)} \tag{1}$$

$$p'_{xy} = \begin{cases} -\frac{r}{r+2t}p_{xy}+\frac{2t}{r+2t}, & -1 \le p_{xy} < -\frac{1}{2}(r+2t+1)+\frac{t}{r} \\ -\frac{r}{r-2t}p_{xy}-\frac{2t}{r-2t}, & -\frac{1}{2}(r+2t+1)+\frac{t}{r} \le p_{xy} < -\frac{1}{2}r-t \\ -\frac{r}{r+2t}, & -\frac{1}{2}r-t \le p_{xy} < 0 \\ \frac{r}{r+2t}p_{xy}, & 0 \le p_{xy} < \frac{1}{2}r+t \\ \frac{r}{r-2t}p_{xy}-\frac{2t}{r-2t}, & \frac{1}{2}r+t \le p_{xy} < \frac{1}{2}(r+2t+1)-\frac{t}{r} \\ \frac{r}{r+2t}p_{xy}+\frac{2t}{r+2t}, & \frac{1}{2}(r+2t+1)-\frac{t}{r} \le p_{xy} \le 1 \end{cases} \tag{2}$$

Amongst, $f_{\max}$ and $f_{\min}$ are the maximum and minimum of the pixels, $0 < D \le (f_{\max} - f_{\min})/2$, $r \in (0,1)$, $t \in (0, r/2)$ are adjustable parameters.

The Linear Generalized Fuzzy Operator(LGFO) has such properties[7]: if $-1 \le P_{xy} \le 0$ or $r \le P_{xy} \le 1$, $P'_{xy} \ge P_{xy}$; if $0 \le P_{xy} \le r$, $P'_{xy} \le P_{xy}$, which is the transformation from P into P' and increases the pixel value of the range and $[r,1]$,and decreases the pixel value of the range $[0,r]$.According to formula (1), the range $[-1,0]$ of P is determined by the value D. Therefore, the value of D and r can influence the effect of fuzzy enhancement contrast and the parameter t determine the intensity of enhancement.

The outcome of homomorphism filtering which suppresses the low frequency and amplifies the high frequency is that the high frequency parts such as some grey level of edge details distribute on the high-end while most of the background grey level distribution in the low-end. According to this, this paper adopts the simple and efficacious maximum classification square error method [8] $\max_k \delta^2(f,k)$ to calculate the gray value by setting the self-adaptive adjustable parameter r, D is set to be the minimum $f_{\min}$ of the homomorphism filtered images.

$$r = (\max_{k \in [f_{ave}, f_{\max}]} \delta^2(f,k) - D)/(f_{\max} - D) \tag{3}$$

$$D = f_{\min} \tag{4}$$

Amongst, f_{ave} is the grey average of image f.

2) Transform the normal fuzzy sets $P' = (p'_{xy})$ into the enhanced grey image sets $F' = (f'_{xy} \mid f'_{xy} \in [0,255])$ using the linear generalized inverse transformation $f'_{xy} = LT^{-1}(p'_{xy}) = p'_{xy} \times (f_{\max} - M) + M$.

B. *Calculation of Magnitude and Direction of Gradient*

The commonly used Canny operator [9] is the calculation of gradient magnitude in a 3 × 3 neighborhood, we consider the pixel diagonal direction, add the direction of computing the pixels' partial derivatives and improve the traditional Canny operator to calculate the gradient, suppressing the noise effectively and improving the accuracy of edge location.

The algorithm steps are as follows:

Firstly calculate the partial derivatives of 4 directions:

0°-partial derivative: $P_0(x,y) = f'(x+1,y) - f'(x-1,y)$

90°-partial derivative: $P_{90}(x,y) = f'(x,y+1) - f'(x,y-1)$

45°-partial derivative: $P_{45}(x,y) = f'(x-1,y+1) - f'(x+1,y-1)$

135°-partial derivative: $P_{135}(x,y) = f'(x+1,y+1) - f'(x-1,y-1)$

The partial differential in horizontal direction is:

$$P_X = P_0 + (P_{45} + P_{135})/2$$

The partial differential in vertical direction is:

$$P_Y = P_0 + (P_{135} - P_{45})/2$$

The magnitude of the gradient is:

$$M(x,y) = \sqrt{P_X^2(x,y) + P_Y^2(x,y)}$$

The direction of the gradient is:

$$\theta(x,y) = \arctan[P_X(x,y)/P_Y(x,y)]$$

C. *Non-maxima Suppression of the Gradient Magnitude*

The only overall gradient is not sufficient to determine the edge, thus this paper uses the direction of the gradient to determine the edge by reserving the maximum point of local gradients and suppressing the non-maxima.

The direction of gradient θ can be equally devised into 4 directions of 0°, 45°,90°and 135°, as shown in figure 1.

$$\overline{\theta} = \begin{cases} 0^{\circ}, & -\pi/8 \le \theta < \pi/8 \\ 45^{\circ}, & \pi/8 \le \theta < 3\pi/8 \\ 90^{\circ}, & \theta \ge 3\pi/8 \ or \ \theta < -3\pi/8 \\ 135^{\circ}, & -3\pi/8 \le \theta < -\pi/8 \end{cases} \tag{5}$$

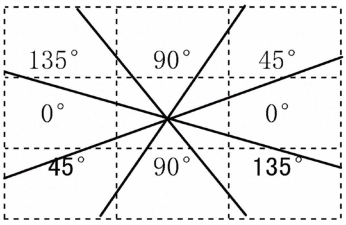

Figure1. Schematic diagram of gradient direction

Conduct the non-maximum amplitude suppression by the direction of $\overline{\theta}$:

When $\overline{\theta} = 0^{\circ}$:

$$M(x,y) = \begin{cases} M(x,y), & if \ M(x,y) \ge M(x-1,y) \ and \ M(x+1,y) \\ 0, & else \end{cases}$$

When $\overline{\theta} = 45^{\circ}$:

$$M(x,y) = \begin{cases} M(x,y), & if \ M(x,y) \ge M(x-1,y+1) \ and \ M(x,y) \ge M(x+1,y-1) \\ 0, & else \end{cases}$$

When $\overline{\theta} = 90^{\circ}$:

$$M(x,y) = \begin{cases} M(x,y), & if \ M(x,y) \ge M(x,y-1) \ and \ M(x,y) \ge M(x,y+1) \\ 0, & else \end{cases}$$

When $\overline{\theta} = 135^{\circ}$:

$$M(x,y)=\begin{cases} M(x,y), & \text{if } M(x,y)\ge M(x-1,y-1) \text{ and } M(x,y)\ge M(x+1,y+1) \\ 0, & \text{else} \end{cases}$$

D. Dual-threshold Algorithm to Detect the Edges

Calculate the dual-thresholds using maximum classification square error method and detect the edge according to the dual-thresholds.

$$\tau_1 = \max_{k\in[M_{\min},M_{\max}]} \delta^2(M,k),\ \tau_2 = \max_{k\in[M_{\min},\tau_1]} \delta^2(M,k)$$

$M_{\min}$ and $M_{\max}$ are maximum and minimum of amplitude of gradient respectively.

IV. Experimental Results

The comparative experiments are conducted on night-time traffic images using the following algorithms:

Algorithm A: The method in this paper – the Canny edge detection algorithm after homomorphism filtering using bilinear generalized self-adaptive fuzzy enhancement.

Algorithm B: the Canny edge detection algorithm after homomorphism filtering using bilinear generalized fuzzy enhancement, $D = f_{\min}$, $r = 0.2$.

Algorithm C: the Canny edge detection algorithm after homomorphism filtering using bilinear generalized fuzzy enhancement, $D = f_{\min}$, $r = 0.7$.

Algorithm D: the Canny edge detection algorithm without homomorphism filtering using bilinear generalized self-adaptive fuzzy enhancement.

By experiments, set the incident light constant $i_0 = 10$, $t = r/3$, the experimental results are shown as figure 2: figure 2(a) is the original image, figure 2(b) is homomorphism filtering fuzzy enhancement effect figure; figure 2(c)-(f) are the edge detection effect figure using all algorithms; amongst white is strong edge and gray is the weak edge. Seen from figure 2(c) and (f), homomorphism filtering can effectively eliminate the influence of illumination; Seen from figure 2(c), (d) and (e), the detection results using self-adaptive adjustable parameters are better than the fixed adjustable ones, the r in figure 2(d)、(e) is larger or less, it will lead to missed detection of edges or false edge phenomenon. Experimental results show the effectiveness and practicality of the method in this paper.

V. Conclusions

This paper presents a vehicle edge detection method in nighttime light affecting environment. This method can effectively eliminate the impact of light and increase the accuracy of the fuzzy enhancement, and its high-speed and efficacy also meets the requirements of vehicle detection quickly and efficiently. After gaining the edge of the vehicle, the strong and weak edges can be connected, and then determine the length of the edge, remove the isolation of pseudo-edge.

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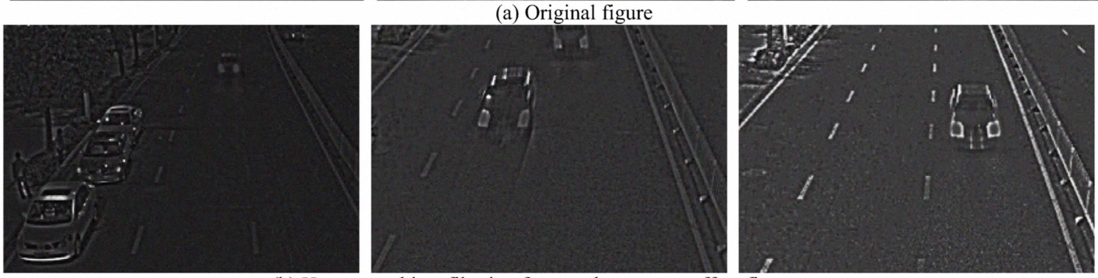
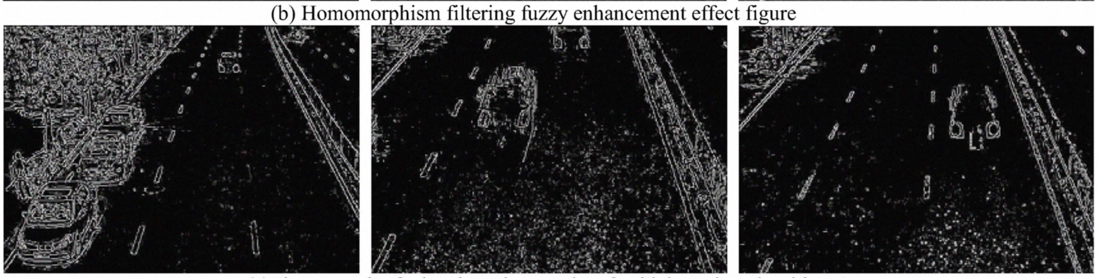
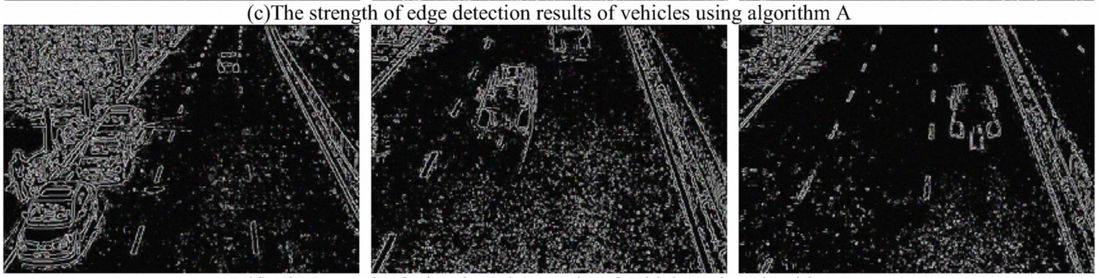
(a) Original figure



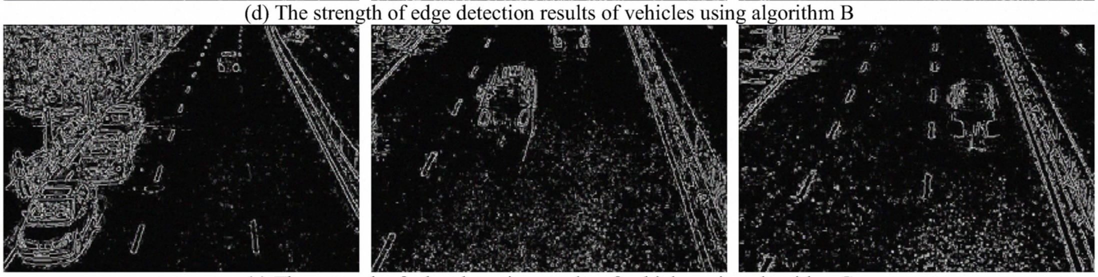
(b) Homomorphism filtering fuzzy enhancement effect figure



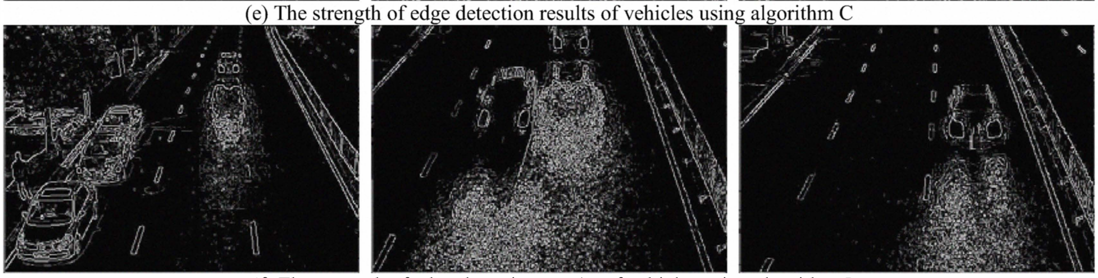
(c)The strength of edge detection results of vehicles using algorithm A



(d) The strength of edge detection results of vehicles using algorithm B



(e) The strength of edge detection results of vehicles using algorithm C



(f) The strength of edge detection results of vehicles using algorithm D

Figure 2. Experimental Results Figure