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Symmetrical Logarithm Transformation Method for Driving Vision Enhancement

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Abstract

Low visibility is the primary cause of the driving accidents. Current image enhancement methods can not effectively improve driving visibility. An image enhancement method based on symmetrical logarithm transformation is proposed to improve this situation. Symmetrical logarithm transformation based on two-scale luminance distribution features is used to obtain an enhanced image. The advantages of proposed method include its self-adaptive ability to varied brightness, low computational complexity and parameter-free input. Experimental results show that the performance of proposed method is more robust and effective than that of other state-of-the-art image enhancement methods.

Keywords: *image enhancement, symmetrical logarithm transformation, driving vision*

1. Introduction

At present, about 1.3 million people worldwide die in car accidents every single year. Low visibility should be blamed in most accidents. To assist car drivers driving smoothly at night, many researches on vehicle detection using vision sensor have been conducted [1-4]. Due to probable false detection and long processing time, the achievements of these researches are impractical. Infrared vision system is used for night driving [5]. However, some information of color and texture will be lost, which makes images unnatural. Enhancement methods using multi-sensors [6, 7] can overcome this disadvantage, but the high demand on hardware devices hinders such methods from being widely applied to ordinary electronic products.

Image enhancement methods are usually used to improve the visibility of single vision sensor in ordinary electronic products. Among them, histogram equalization technique [8] is widely-used, but it may result in over-enhancement. Modified methods are proposed to restrain over-enhancement [9, 10]. However, halos and transition are both intense in the enhanced images. The effect of enhancement is not so obvious to improve image visibility. Image enhancement methods based on histogram adjustment methods can alleviate the problem [11-14]. However, parameter setting will directly affect the enhancement effect.

The transformation-domain enhancement method is the other mainstream way of image enhancement. The basic idea of such techniques is to enhance the image by manipulating the transformation coefficients [15-17]. These techniques can effectively reduce the intensity of transition yet share the disadvantage of high computational complexity.

In this paper, a vision enhancement method based on symmetrical logarithm transformation is proposed. Firstly, original image is transformed into HSV color space. Two-scale feature is obtained to realize symmetrical logarithm transformation in the V component of image. Then, enhanced image is transformed into RGB color space to assist driving. The results of various experiments show that the proposed method can efficiently enhance the

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driving visibility. Furthermore, the proposed method has a self-adaptive ability to varied brightness, high processing speed and parameter-free input.

The organization of the rest paper is as follows. In Section 2, the proposed image enhancement method is described. Some experimental results and comparisons are shown in section 3. The conclusions are made in Section 4.

2. Symmetrical Logarithm Transformation

Since the HSV color space corresponds closely to the human perception of color [18], it is selected to do image enhancement. In the HSV color space, the hue (*H*) and the saturation (*S*) represent the color contents, whereas the value (*V*) represents the luminance intensity. The *V* component is enhanced only when both *H* and *S* ones are preserved. Figure 1 shows the flowchart of the proposed method.

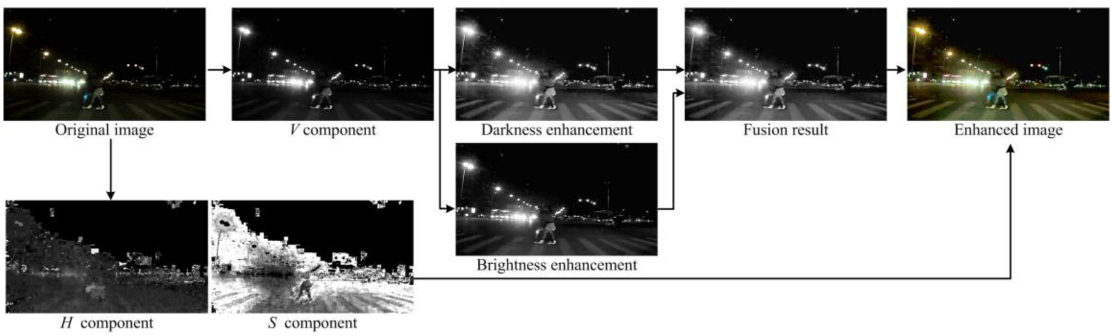

Figure 1. The Flowchart of the Proposed Method

As a typical contrast-stretching approach, normalization transformation is described as:

$$T_n(I) = \frac{I - I_{\min}}{I_{\max} - I_{\min}}(b - a) + a \quad (1)$$

I is a matrix or vector, I_{max} and I_{min} are the maximum and the minimum values of *I* respectively; *a* and *b* are the boundary values of the dynamic range within [*a*, *b*]. Without the loss of generality, *a* is set as 0 and *b* is 255.

Normalization transformation is done in *V* component.

$$V(x, y) = T_n(V_o(x, y)) \quad (2)$$

where $V_o(x, y)$ is original luminance value, (x, y) is the pixel coordinate.

Symmetrical logarithm transformation is done to $V(x, y)$.

$$\begin{cases} G_1(x, y) = \log(V(x, y) + \beta_1) \\ G_2(x, y) = \log(b - V(x, y) + \beta_2) \end{cases} \quad (3)$$

$G_1(x, y)$ and $G_2(x, y)$ are the results of symmetrical logarithm transformation. $G_1(x, y)$ can improve darkness range. $G_2(x, y)$ can improve brightness range. β_1 and β_2 are the low-scale features of luminance distribution, the calculation formula is as follows:

$$\begin{cases} \beta_1 = \sum_{(x,y)\in(m,n)} V(x,y) / \sum_{i_1=1} i_1 & a \le V(x,y) < \frac{a+b}{2} \\ \beta_2 = \sum_{(x,y)\in(m,n)} V(x,y) / \sum_{i_2=1} i_2 & \frac{a+b}{2} \le V(x,y) \le b \end{cases} \quad (4)$$

where i_1 and i_2 are the number of pixels meeting the corresponding conditions.

$$G_3(x,y) = T_n(G_1(x,y)) + \frac{2\mu}{a+b}(b - T_n(G_2(x,y))) \quad (5)$$

where μ is the mean value of $V(x, y)$ which is the high-scale feature of luminance distribution. $G_3(x, y)$ is the fusion result of $G_1(x, y)$ and $G_2(x, y)$.

$$V_{en}(x,y) = \frac{1}{b-a} T_n(G_3(x,y)) \quad (6)$$

$V_{en}(x, y)$ is the enhanced result of V component. The image is enhanced after the enhanced V component and the H, S components of the original image being combined and transformed into RGB color space. As shown in Figure 2, with a nonlinear smooth transition curve and flexible transformation based on the two-scale features, the proposed method shows its adaptive ability to enhance image. It can be concluded from the above analysis that the method is of low computational complexity.

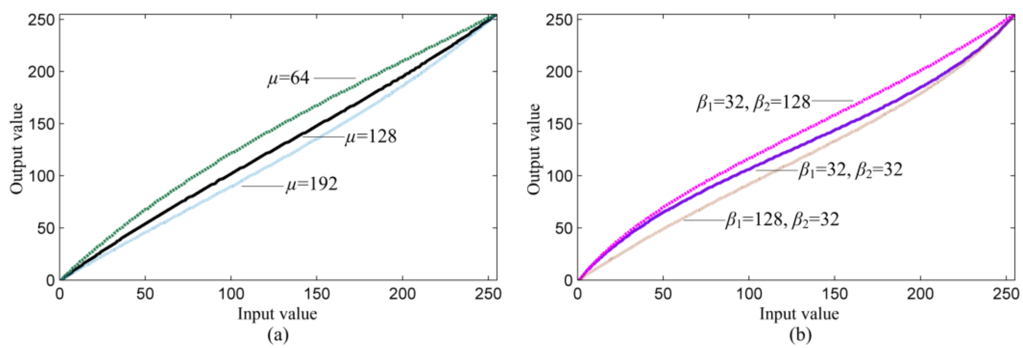

Figure 2. Value Transformation Curve of the Proposed Method (a) β_1=128 and β_2=128, (b) μ=128.

3. Experimental Results

In order to show its superiorities, the proposed method will be compared with some other advanced methods, which include histogram equalization (HE) [8], scaling coefficients enhancement (CES) [16], dynamic fuzzy histogram equalization (DFHE) [10], fourier domain multi-scale retinex enhancement (FRE) [17], adaptive gamma correction (AGC) [18], and naturalness-preserved enhancement algorithm (NPEA) [19]. The experimental images are captured by ordinary tachograph.

3.1. Subjective Evaluation

The common case of low visibility is dark vision, which is very likely to cause accidents. Figures 3-5 present the enhanced results of crosswalk from different viewing angles. Original images are so dark that the front scene can't be seen clearly. In addition, the attention of car drivers is easily attracted by the strong light of high beams, thus things and people around are easily overlooked.

Due to over-enhancement, the processed images become very bright and blurred in HE and AGC. The situation is improved in NPEA, but the halo effect is still apparent. DFHE can reduce the brightness of high beams, but the processed image is still of low visibility. Visibility is improved but not so obvious in CES and FRE. The proposed method can improve visibility, reduce the high light, and finally generate the clearest enhanced images.

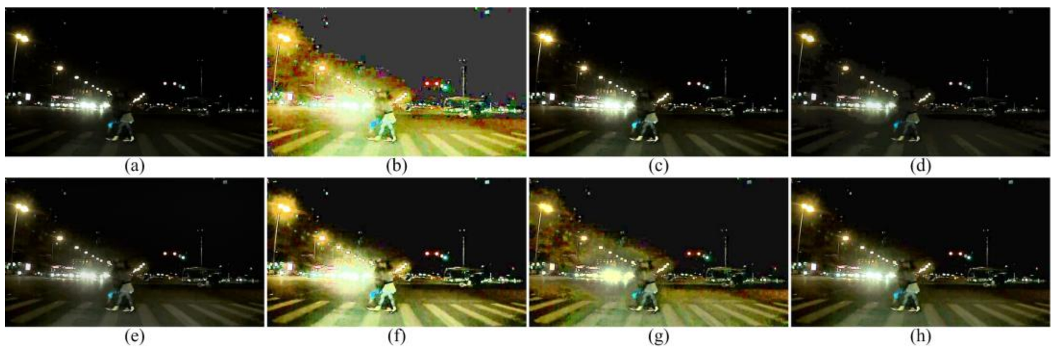

Figure 3. Enhanced Results of Crosswalk #1 (a) Original Image, (b) HE, (c) CES, (d) DFHE, (e) FRE, (f) AGC, (g) NPEA, (h) The Proposed Method

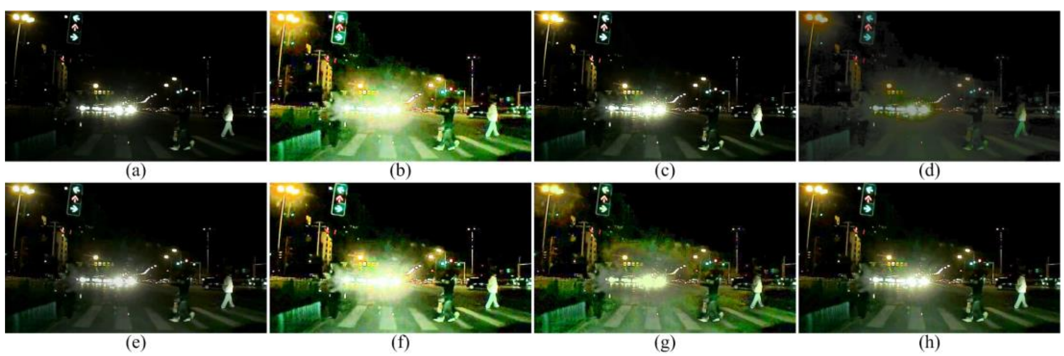

Figure 4. Enhanced Results of Crosswalk #2 (a) Original Image, (b) HE, (c) CES, (d) DFHE, (e) FRE, (f) AGC, (g) NPEA, (h) The Proposed Method

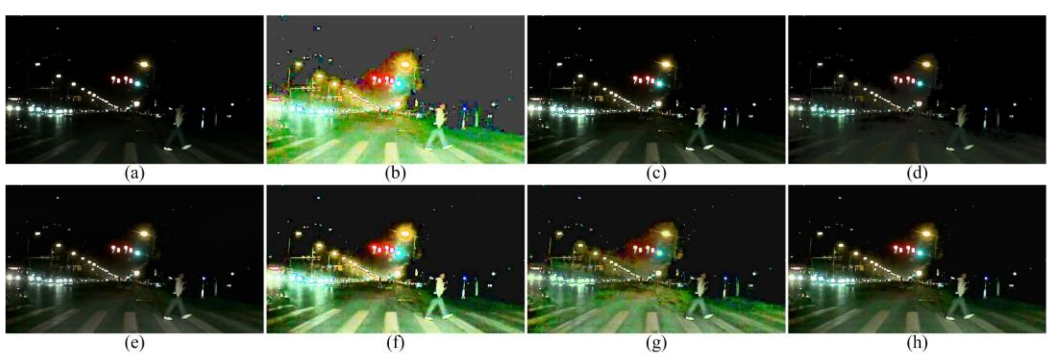

Figure 5. Enhanced Results of Crosswalk #3 (a) Original Image, (b) HE, (c) CES, (d) DFHE, (e) FRE, (f) AGC, (g) NPEA, (h) The Proposed Method

Figures 6 and 7 show the enhanced results of residential area and rural trail, correspondingly. The original image is darker than the crosswalk images because of its weak light sources. People in front of the driving direction are easily ignored. HE makes the processed image bright and blurred. There exist very severely unnatural color blocks. The situation is improved in AGC and NPEA, but there still exist unnatural color blocks in their processed images. Visibility is weakly improved in CES, DFHE and FRE and the scene is still not clear. These problems are effectively resolved with the proposed method.

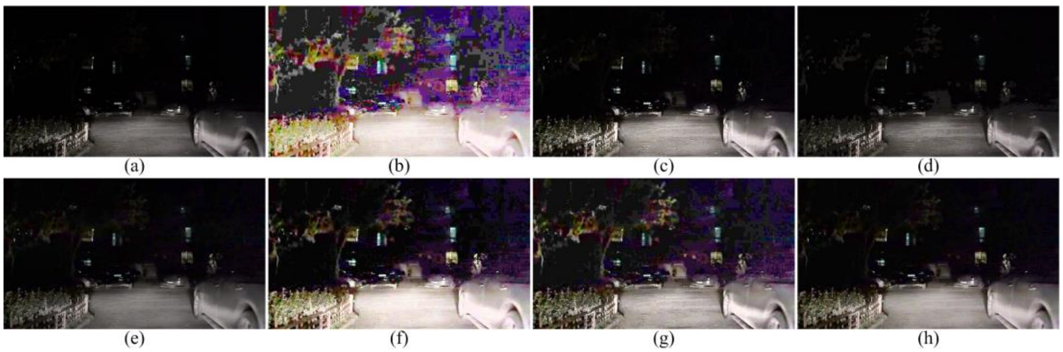

Figure 6. Enhanced Results of Residential Area (a) Original Image, (b) HE, (c) CES, (d) DFHE, (e) FRE, (f) AGC, (g) NPEA, (h) The Proposed Method

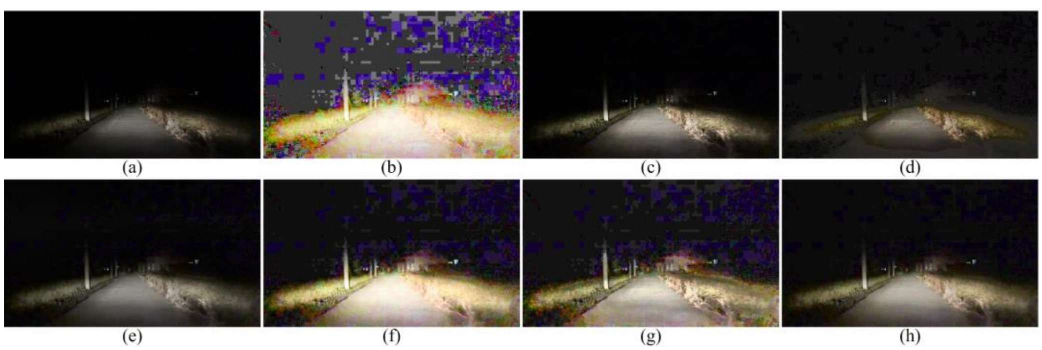

Figure 7. Enhanced Results of Rural Trail (a) Original Image, (b) HE, (c) CES, (d) DFHE, (e) FRE, (f) AGC, (g) NPEA, (h) The Proposed Method

Figure 8 shows the enhanced results of road. The original image is brighter than the above images yet not clear enough. The processed images become bright and dazzling in HE and AGC. CES makes high beams brighter, thus reducing visibility. The effect of enhancement is not obvious in DFHE. The contrast of processed image is reduced in FRE. Noise becomes obvious in NPEA. The enhanced images are the clearest by using the proposed method.

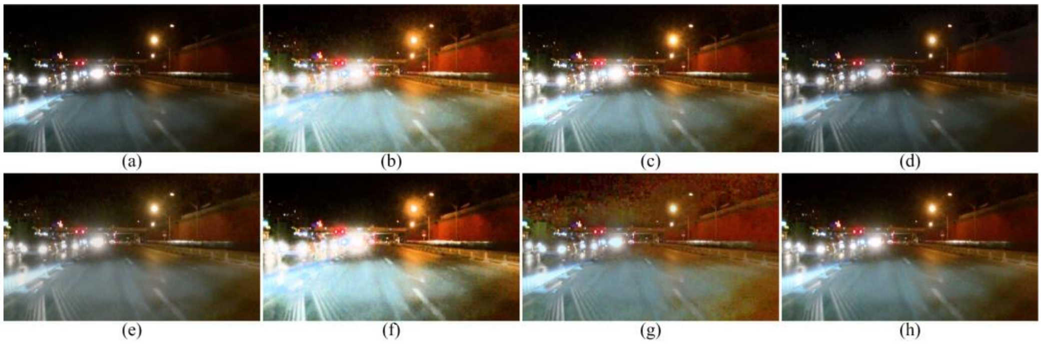

Figure 8. Enhanced Results of Road (a) Original Image, (b) HE, (c) CES, (d) DFHE, (e) FRE, (f) AGC, (g) NPEA, (h) The Proposed Method

To compare the robustness of the investigated methods under varied brightness, the processed results of highway and street in daylight with different methods are shown in Figures 9 and 10, correspondingly.

In Figure 9, the original image is a little dim. HE makes the processed image unnatural. The processed images look dazzling in CES and AGC. The processed image becomes very clear, but noise also becomes obvious in NPEA. The enhancement effect of DFHE is not obvious. The processed image becomes a little vague in FRE. By contrast, the processed image becomes clear by employing the proposed method.

In Figure 10, the original image is clear. However, HE makes the processed image dark while CES and NPEA make the processed images too bright and blurred. The color of processed image changes greatly in FRE. The processed image looks dazzling in AGC. The effects of proposed method and DFHE are better.

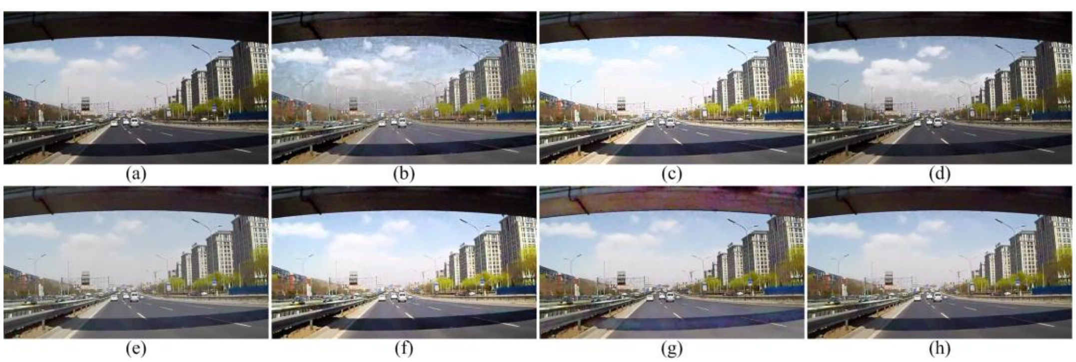

Figure 9. Enhanced Results of Highway (a) Original Image, (b) HE, (c) CES, (d) DFHE, (e) FRE, (f) AGC, (g) NPEA, (h) The Proposed Method

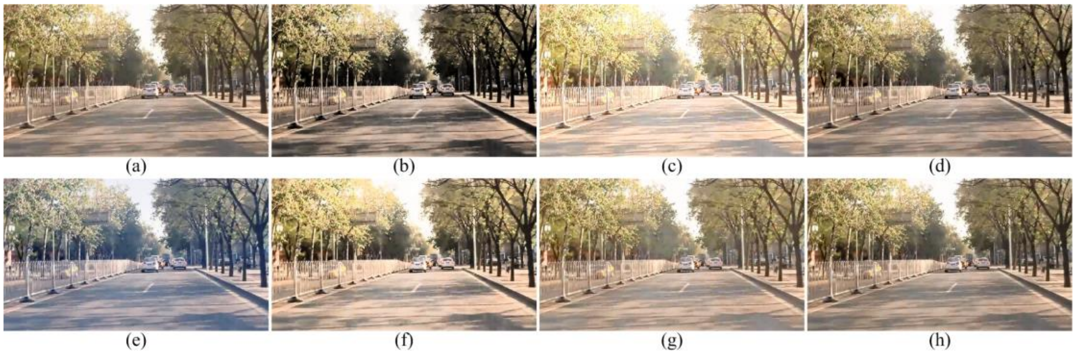

Figure 10. Enhanced Results of Street (a) Original Image, (b) HE, (c) CES, (d) DFHE, (e) FRE, (f) AGC, (g) NPEA, (h) The Proposed Method

According to the above experimental results, the proposed method can be applied to various scenes of nighttime driving in different light conditions with good effect. The proposed method is more robust and effective than other enhancement methods in these experiments.

3.2. Objective Evaluation

The subjective evaluation can demonstrate qualitatively the effectiveness of the developed method. To illustrate the good performance of the proposed method, objective evaluation which includes the preservation of main features and the assessment of image quality is necessary.

Feature Similarity (FSIM) [20] index is used to assess the preservation degree of main features as shown in Table 1. The value of FSIM is between 0 and 1. The value is closer to 1, and features contained in the processed image are closer to those of the raw image.

Table 1. FSIM in the Investigated Methods

Image	HE	CES	DFHE	FRE	AGC	NPEA	**Proposal**
Crosswalk #1	0.64	0.95	0.95	0.95	0.68	0.72	**0.88**
Crosswalk #2	0.65	0.95	0.85	0.95	0.68	0.74	**0.88**
Crosswalk #3	0.66	0.96	0.94	0.96	0.69	0.75	**0.89**
Residential Area	0.59	0.95	0.94	0.95	0.74	0.73	**0.91**
Rural Trail	0.59	0.96	0.87	0.94	0.74	0.73	**0.90**
Road	0.86	0.94	0.98	0.97	0.84	0.89	**0.98**
Highway	0.90	0.94	0.97	0.97	0.95	0.93	**0.99**
Street	0.94	0.93	0.99	1.00	0.92	0.99	**1.00**
Average	0.73	0.95	0.94	0.96	0.78	0.81	**0.93**

Blind image spatial quality evaluator (BISQ) [21] is used to assess the quality of processed image as shown in Table 2. The value of BISQ is between 0 and 100 (0 represents the best quality and 100 the worst).

Table 2. BISQ in the Investigated Methods

Image	HE	CES	DFHE	FRE	AGC	NPEA	**Proposal**
Crosswalk #1	38.63	46.74	55.10	47.85	35.86	45.27	**40.64**
Crosswalk #2	23.24	36.76	28.12	32.95	22.73	24.09	**26.50**
Crosswalk #3	29.28	58.07	56.47	51.67	39.43	25.80	**46.12**
Residential Area	51.33	31.59	44.93	33.62	39.45	42.36	**33.04**
Rural Trail	53.14	42.02	54.23	40.95	32.86	49.33	**38.76**
Road	34.07	29.27	40.63	38.47	34.08	32.69	**39.25**
Highway	27.35	26.70	25.99	28.93	27.27	27.71	**28.45**
Street	39.87	39.22	41.25	40.52	40.87	40.05	**40.80**
Average	37.11	38.80	43.34	39.37	34.07	35.91	**36.69**

One can note that the general performance of the proposed method is better than most of other advanced methods according to Table 1 and 2. By using the proposed method, the main features of the original image are retained to a large degree, while the quality of the image is good. In other words, the proposed method gets an image of good quality with the minimal loss of main features.

3.3. Real Time

The real-time processing of driving vision is essential. The experiment is tested in Matlab7.10.0 environment of a PC with 3.3GHz CPU and 3GB RAM. Without considering the time spent on color space conversion, the results of real-time experiment are shown in Table 3. Since the proposed method has a relatively low computational complexity, the real-time performance of the proposed method is better than most other methods. The proposed method is realized by Android platform and applied to ordinary tachograph, the processing is real-time.

Table 3. Average Processing Time of 640×360 Image in Different Methods

	HE	CES	DFHE	FRE	AGC	NPEA	**Proposal**
Time (ms)	21	3006	113	1108	66	14029	**32**

4. Conclusion

An image enhancement method based on symmetrical logarithm transformation is proposed to assist driver driving. The proposed method can be applied to various scenes of driving in different light conditions in order to improve the driver's vision, and it is compared with other advanced image enhancement methods. The results of various experiments show that the proposed method is the most practical one among the methods being investigated. With the application of the proposed method, the rate of car accidents caused by low visibility will be effectively reduced.

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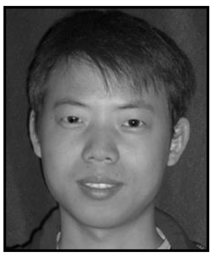

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