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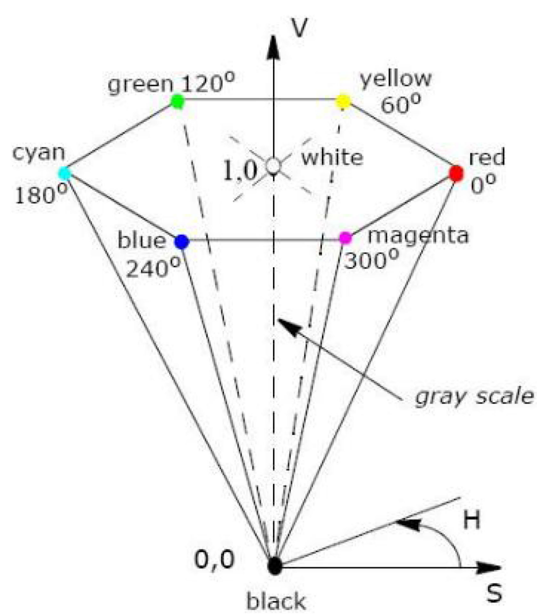

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Low Illumination Video Image Enhancement

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Abstract: Due to weather conditions, brightness conditions, capture equipment and other factors, leads to video unclear or even abnormally confused, which is not conducive to monitoring, and can not meet the needs of applications. Based on the actual data of night video surveillance, this paper proposes a new low illumination video image enhancement algorithm, which overcomes the existing problems. We analyze the characteristics of low illumination video image, and use HSV color space instead of traditional RGB space to enhance the robustness of video contrast and color distortion. At the same time, we use wavelet image fusion to highlight the details of video image, so the enhanced video has higher clarity and visual effect. Compared with other four algorithms, the proposed algorithm outperforms the above algorithms in subjective evaluation and objective evaluation. At the same time, compared with other algorithms, the proposed algorithm has faster processing time for each frame. Experiments show that the algorithm can effectively improve the overall brightness and contrast of video images, and avoid the over-enhancement of bright areas near the light source, which can meet the practical application requirements of video surveillance.

Index Terms: Low illumination, Video image, Wavelet fusion, HSV.

1. Introduction

Video is widely used in public security surveillance, but under normal circumstances, due to insufficient light, the quality of video decreases, which makes it impossible for us to capture useful information from video images. If we want to make the best use of the information in the video, we must enhance the video image and analyze it further.

At present, video image enhancement algorithms can be divided into machine learning and non-machine learning. Using machine learning to enhance video images can usually achieve good results in large data sets, but this method also has its own shortcomings [1], [2]. First, it needs a lot of data to train. If there is not enough data to train, this method has poor enhancement effect on video images, and then training. The process takes a long time. But the traditional algorithm does not need training and enhances the effect in small data, in many cases the enhancement effect is good [3]–[6]. Therefore, many scholars have done a lot of work in the traditional field of video image enhancement [7], and invented many algorithms for low illumination video image enhancement. By fusing the information of the daytime background image to restore the surrounding scene [8],but the visual effect of the video is poor. Subsequently, some scholars improved the algorithm. Some scholars believe that the captured night video can improve the dark channel to improve the quality of night video. Night video enhancement using improved dark channel prior proposes an improved dark channel priori model and combines it with local smoothing and image Gauss pyramid operators. It not only enhances the visual effect of low illumination video image, but also effectively enhances the edges of the image [9], [10]. In image processing, many real images are taken under ambiguous conditions, and need to be processed to obtain better quality. So far, most methods have tried to transform the standard fuzziness into the standard fuzziness image degradation model. In this method, it is not only a basic problem that can not be solved theoretically, but also the parameters used in many methods are often difficult to accurately estimate. In recent years, some scholars have first come to the fog model in standard HSV color space. Compared with traditional RGB color space, HSV color space is more suitable for contrast enhancement because it has robustness to color distortion. Only V channel uses the same haze model as RGB channel, thus reducing the “halo effect” of high contrast edge areas in night image processing [11], [12]. However, only the conversion of color space will result in blurry image details, resulting in poor video quality. In the process of image enhancement, we usually convert the image to transform domain to enhance the image. For example, low-light image enhancement is performed by wavelet. Wavelet transform has been widely used in the field of image processing because of its excellent time-frequency localization and multi-resolution analysis ability [13]–[15]. The use of stationary wavelet transform for sharpening to enhance the details of the image. The stationary wavelet transform was used to divide the image into four sub-pictures, and then the four sub-pictures were enhanced separately to produce a clearer edge image [16]. The discrete wavelet transform (DWT) and singular value decomposition (Sag) after the filter processing to obtain a new image with enhanced contrast and resolution, and obtains a better subjective visual effect [17] .Dual Tree complex wavelet transform and non-local mean enhance the details of low-illuminance images, and use DT-CWT to shift without distortion, reducing image noise [18]. Although these transform-domain algorithms all improve the details of the image, for low-illuminance images, improving the robustness of contrast and color distortion is the same key factor. Therefore, how to improve the contrast and color distortion of the algorithm is the key to the image enhancement process.

Aiming at the problem that low illumination video image has poor clarity and image details, a new low illumination video image enhancement algorithm is proposed. We use HSV color space instead of traditional RGB space to enhance the robustness of video contrast and color distortion. At the same time, we use wavelet image fusion to highlight the details of the video image, so the enhanced video has higher clarity and visual effect.

2. Materials and Methods

2.1 Color Space Conversion

In RGB color space, the chromaticity H, saturation S and brightness V of an image do not intersect with each other, that is, the color and brightness cannot be effectively separated. Simply enhancing the three channels of RGB to adjust the brightness of the image may affect the chromaticity of the image. Therefore, the true color image can be changed from RGB space to the space where the color and brightness can be effectively separated. HSV space is not only better than RGB space is more suitable for describing human color sensation, and it effectively separates chroma, saturation and brightness, making chroma and color saturation and brightness nearly orthogonal, which brings great convenience to subsequent true color image enhancement. In this paper, the true color image is transformed from RGB color space to HSV color space. In SV color space, H

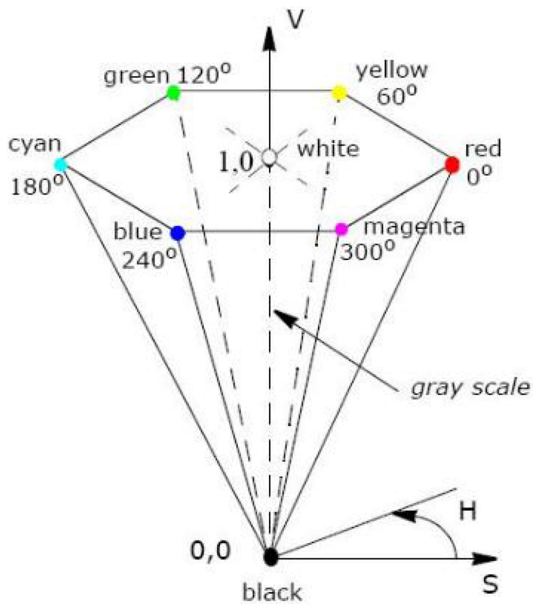


Fig. 1. HSV mathematical model.

is the abbreviation of Hue, S is the abbreviation of Saturation and V is the abbreviation of Value. Chromaticity is usually used to distinguish a certain color from a macro perspective, such as white, yellow, green, magenta, red, blue, black and so on. Saturation refers to the purity of the color. Usually, the brighter the color is, the darker the color is, the lower the saturation is. Brightness refers to the brightness of the color, the brighter the color is, the brighter the brighter the color is, the lower the brighter the color is, and the lower the color is. Dark [19].HSV color space is not suitable for display system, but more in line with the visual characteristics of the human eye. Therefore, color is usually converted from RGB space to HSV color space for processing, and then displayed in the RGB space. Scholars usually use HSV mathematical model as follows: HSV color space can be represented by a cone, as shown in the following graph: as shown in the figure, the H of a pixel can be represented by the center angle formed by the point and the white reference line, and the value range of H is [0, 360]; the S of a point can be expressed by the distance between the point and the center of the circle of the circle, the greater the distance, the higher the saturation, and vice versa; the V of a point can be expressed by the distance between the circle and the top of the cone, the greater the distance, the brightness. The higher, the lower.

This paper analyses the problems of low illumination video images, such as low brightness, blurred image details, poor visual effect and so on. Firstly, aiming at the problem of low brightness of low illumination video image, the traditional RGB space is converted to HSV space, so that the brightness of the image is processed separately, instead of directly manipulating the three primary colors of R, G and B, the relationship between hue phase and saturation of the original image can not be changed.

2.2 Wavelet Fusion

Image fusion is a technology that combines the information contained in each image data organically by using certain algorithm after geometric registration of image sequences acquired by two or more sensors at the same time or at different times to produce a new image of high quality. The fused image is more suitable for human vision and easy for subsequent image processing, such as Image segmentation, feature extraction, etc.

The image fusion based on wavelet transform firstly decomposes the source image by orthogonal wavelet transform, and four sub-images are obtained to express low-frequency information, horizontal information, vertical information and diagonal information respectively. Then the low-frequency sub-images are further decomposed into four sub-images. Then feature selection is performed in the transform domain to create the fused image. Finally, the fused image is reconstructed by inverse transform [20], [21]. For the object of image fusion, it can be divided into two categories: the fusion between multispectral image (usually RGB color image) and gray image, and the fusion between gray image. The fusion of gray-scale images can be divided into three main categories. One is single fusion method, in which two images aligned in space are directly weighted average. The other is fusion method based on pyramid decomposition and reconstruction algorithm, including gradient pyramid method. The first step is to construct pyramids that need input, and then form fusion pyramids according to certain characteristics. The image is reconstructed by inverse transformation, and the fused image is finally generated, so the final effect is better than that of the first kind of method.

According to the traditional wavelet image fusion, improved the corresponding coefficient value method, so as to enhance the details of the image [22]. In this paper, the wavelet transform method proposed in document [23] is used to divide the image into subgraphs containing high frequency information and low frequency information. The following are the fusion rules for high frequency and low frequency domains respectively.

3. Algorithmic Steps

1) divide the video into frames and divide them into frames.
2) Rename each frame and write each new picture to disk;
3) Transform the image from RGB color space to HSV space;

In RGB color space, the relationship between the values of three color components and the generated color is not intuitive. HSV color space, however, is more similar to the way humans perceive color. In our study, RGB color space is converted to HSV space; let Max be equal to the maximum in r, g and b, and min be the minimum. The corresponding (h, s, v) values in HSV color space are:

$$h = \begin{cases} 0^0 \\ 60^0 \times \frac{g-b}{\max - \min} + 0^0 \\ 60^0 \times \frac{g-b}{\max - \min} + 360^0 \\ 60^0 \times \frac{g-b}{\max - \min} + 120^0 \\ 60^0 \times \frac{g-b}{\max - \min} + 240^0 \end{cases} \tag{1}$$

where max = min, h equals segment A, where max = R and G are greater than or equal to b, h equals segment B; where max = R and G are less than b, h equals segment C; when h equals max = g, h equals segment D; and when Max equals b, h equals segment E. The value of H is usually normalized to between 0 and 360 degrees. And H = 0 is used for max = min (that is, grey) instead of leaving h undefined.

$$s = \begin{cases} 0 \\ \frac{\max - \min}{\max} \end{cases} = 1 - \frac{\min}{\max} \tag{2}$$

Where max = 0, S equals 0; otherwise, S equals the second paragraph.

$$v = \max \tag{3}$$

4) In RGB space, the brightness of each pixel of the picture is enhanced 10 times.
5) Transfer the image from HSV space to RGB space. The specific operation is as follows:

$$h_i \equiv \left[\frac{h}{60}\right] \tag{4}$$

$$f = \frac{h}{60} - h_i \tag{5}$$

$$p = v \times (1 - s) \tag{6}$$

$$q = v \times (1 - f \times s) \tag{7}$$

$$t = v \times (1 - (1 - f) \times s) \tag{8}$$

For each color vector (r, g, b):

6) The Brightness-enhanced image is processed by wavelet fusion. Haar wavelet, orthogonal normalized wavelet, is used here.

Haar wavelet transform is interpreted as follows:

For example, there are four numbers a = [8, 7, 6, 9], and b[4] arrays are used to save the results. Then the results of first-order Haar wavelet transform are as follows:

$$b[0] = (a[0] + a[1]) \tag{9}$$

$$b[1] = (a[2] + a[3])/2 \tag{10}$$

$$b[2] = (a[0] - a[1])/2 \tag{11}$$

$$b[3] = (a[2] - a[3])/2 \tag{12}$$

That is to say, two numbers are taken from the array in turn, and their sum and difference are calculated, and half of the sum and difference are stored in the first half and the second half of the array in turn.

For example, if there is *a[8]*, the result of one-dimensional Haar wavelet transform is preserved in *b[8]*, then the result of first-order Haar wavelet transform is obtained.

$$b[0] = (a[0] + a[1])/2 \tag{13}$$

$$b[1] = (a[2] + a[3])/2 \tag{14}$$

$$b[2] = (a[4] + a[5])/2 \tag{15}$$

$$b[3] = (a[6] + a[7])/2 \tag{16}$$

$$b[4] = (a[0] - a[1])/2 \tag{17}$$

$$b[5] = (a[2] - a[3])/2 \tag{18}$$

$$b[6] = (a[4] - a[5])/2 \tag{19}$$

$$b[7] = (a[6] - a[7])/2 \tag{20}$$

If the second-order Haar wavelet transform is needed, only the Haar wavelet transform of b[0]-b[3] is needed.

For a two-dimensional matrix, each level of Haar wavelet transform requires two one-dimensional wavelet transforms in horizontal and vertical directions, and the order of rows and columns has no effect on the results.

7) By using wavelet transform, the image is divided into high-frequency part and low-frequency part. In this paper, the image is divided into high-frequency part and low-frequency part, which are the main parts of high-frequency and low-frequency images. Because the low contrast in the low frequency part results in poor visual effect, and the local variance of the image can enhance the sensitive details of the human eye, so the square sum of the low frequency coefficients of the image is equivalent to the local variance. In this paper, the absolute value of high-frequency coefficients is larger because of the rich high-frequency components, high brightness and contrast. The energy contained in these large wavelet coefficients is much larger than that contained in small coefficients. Therefore, in signal reconstruction, large coefficients are more important than small coefficients.

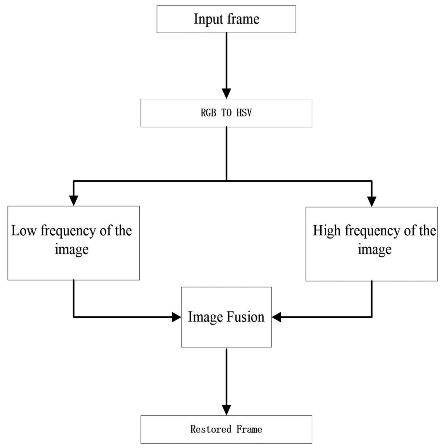


Fig. 2. Flow chart.

8) The high-frequency and low-frequency parts of the image are fused to obtain the final enhanced image.
9) Rename the enhanced image and write it to disk.
10) Write the image into the function of the video to get the final enhanced video.

4. Experimental Analysis

4.1 Visual Effect Analysis

In our experiment, we evaluated the proposed method by testing the video taken in the field. In the experiment, the algorithm and Readability Enhancement of Low Light Videos Based on Discrete Wavelet Transform (RELLVBDWT) [24], Night video enhancement using improved dark channel prior (NVEIDCP) [25], Artifact-free Low-light Video Enhancement Using Temporal Similarity and Guide Map (ALVEUTSGM) [26], Video enhancement by using discr resolution enhancement Ete and stationary wavelet transforms with illumination compensation (VREDSWTLC) [27] were compared.

As shown in Figs. 3– 6, as shown in Fig. 3, it can be seen from the original image of image 3(a) that the overall brightness and contrast of the image are relatively low, while there are smaller areas that are relatively bright. Through the processing of each algorithm, the brightness and contrast of the image are enhanced. The brightness of the image is enhanced by RELLVBDWT and NVEIDCP, but the subjective effect is still very poor. The results of ALVEUTSGM algorithm are obviously enhanced. We can see the car in the lower left corner and the white wall shows normal color after enhancement, but the image details in the upper right part of the image are not enhanced. The result of ALVEUTSGB processing is more obvious than that of RELLVBDWT and NVEIDCP. However, there is still a phenomenon that the enhancement is not obvious. The wall in the image is still grey after enhancement. The algorithm proposed in this paper first enhances the overall brightness of the image. In image 3 (a), the lower left part of the car and the wall can be clearly seen, as well as the upper right part of the car can be seen, showing a good visual effect. From the above analysis, we can see that the algorithm can effectively enhance the overall brightness and contrast of the image and enhance the details better, thus reflecting the effectiveness of the algorithm in this paper. From the original image of image 4 (a), we can see that the contrast and brightness of the image are very low and dark, and the visual effect is very poor. The enhancement effects of RELLVB DWT, NVEIDCP and VREDSWTLC are poor. But ALVEUTSGM has a better enhancement effect. It can be seen that this is the rear of the car, but the details have not been well enhanced. The algorithm proposed in this paper can not only see that this is the tail of the car, but

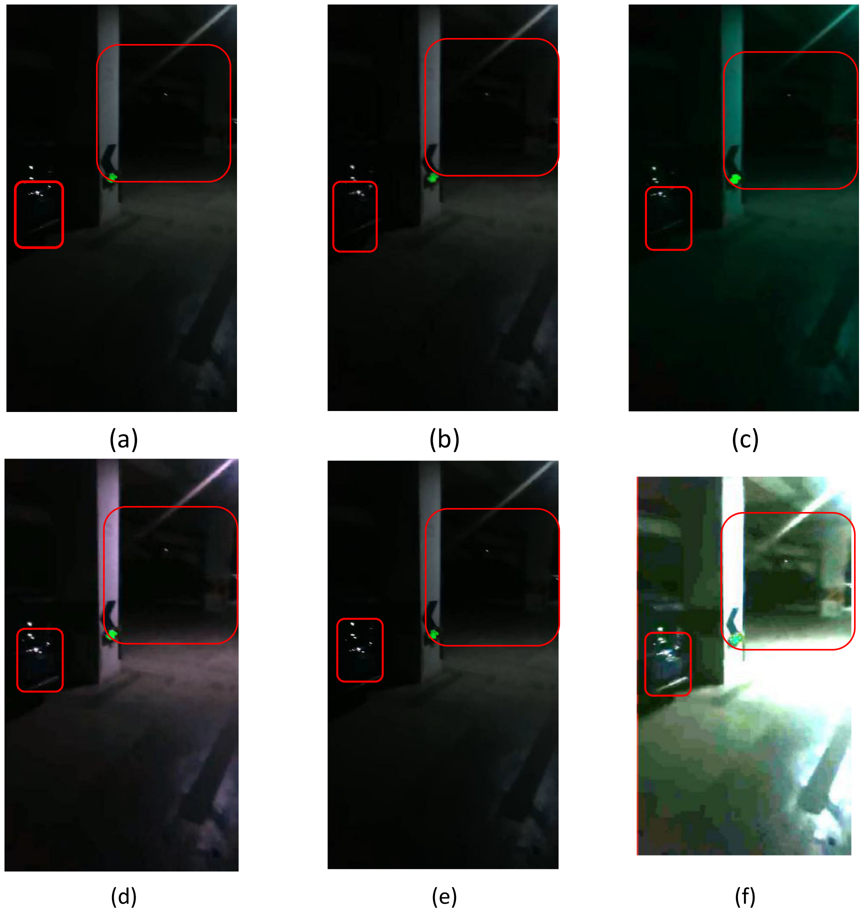


Fig. 3. (a) Test image enhanced using; (b) RELLVBDWT; (c) NVEIDCP; (d) ALVEUTSGM; (e) VREDSWTLC; and (f) Proposed algorithm.

also the red light in the tail of the car, and the white part in the red can be clearly observed. From the above analysis, the algorithm can effectively enhance the overall brightness of the image and enhance the color of the image, thus reflecting the superiority of this algorithm. The original image of image 5 and 6 is basically black and can not see the useful information of the original image at all. Comparing with each algorithm, the enhancement effect of this algorithm is better. The license plate numbers of Fig. 5 and Fig. 6 can be clearly seen as ‘H. BE60’and ‘A. 263’, respectively. In ALVEUTSGM algorithm, the whole image is dark, so the algorithm presented in this paper has high definition and good visual effect.

4.2 Analysis of Various Indicators

In this section, we use objective image quality evaluation indicators to evaluate image quality, including information entropy (H), clarity (G), mean value as evaluation criteria, in order to verify the effect of video enhancement more objectively and comprehensively. The larger the value of information entropy is, the richer the detail information is. The clearer the texture and detail of the image is, the clearer the image is. The mean value of the image pixel is the average value of the image pixel, which reflects the average brightness of the image. The bigger the average brightness is, the better the image quality is. The comparison of the objective image quality assessments

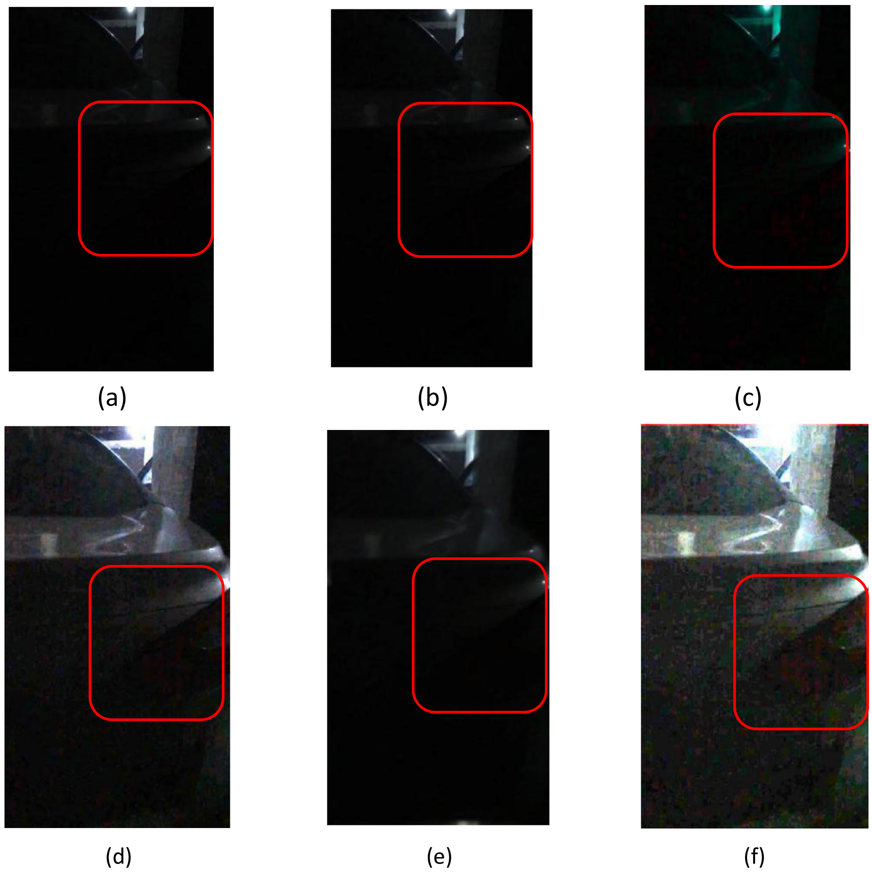


Fig. 4. (a) Test image enhanced using; (b) RELLVBDWT; (c) NVEIDCP; (d) ALVEUTSGM; (e) VREDSWTLC; and (f) Proposed algorithm.

TABLE 1
Comparison of the Objective Index Using Different Methods

Parameter	Data Set	RELLVBDWT	NVEIDCP	ALVEUTSGM	VREDSWTLC	Proposed algorithm
information entropy	1	4.95	5.037	4.65	6.21	6.43
	2	3.90	3.68	4.14	5.63	6.46
	3	3.83	3.26	3.80	3.80	6.35
	4	5.68	2.10	4.84	1.87	7.19

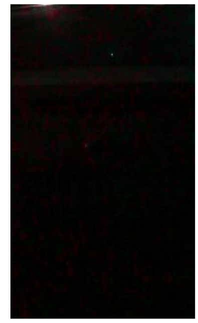
is summarized in Tables 1–3, where data sets 1 to 4 represent four images in Figs. 3 to 6, respectively.

From Tables 1 to 3, we can see that RELLVB DWT, NVEIDCP, ALVEUTSGM, VREDSWTLC and the algorithm in this paper can effectively enhance the image. The enhanced image has been enhanced in the aspects of image information entropy, image clarity and image mean. This algorithm is superior to other image enhancement algorithms in image information entropy, image sharpness and image mean, and shows the superiority of this algorithm.

From Table 1, we can see that the information entropy of the proposed algorithm is better than that of other algorithms. Among them, in data set 3, the information entropy of the algorithm in this paper is more than two times more than that of other algorithms, and the information entropy is

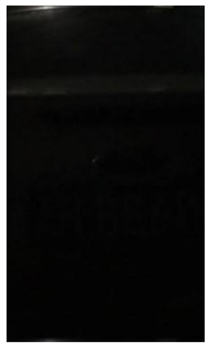
(a)

(b)



(c)

(d)



(e)

(f)

Fig. 5. (a) Test image enhanced using; (b) RELLVBDWT; (c) NVEIDCP; (d) ALVEUTSGM; (e) VREDSWTLC; and (f) Proposed algorithm.

TABLE 2
Comparison of the Objective Index Using Different Methods

Parameter	Data Set	RELLVBDWT	NVEIDCP	ALVEUTSGM	VREDSWTLC	Proposed algorithm
Resolution	1	0.25	0.24	0.31	0.61	1.97
	2	0.36	0.24	0.23	0.32	2.14
	3	0.36	0.18	0.17	0.34	2.06
	4	1.00	0.09	0.86	1.87	2.43
	avg.	0.49	0.18	0.39	0.785	2.15

TABLE 3
Comparison of the Objective Index Using Different Methods

Parameter	Data Set	RELLVBDWT	NVEIDCP	ALVEUTSGM	VREDSWTLC	Proposed algorithm
mean value	1	4.95	5.04	4.65	6.21	6.43
	2	3.94	3.60	4.15	3.75	6.46
	3	3.83	3.26	3.80	3.65	6.35
	4	5.68	2.10	4.84	1.87	7.19
	avg.	4.60	3.50	4.36	3.87	6.60

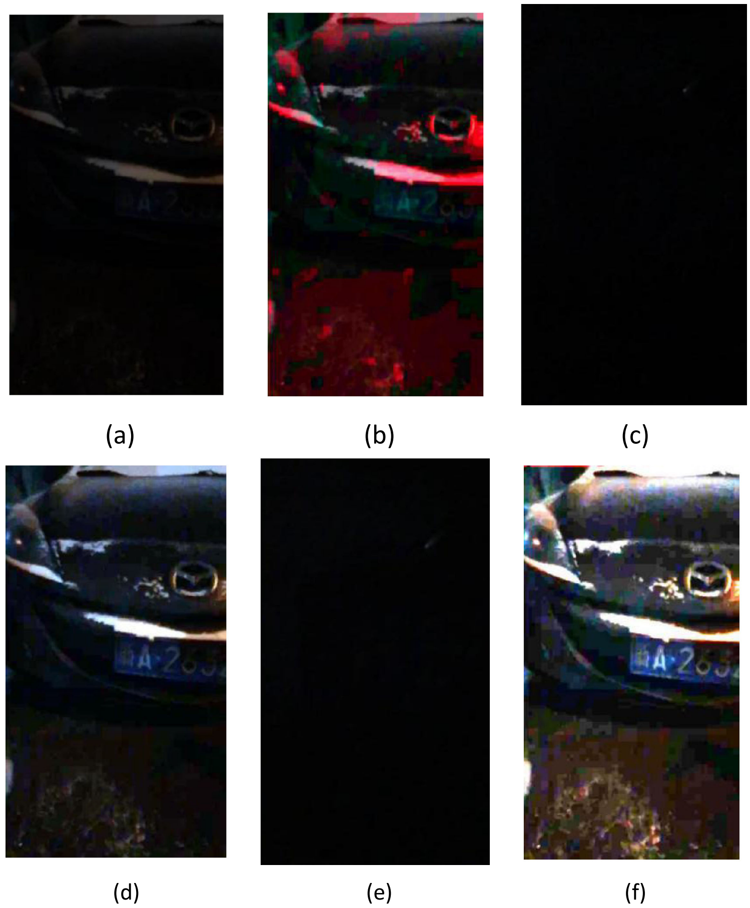


Fig. 6. (a) Test image enhanced using; (b) RELLVBDWT; (c) NVEIDCP; (d) ALVEUTSGM; (e) VREDSWTLC; and (f) Proposed algorithm.

to measure the amount of image detail information. The larger the value of information entropy is, the richer the detail information of the image is. Therefore, the enhancement of video image in this algorithm is significantly improved compared with other algorithms.

As can be seen from Table 2, the sharpness of the image has been greatly improved by the enhancement algorithm of this algorithm. Comparing with RELLVB DWT and NVEIDCP, the definition of this paper is improved by 8 times. In data set 4, the sharpness of each contrast is improved compared with that of the previous data set, but it can be seen from Table 2 that the sharpness of the algorithm in this paper is the highest. To sum up, the algorithm in this paper is the best in the objective evaluation index of clarity.

From Table 3, we can see that the average brightness of the image is greatly improved by comparing this algorithm with other contrast algorithms. From data set 1 to 4, we can see that the average value of this paper is the highest. Finally, the brightness of the enhanced image is obviously improved. It is convenient for people to capture useful information by video surveillance.

Aiming at the problem that low illumination video image has poor clarity and image details, a new low illumination video image enhancement algorithm is proposed. From each objective index and compared with each comparison algorithm. so the algorithm in this paper can enhance the low illumination video image very well.

TABLE 4
Comparison of the Time Using Different Methods

Image	RELLVBDWT	NVEIDCP	ALVEUTSGM	VREDSWTLC	Proposed algorithm
1	0.92	4.10	1.77	3.065	0.64
2	0.70	3.99	1.68	3.01	0.59
3	0.72	4.00	1.45	3.01	0.48
4	0.76	3.94	1.63	3.08	0.64

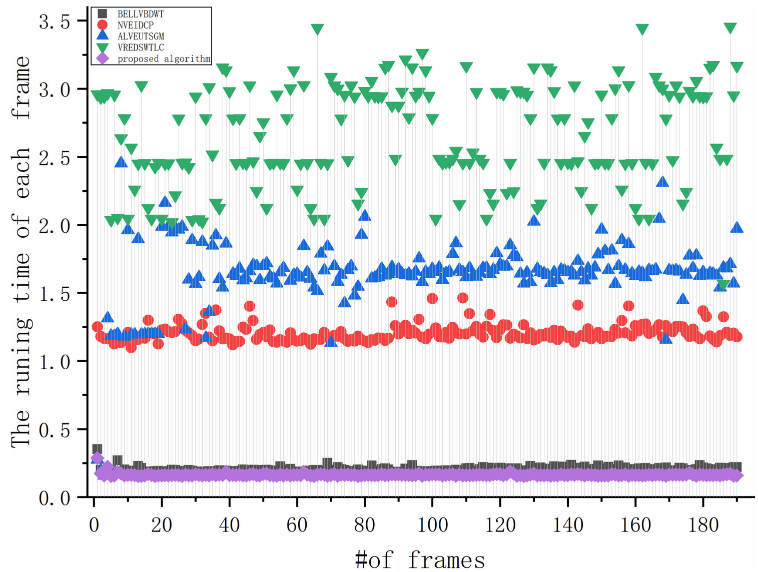


Fig. 7. The runing time of each frame.

4.3 System Processing Time

This section describes the processing time of each frame in low illumination video images. In order to make the video more real-time, we evaluated various algorithms in each frame of image processing time.

Table 4 shows the runing time of each frame using various video imaging enhancement algorithms. We compare the processing time of each frame of image from Fig. 3 to Fig. 6. For example, in Table 4, the running time of each frame of image is less than 1 s. In the table, we can see that the processing time of ALVEUTSGM algorithm for each frame of image is more than 2 times of that of this algorithm. On the basis of this, there are significant advantages. The processing time of NVEIDCP and VREDSWTLC algorithms is too long, and the real-time performance of video image enhancement is poor. The processing time of RELLVB DWT algorithm is the same as that of the algorithm in this paper. From the above, we can see that the algorithm in this paper has better real-time performance.

In this paper, we test 190 frames in a data set, and test the running time of each frame in 190 frames, so as to better illustrate the universality of the algorithm. As shown in Fig. 7, it is obvious that the proposed algorithm not only has the fastest processing time for each frame, but also has the best robustness.

In summary, the proposed algorithm not only enhances the quality of low illumination video image, but also has better real-time performance.

5. Discussion Section

The new algorithm proposed in this paper consists of four steps: the first step is to frame the video image; the second step is to transform the image from RGB space to HSV space for contrast enhancement, which improves the contrast of low illuminance video image, avoids the low brightness of the image resulting in low image quality, and enables people to extract effective information from the image effectively. In the third step, the image is copied into two identical images, and the low-frequency coefficients of the low-frequency subgraph of the image are averaged as the low-frequency coefficients of the final image fusion by two-dimensional wavelet transform; secondly, for the possible edge blur, the fourth high-frequency subgraph is passivated twice (sharpened image). In the fourth step, four sub images are fused to get the enhanced image. Finally, the enhanced image is written to disk to get the final enhanced video image.

In terms of visual effect, compared with other latest contrast algorithms, the new low illumination video image enhancement algorithm proposed in this paper has obvious visual effect, which not only greatly improves the contrast of the image, but also improves the brightness of each frame in the video and enriches the details of the image. As shown in Fig. 5, in the algorithm of rellvbdwt, nvidcp and vredswtlc, the image is dark in this frame, and the visual effect is very poor. The new algorithm proposed in this paper can not only see the contour of the car tail, but also the color of the car tail lamp. At the same time, compared with the comparison algorithm, the new algorithm in Fig. 5 and Fig. 6 can clearly see the license plate number. Therefore, in terms of visual effect, the algorithm proposed in this paper not only improves the contrast of video, but also enriches the details. Make the image present a good visual effect.

In order to illustrate the advantages of this algorithm in terms of system processing time, clarity and information entropy, we compare several latest algorithms. From Tables 1 to 3, we can see that the new algorithm we proposed, the information entropy is more than twice that of other comparison algorithms, which shows that after the algorithm in this paper is enhanced, the details of the image are more abundant, and the effectiveness of people obtaining useful information from the low illumination video image is improved. It can be seen from Table 4 and Fig. 7 that the algorithm proposed in this paper tests 190 frames of low illuminance video image, and tests the running time of each frame of 190 frame image. It can be seen from Table 4 that compared with the latest algorithm of low illuminance video image, the algorithm proposed in this paper not only has the fastest processing time for each frame, but also the processing time of the algorithm proposed in this paper The robustness is the best. For example, the processing time of alveutsgm algorithm is not only more than twice of that of this algorithm, but also more than 8 times of that of nvidcp and vredswtlc algorithm. It can be seen from Fig. 7 that the processing time of this algorithm for each frame of image is less than 1 second, which greatly saves the processing time of low illumination video image and improves the efficiency of the algorithm. Therefore, the system processing time, clarity and information entropy are all optimal.

The algorithm in this chapter has the best visual effect and objective index, and the lowest running time, which proves the practicability of the algorithm in this chapter. Therefore, the new algorithm proposed in this chapter can process the low illumination video image quickly and accurately.

6. Conclusion

This paper proposes a low illumination video image enhancement algorithm to solve the problem of low contrast and fuzzy details of night video under low illumination. In this paper, firstly, the video is divided into one frame image, then the image is transformed from RGB space to HSV space for processing, so as to improve the contrast and robustness of low illuminance video image, and then the low illuminance video image is processed by wavelet, so as to enrich the details of the image. The experimental results show that the algorithm proposed in this paper has a good enhancement effect compared with the four kinds of related algorithms, such as improving the contrast of low illuminance image, making the image more detailed, and greatly improving the operation efficiency of the algorithm. So this research direction has very important practical significance, and can meet the actual needs of night video monitoring.

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