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Brightness Measurement and Auto Exposure Control For High-Speed Camera

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Abstract

This paper proposes a method of automatic exposure that applies image histogram feature (HF) function, which is used under the condition of fast and extensively changing background lighting so as to take automatic exposure control of the high-speed camera. First, multi-spot metering is employed to fetch region of interest from the acquired images and to reduce the calculation amount of systematic metering. Then, by calculating HF function in the region of interest, large step length is selected and exposure time is roughly adjusted. Finally, fuzzy logic is used to calculate the accurately adjusted step length, and threshold limit is applied to search for the optimal exposure time with variable step length, in order to improve the accuracy and the stability of automatic exposure of high-speed cameras. According to the results, within 2ms, the brightness of a one-frame image is measured and exposure time is adjusted. Compared to the conventional automatic exposure methods that are based on the average brightness value, within 0 to 110ms, when light intensity of the light source repeatedly changes between 760lux and 23100lux, the image information entropy obtained by this method is increased by 48.38%, and the variance is reduced by 62.13%. As verified by dynamic experiments, on the premise of ensuring dynamic resolution of the camera, the method in this paper is able to rapidly acquire the optimal exposure time, to provide more favorable and more stable image details, and to offer reference for the subsequent automatic focusing, image recognition and target tracking.

Keywords: *histogram feature; high-speed camera; region of interest; automatic exposure.*

1. Introduction

With the rapid development of CMOS image sensor (CIS) technology, CIS system has been widely used in military fields and civil projects. High-speed camera adopts one type of CIS system, whose frame rate is several times to several thousand times or even more the common CIS system (*e.g.:* NTSC 30fps or PAL 25fps). By virtue of this feature, high-speed camera is widely used to record the movement of the object at certain instantaneous state or the entire process, to obtain accurate time and spatial information, and to provide a reliable basis for the study of the movement rules of high-speed phenomena. High-speed camera usually employs image sensor with high sensitivity, which requires a high brightness of the observed target and background lighting. Early high-speed cameras could generally be applied under good artificial light conditions, such as industrial inspection and observations of motion state of athletes. Now, with a wider range of demand for movement characteristics analysis of high-speed targets, high-speed camera begins to be used under natural light conditions, such as photoelectric theodolite. However, the dynamic range of nature light is much higher than that of CIS. Images taken by high-speed camera are particularly vulnerable to saturation, which leads to the loss of a

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large number of image details. The distinguishment of image features either with human observation or image tracker will be greatly influenced, thereby affecting the tracking performance of photoelectric theodolite. Therefore, this paper focuses on how photoelectric theodolite uses high-speed camera to quickly exit the state of overexposure or underexposure during the operation of tasks, locates more accurate exposure values, and provides images with favorable exposure for the subsequent focusing and target tracking.

Auto exposure (AE) has become an important factor affecting the image quality of a digital camera. By automatically adjusting the camera's exposure time, the automatic exposure system could effectively reduce the camera's overexposure or underexposure and maximize the details of acquired images. Currently, many domestic and international studies on automatic exposure are carried out from the perspective of average brightness value [1]-[5], image brightness histogram [6], information entropy [7], DCT conversion [8], mathematical iteration [9], image fusion [10] - [12] and other algorithms. However, most of them only focus on digital cameras that shoot static images, or cameras that work at the conventional frequencies [13]. Few studies are concerned with automatic light adjustment of high-speed cameras in the case of ever-changing target background lighting. Gu *et al* [14] propose an automatic light adjustment algorithm of high-speed camera based on FPGA platform, which operates in the case of 8-bit grayscale image, 512x511 resolution and 2000 frames per second, but the algorithm requires a reference image with favorable exposure in advance.

This paper proposes a method of automatic exposure that applies image histogram feature (HF) function, which is used under the condition of fast and extensively changing background lighting so as to take automatic exposure control of the high-speed camera. First, multi-spot metering is employed to fetch region of interest from the acquired images and to reduce the calculation amount of systematic metering. Then, by calculating HF function in the region of interest, large step length is selected and exposure time is roughly adjusted. Finally, fuzzy logic is used to calculate the accurately adjusted step length, and threshold limit is applied to search for the optimal exposure time with variable step length. This method measures the brightness of a one-frame image within 2ms and adjusts exposure time. Compare to methods that directly adopt brightness information of images as the evaluation criterion, like the average brightness value method and the mathematical iterative method, the method of image histogram feature function provides a higher value of information entropy in a short time. Compared with methods that directly employ image information entropy as the evaluation criterion, this method uses HF function to determine the compensation direction and the search time of the automatic exposure system reduced by step length. According to experimental results, automatic exposure method that uses image histogram feature function effectively improves the accuracy and the stability of automatic exposure of high-speed cameras, and provides more image details for the subsequent image recognition [15]- [17] and image tracking.

2. Research Background

The automatic exposure of high-speed cameras is divided into two steps. The first step is to measure the brightness of the image, and the second step is to adjust the exposure time. Figure 1 shows the overall process of automatic exposure system of high-speed camera. High-speed camera displays images to the user via Camera Link. When automatic exposure operates on the camera, in order to reduce the amount of system calculation, the current obtained images first extract region of interest with the metering mode. This paper only extracts the green component of region of interest to measure brightness.

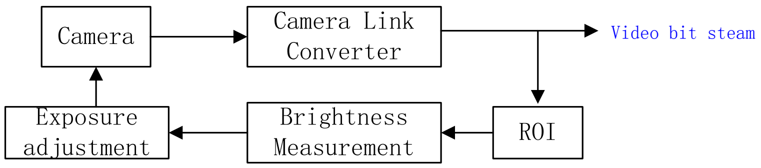


Figure 1. The Flowchart of The High-Speed Camera Auto Exposure Control

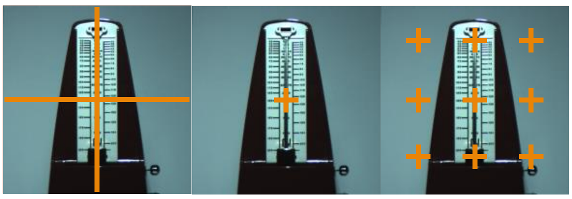
2.1. Metering Mode

When the high-speed camera works, the difference of light intensity among frames is small, so the photometric value of the previous frame is usually considered as the reference of the next frame. In order to cope with different lighting conditions, there currently are three metering modes: average metering, spot metering and multi-spot metering, as shown in Figure 2.

Average metering: according to Figure 2 (a), average metering effectively reflects the light intensity of the whole image. In this mode, the camera measures the gray value of every pixel in the whole image, and the average value is used as the reference for the adjustment of exposure time.

Spot metering: in terms of the metering range of spot metering, a very small range area in the center of the image sensor is used as the exposure reference point. The metering area of most spot metering cameras accounts for 1% to 5%. The lighting measured in this relatively narrow area is the exposure basis of the camera. Spot metering only accurately measures the lighting within a small area, and the shades of the scene outside the region have no effect on metering. A typical spot metering area is located in the center of the scene, as shown in Figure 2 (b).

Multi-spot metering: with the improvement of the resolution of image sensor, the time assumed by average metering assumes increases exponentially. Multi-spot metering extracts a number of region of interest from the image, in order to reduce the amount of metering computation and metering time. Typically, these points are evenly distributed in the whole image, as shown in Figure 2 (c).



(a) (b) (c)

Figure 2. Three Typical Metering Modes: (A) Average Metering, (B) Spot Metering, and (C) Multi-Spot Metering

When high-speed camera implements a tracking task, the background of the obtained image is relatively simple, but the size and the position of the target make real-time changes in the image. Thus, compared to the other two metering modes, multi-spot metering holds an advantage for high-speed cameras. Average metering reflects image details more effectively, but after the image resolution increases, the processing speed of the camera often does not meet the frequency of high-speed camera. Though the computational amount of spot metering is small, the metering area is too small. Thus, metering easily fails when metering area could not cover the target. Compared with traditional methods, this paper mainly applies the mode of multi-spot metering.

2.2. Relationship between Camera Frame Frequency and Exposure Time

Generally, the minimum exposure time of the high-speed camera is the permissible minimum exposure time of the high-speed camera, and the maximum exposure time is mainly affected by two factors: one is the limit of working frame frequency (fps) of the camera, and the second one is the amount of image motion of the image.

Working frame frequency of the camera: the exposed images require real-time transfer to the internal storage, and therefore each frame must allow sufficient transfer time to complete the transfer of the image. Figure 3 illustrates the overlapped working mode of image capture of the high-speed camera. When the next frame starts exposure, image data obtained from the previous frame is read and transmitted. When high-speed camera works, its maximum exposure time is inversely proportional to the working frame frequency. In other words, the higher the frame frequency is, the shorter the maximum exposure time, the camera adapts to lighting changes of the scene would be worse.

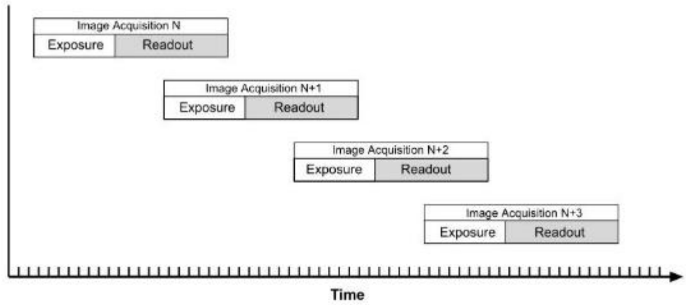


Figure 3. Overlapped Exposure Mode

Image motion control: as shown in Figure 4, when the target moves at a speed of V, spot A on the ground move back to A’ relative to the target. Through an optical system, it is imaged at point a’, and then point a turns into a short line on the target surface of the camera, which produces the movement of an image. The image motion speed on the target surface of the camera is:

$$V' = \frac{V}{H} f \quad (1)$$

V is the speed of the target relative to the camera.

H is the distance between the target and the camera target surface.

f is the focal length of optical system.

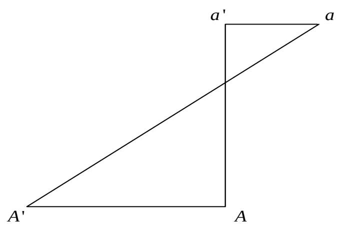


Figure 4. Sketch of the Image Motion

ΔL is the amount of image motion of the target within the exposure time of each frame.

$$\Delta L = V' \times t \quad (2)$$

In the formula, t is the exposure time of one frame of the camera.

The existence of image motion blurs the image. In order to get a clear picture, the image motion must be under control, which means that the camera’s exposure time must be controlled within an appropriate range. According to the experiment, when the amount of image motion does not exceed 1/3 of the image pixel, the camera's dynamic resolution is guaranteed, and therefore:

$$t = \frac{1}{3}\frac{H}{Vf} \times \zeta \tag{3}$$

In the formula, ζ represents the pixel size of the camera.

2.3. Image Histogram Feature (HF) Function

Grayscale histogram is a gray-scale function. It represents the number of pixels that have each gray scale in the image, and reflects the occurrence frequency of each gray scale in the image. If the input image is I(x,y), the pixel point is xy, the gray scale is L, and h(i) is the gray histogram of I(x,y):

$$h(i) = \sum_{x,y} C_i(x,y) \ (i = 0, \cdots, 2^L - 1; x, y \in N^+) \tag{4}$$

Among which

$$C_i(x,y) = \begin{cases} 1 & \text{(I(x,y)=i)} \\ 0 & \text{(otherwise)} \end{cases} \tag{5}$$

Normalized histogram, and result in:

$$norm(i) = {h(i)}/{xy} \tag{6}$$

and

$$\sum_i norm(i) = 1 \tag{7}$$

Figure 5 is the normalized grayscale histogram and it applies the multi-spot metering mode to extract region of interest in Figure 2 (c).

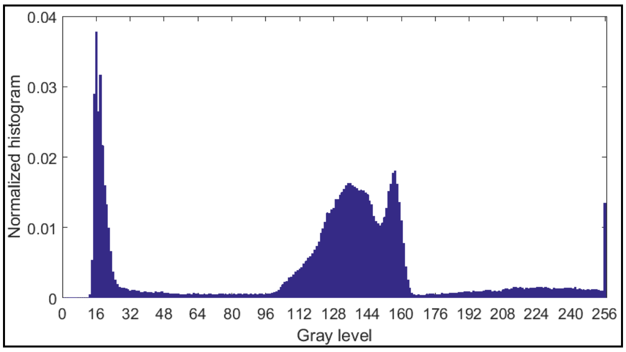


Figure 5. The Normalized Gray Histogram of Image

Although the grayscale histogram accurately represents the distribution of all the pixels at each gray scale in the image, it is oversensitive to slight changes of brightness and noise effects. When it is applied in the machine to determine the brightness of an image, evaluation function usually oscillates. In order to improve the brightness robustness of the measured target and the background, HF function is defined as the probability density function where brightness is above the threshold value *th* in the normalized image histogram, and the HF function is:

$$HF(th) = \sum_{i=th}^{2^L-1} norm(i) \ (th \in i = 0, \cdots, 2^L - 1) \tag{8}$$

This paper mainly uses four parameters to measure the image captured by the high-speed camera. Three of them are obtained through HF function: H_mean, H_half and H_twice, which respectively stand for the function value of HF when *th* is the average brightness value, the function value of HF when *th* is half of the average brightness value, and the function value of HF when *th* is two times the average brightness value. The fourth parameter—H_diff is calculated as:

$$H\_diff = MIN\{|H\_twice - H\_mean|, \\ |H\_mean - H\_half|\} \tag{9}$$

The distribution diagram of HF function in the image is shown in Figure 6.

3. Proposed Method

3.1. Rough Adjustment of Exposure Time

According to Figure 7, the automatic exposure method proposed in this paper is broadly divided into two steps: rough adjustment and accurate adjustment.

In the stage of rough exposure adjustment, first, region of interest of the image is extracted and four HF function values in the region of interest is obtained. Then, there are two conditions that trigger rough exposure adjustment as follows:

If (H_twice≥ α)
then exposure time substantially decreases
else If (H_half≥ β)
then exposure time substantially increases
else
access accurate exposure adjustment
end if

The decrease and increase margin of α, β and exposure time are preset and fixed. At the same time, it should be determined whether exposure time has reached the minimum or maximum exposure time of the high-speed camera. When the system detects that the camera's exposure time should be above the minimum or maximum exposure time, it is indicated that, under the current lighting condition, automatic exposure system has been unable to control favorable images of the camera, and automatic exposure control needs to be terminated.

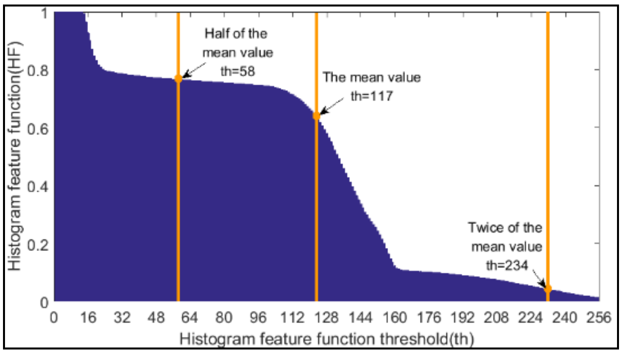


Figure 6. The HF Function Distribution of Image

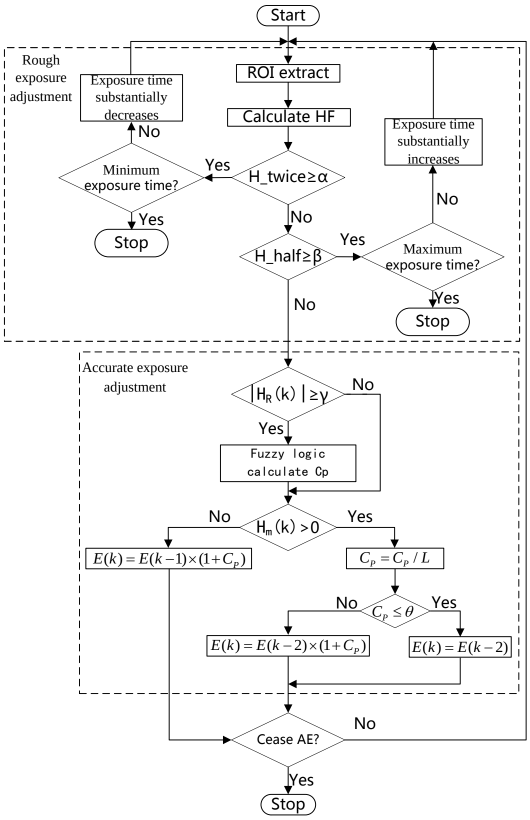


Figure 7. Proposed Control Flow of AE

3.2. Accurate Adjustment of Exposure Time

In the stage of accurate exposure adjustment, $H_R(k)$ represents the ratio of overexposure pixels between the **k-***th* image and the first image $H_o(0)$ that is compensated by fuzzy rules. The estimated function of $H_R(k)$ is:

$$H_R(k) = \frac{H_O(k) - H_O(0)}{H_O(k) + H_O(0)} \tag{10}$$

$H_o(k)$ represents the sum of overexposure pixels in the **k-***th* image. In this paper, overexposed pixel is defined as the pixel that is more than 95% of the maximum brightness value, and the preset threshold value γ is 0.2. When the image is obtained as the first image or $H_R(k)$ exceeds the threshold value, the automatic exposure system in this paper compensates the direction of exposure time and determines the compensation through fuzzy rules. The triangular membership function classifies H_mean and H_diff as five degrees—VS, S, M, B and VB, as shown in Figure 8.

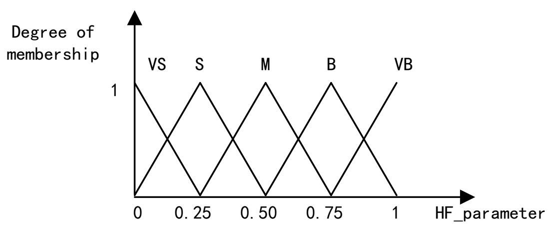


Figure 8. Membership Functions of HFS

In response to these membership functions, 12 fuzzy rules are proposed to compensate the exposure values, as shown in Table 1.

Table1. Fuzzy Logic in Linguistic Form

Rule (1,1)	IF (H_diff is VS) and (H_mean is VS)	THEN (C(1,1) is -2λ)
Rule (1,2)	IF (H_diff is VS) and (H_mean is S)	THEN (C(1,2) is +2λ)
Rule (1,3)	IF (H_diff is VS) and (H_mean is M)	THEN (C(1,3) is +4λ)
Rule (1,4)	IF (H_diff is VS) and (H_mean is B)	THEN (C(1,4) is +3λ)
Rule (1,5)	IF (H_diff is VS) and (H_mean is VB)	THEN (C(1,5) is +λ)
Rule (2,1)	IF (H_diff is S) and (H_mean is VS)	THEN (C(2,1) is -λ)
Rule (2,2)	IF (H_diff is S) and (H_mean is S)	THEN (C(2,2) is +λ)
Rule (2,3)	IF (H_diff is S) and (H_mean is M)	THEN (C(2,3) is +3λ)
Rule (2,4)	IF (H_diff is S) and (H_mean is B)	THEN (C(2,4) is +2λ)
Rule (2,5)	IF (H_diff is S) and (H_mean is VB)	THEN (C(2,5) is λ)
Rule (3,3)	IF (H_diff is M) and (H_mean is M)	THEN (C(3,3) is λ)
Rule else	ELSE	(C is 0)

In the table, C(i,j) represents the compensation value of exposure time. The plus-minus sign indicates the adjustment direction of exposure time, and λ is the adjusted step length of exposure time. In the process of defuzzification, the weighted compensation values of THEN part in the rules is determined by the membership of the IF conditions, as indicated in the formula:

$$\begin{aligned} u(i,j) = MIN(&H\_diff \times U(i), \\ &H\_mean \times U(j)) \\ &1 \le \mathrm{i} \le 5, 1 \le j \le 5 \end{aligned} \tag{11}$$

In the formula, u(i,j) stands for the membership degree of **Rule(i,j)**. U(i) and U(j) represent the membership function of H_diff and H_mean respectively.

Compensation values are calculated by this formula:

$$Cp = \frac{\sum [u(i,j) \times C(i,j)]}{\sum u(i,j)} \qquad 1 \le \mathrm{i} \le 5, 1 \le j \le 5 \tag{12}$$

Then the exposure time of the next image is drawn in the following formula:

$$E(k) = E(k-1) \times C_P \tag{13}$$

In the formula, E(k) stands for the exposure time of the **k**-*th* image.

When $H_o(k)$is lower than the threshold value, $H_m(k)$ continues to be estimated.

$H_m(k)$represents the difference between the H_half value of the **k**-*th* image and the minimum H_half value of the known image sequence, and its function is indicated as below:

$$H_m(k) = H\_half(k) - H\_half(k-1) \tag{14}$$

When $H_m(k)<0$, the exposure value of the **(k-1)**-*th* image is used as the reference to compensate the exposure time of the **k**-*th* image, as illustrated in formula (13).

When $H_m(k)>0$, the value of C_p is reduced by L times; meanwhile the exposure value of the **(k-2)**-*th* image is used as the reference, as indicated by the formula:

$$E(k) = E(k-2) \times C_P \tag{15}$$

Meanwhile, if C_p is less than the threshold value θ, the exposure value of the **(k-2)**-*th* image remains unchanged, as indicated by the formula:

$$E(k) = E(k-2) \tag{16}$$

As described in this section, concerning the method proposed in this paper, a wide range of adjustments in the camera's exposure time are made through rough exposure adjustments. Also, it should be under real-time monitor whether the background illuminance of the image exceeds the preset range. Once transitional changes occur in the background, exposure compensation value is recalculated through the fuzzy rule. On the contrary, when the change of background illuminance is small, exposure is accurately adjusted through the approach of variable step length, in order to ensure the dimming accuracy of the high-speed camera.

4. Automatic Exposure Control Experiments and Results

This paper designs static experiments and dynamic experiments to evaluate the validity and the reliability of automatic exposure in our proposed method with rapid and violent lighting changes.

4.1. Static Experiments

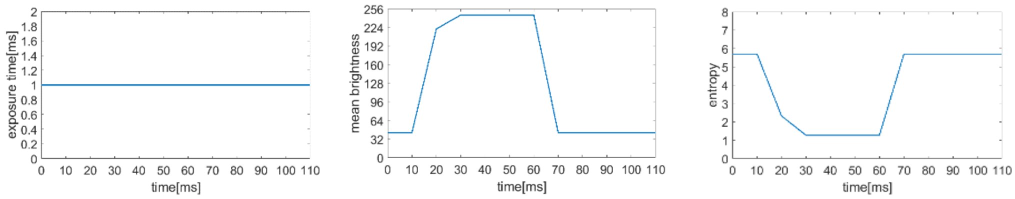
Three methods are compared in the static experiment: (i) fixed exposure time, (ii) the proposed method in this paper, and (iii) automatic exposure method based on the average brightness. Among the three control methods, the images are acquired through the same experiment platform, which includes cameras and PCs. The camera resolution, the frame frequency and the gray scale are 1024x1024, 100 frame/sec and 8bit respectively. When the automatic exposure function operates, 25 regions of interest are extracted from the images through multi-spot metering. In each region, the resolution of is 50×50, and the image resolution is reduced to 250×250. The configuration of the PC is: Intel Core I5-6500, 3.2GHz, 4G memory, software that applies VC ++ language under the Windows 7x64 bit system, and software compiled by Visual Studio 2010. In terms of Method (i), the exposure time is fixed at EN=1ms. In the stage of exposure rough adjustment of Method (ii), the threshold value α = 0.79, and β = 0.82. The exposure time increases and decreases, respectively, 20 times the original exposure time and 1/30 times the original exposure time. In the stage of accurate adjustment, the threshold value γ = 0.2, the step length of exposure compensation value λ = 0.3, L = 2, and the average brightness of Method (iii) is set as Id=128.

In the experiment, the background light makes significant changes with the switch of a LED light source, to simulate automatic exposure control of high-speed camera in the case of rapidly changing light, and the proposed Method (ii) is compared with the other two methods--(i) and (iii). The target is a metronome in the stationary state, which is 3 meters away from the camera. When the light source is turned on, the background light intensity is 23100lx, about 30 times 760lx where the light is off. Because the shooting object is static, and the camera works in the overlapped mode, the camera's exposure time <10ms.

In Method (i), this paper first verifies the image as well as the average brightness value and the information entropy of the image when the high-speed camera has no automatic exposure control. Figure 9 shows the images acquired when exposure time of the camera is fixed at 1ms (Method (i)) within 60ms that starts from t=10-70ms and has an interval of 10ms. t=0 stands for the time when experiment observation begins, and t =20ms and 60ms respectively represent the switching time of light source. Figure 10 shows exposure time (a), average brightness of the image (b) and information entropy of the image (c) within t=0-110ms. As seen from Figure 9 and Figure 10, at a fixed exposure time, when the light source is turned on, the average brightness of the image rapidly goes up, and the overexposed phenomenon happens to a large number of pixels in the image. The target is basically invisible, and the information entropy quickly drops, which could not provide reference values for the subsequent target identification, tracking and image processing.

t=20ms t=30ms t=40ms t=50ms t=60ms t=70ms

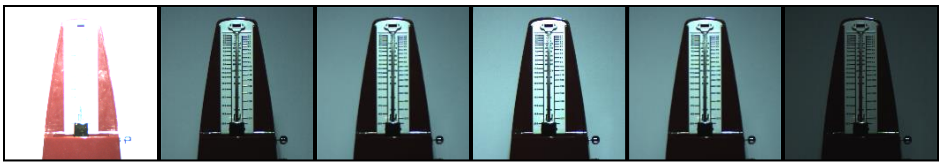
Figure 9. Image under an LED Lamp Using Method (I)



(a) (b) (c)

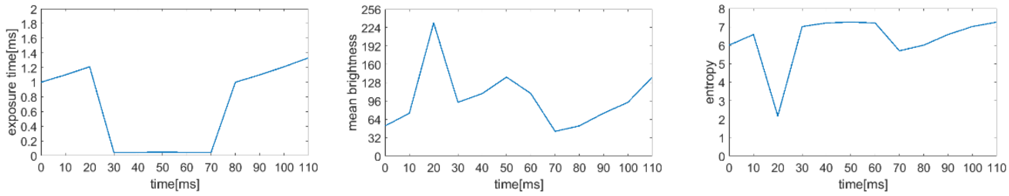
Figure 10. Exposure Time (A), Mean Brightness (B) and Entropy(C) Under an On-Off LED Lamp Using Method (I)

Figure 11 shows the images acquired by the camera with the proposed exposure method within 60ms that starts from the moment t=10-70ms and has an interval time of 10ms. t=0 stands for the moment when experiment observation begins, and t=20ms and 60ms respectively represent the switching moment of light source. Figure 12 shows exposure time (a), average brightness of the image (b) and information entropy of the image (c) within t=0-110ms. According to Figure 12 (a), when the light source is turned on at t=20ms, the exposure time of the camera decreases rapidly from E_N=1.211ms to E_N=0.040ms when t=30ms. The optimal exposure time is located from slight changes of the following three frames. When the light source is turned off at the moment t=70ms, E_N rises rapidly from 0.044ms to 1.01ms at t=80ms, and it continues to increase until the end of automatic exposure control. Meanwhile, as seen from Figure 12(b), compared with Figure 9(b), only when the light source is turned on (t=20ms), the average brightness value has increased dramatically, and the rest of the time is automatically limited to a relatively moderate range. In Figure 11(c), in addition to the case of t=20ms, the value of information entropy remains within the upper range, which provides more detailed information for the subsequent image processing.



t=20ms t=30ms t=40ms t=50ms t=60ms t=70ms

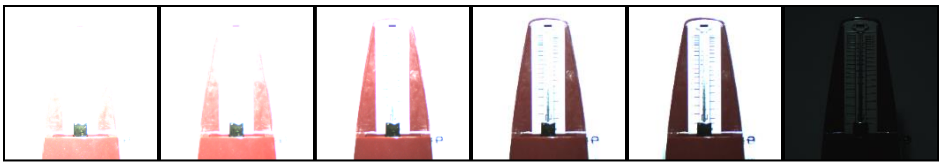
Figure 11. Image under an LED Lamp Using Our Method (Ii)



(a) (b) (c)

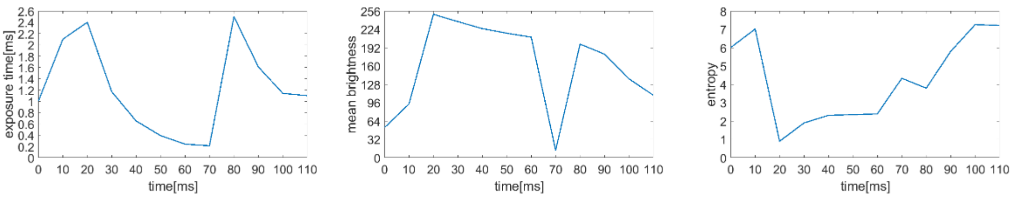
Figure 12. Exposure Time (A), Mean Brightness (B) and Entropy(C) Under an On-Off LED Lamp Using Our Method (Ii)

In the end, a comparison is made between the automatic exposure method based on average brightness value and the method in this paper. Figure 13 illustrates the images acquired by the camera with automatic exposure control within 60ms that starts from the moment t=10-70ms and has an interval of 10ms, with reference of average brightness value (Method (iii)). The moment t=0 stands for the time when experiment observation begins, and t=20ms and 60ms represent respectively the switching moment of light source. Figure 14 shows exposure time (a), average brightness of the image (b) and information entropy of the image (c) within t=0-110ms. As seen from Figure 13 and Figure 14, the automatic exposure method based on average brightness value also adapts to changing background lighting. However, compared with the proposed method (Method (ii)), as shown in Figure 14 (a), in Method (iii), overshoot phenomenon occurs to exposure time at the instant the lighting is switched on or off. In the process of LED light switch, several adjustments are required to achieve relatively favorable exposure time, especially in the case of over-exposure when the light source is on. As shown in Figure 13 and Figure 14(a), Method (iii) does not achieve the optimal exposure value after several adjustments, which becomes more distinct when the lighting changes are more intense. Like exposure time, the evaluated brightness value in Figure 14 (b) could not be kept within a relatively moderate range in a short time. As shown in Figure 14 (c), during the same period, the image information entropy obtained by the proposed method is 48.38% higher than that acquired by Method (iii), and the variance is 62.13% lower, which proves that the proposed method provides more favorable and more stable image details during the same period.



t=20ms t=30ms t=40ms t=50ms t=60ms t=70ms

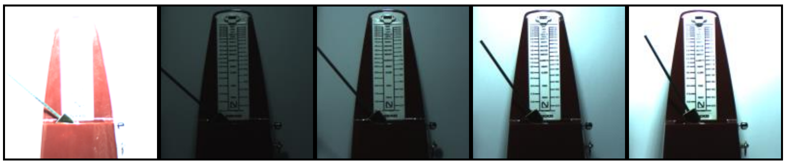
Figure 13. Image under an LED Lamp Using Method (iii).



(a) (b) (c)

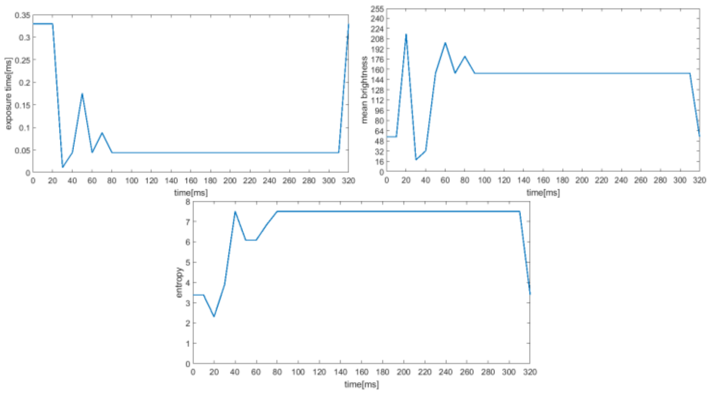
Figure 14. Exposure Time (A), Mean Brightness (B) And Entropy(C) Under an On-Off LED Lamp Using Method (Iii)

4.2. Dynamic Experiments



t=20ms t=30ms t=40ms t=50ms t=60ms

Figure 15. Image under an LED Lamp Using Our Method in Dynamic Experiment



(a) (b) (c)

Figure 14. Exposure Time (A), Mean Brightness (B) and Entropy(C) Under An On-Off LED Lamp Using Method(Ii) In Dynamic Experiment

The high-speed camera is mostly used for recording the process of target movement, and the working frame frequency of the camera is decided by the characteristics of the observed target (especially the dynamic characteristics) and the observation demand. Therefore, dynamic experiments are designed to validate this method. The experimental conditions of static experiments and dynamic experiments are identical, where the light source changes between 760 lux to 23100lux. Similarly, the threshold value setting is the same as that in the static experiment in 4.1 using Method (ii), with a metronome arm length of 14cm and 208 swings by 120 degrees per minute. In most procedures of image processing, auto-focus, object recognition and object tracking based on image processing are conducted after achieving relatively favorable exposure time. Therefore, target speed measurement based on image processing is not discussed in this paper. In terms of the referred speed of the target, the maximum instantaneous speeds of the target are obtained by other approaches. According to Formula (3), the camera's maximum exposure time does not exceed 0.33ms. In order to verify the experiment results, as shown in Figure 7, if the exposure time is found to exceed the threshold value, the automatic exposure control stops. Unlike the case where the entire camera system is under manual control, the system in the dynamic experimental is set as: once the exposure value is found to exceed the threshold value, the exposure value continues to take automatic exposure control at the threshold value. As illustrated in Figure 15, within 300ms, the camera applies this method for automatic exposure control of the acquired images, with an interval of 50ms and t=20ms to 320ms, where t=0 stands for the start of experiment observation, and t = 20ms and t = 320ms respectively represents the switching time of the light source. Figure 16 shows the exposure time (a) from t = 0-330ms, the average image brightness (b) and the image information entropy (c). As shown in Figure 15 and Figure 16, this method is able to rapidly acquire the optimal exposure time, under the premise of ensuring dynamic resolution of the camera.

5. Conclusion

When photoelectric theodolite adopts a high-speed camera, the acquirement of high-quality images depends not only on accurate measurement of background lighting, but also on the rapid and effective adjustment of exposure time. In this paper, we have proposed an automatic light adjustment method with photoelectric theodolite and high-speed cameras that employs HF function. When the camera works in the case of 1024x1024 resolution, 8bit gray scale, and 100 frames/sec, compared with the traditional methods, the metering speed of this method is faster. Also, when background lighting changes frequently, a more accurate degree of exposure compensation is provided. According to the results, in the static experiment, compared to the conventional automatic exposure method based on the average brightness value, when the range of dynamic illumination substantially changes in a short time, the image information entropy obtained by this method is increased by 48.38%, and the variance is reduced by 62.13%. As verified by the dynamic experiment, on the premise of ensuring dynamic resolution of the camera, it is proven that this method rapidly acquires the optimal exposure time, provides more favorable and more stable image details under both the static and the dynamic conditions, and offers reference for the subsequent automatic focusing, image recognition and target tracking. However, the experiment target in this paper approximately accounts for 1/2 of the entire image. And when the high-speed camera is at work, the size and the position of the acquired target in the image change in real time, so there still exist some restrictions in the practical application of this method. We will further study the automatic exposure method that aims at the ever-changing target and small targets in the image, and expand the application scope of this method.

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