Chapter 3

Traditional AE Methods

3.1 Introduction

As in film camera, the light metering scheme in DSCs is quite essential for controlling the exposure. In this chapter, we will introduce the traditional methods for processing the light metering from the simplest to the complex. In section 3.2, two basic light metering methods will be discussed, while, in section 3.3, three scene analysis methods to improve the light metering system in special conditions will be presented. Also, the drawbacks and solutions of these methods will be discussed.

3.2 Light Metering Methods

The film cameras determine the exposure by using additional photometers, while the DSCs use imaging sensor CCD/CMOS with light metering algorithms. In this section, we will introduce the conventional light metering methods in DSCs [16], [17].

3.2.1 Method Based on Constant Gray Value

In the digital video system, the image brightness is digitalized as gray values [18]. The larger gray value represents the higher the luminance as shown in **Fig. 3-1**. Therefore, the simplest way to control the exposure in DSC is to control the average gray value in a constant level which can be determined as the flowchart shown in **Fig.**

3-2. The shutter switches at a certain speed to control the exposure time. If the measured average gray value of the input data is higher/lower than the reference gray value, the system decreases/increases the exposure time by increasing/decreasing the shutter speed. The process of light metering ends when the measured average gray value equals to the reference value.

Since the image brightness in the method is kept at a constant level, the image brightness of different scene luminance looks the same, which means that in the bright/dark environment the subject will look a little dim/bright. The light metering method based on a constant gray value can not control the exposure properly in different luminance of photographic scene.

Fig. 3-1 Gray level from dark state to bright state

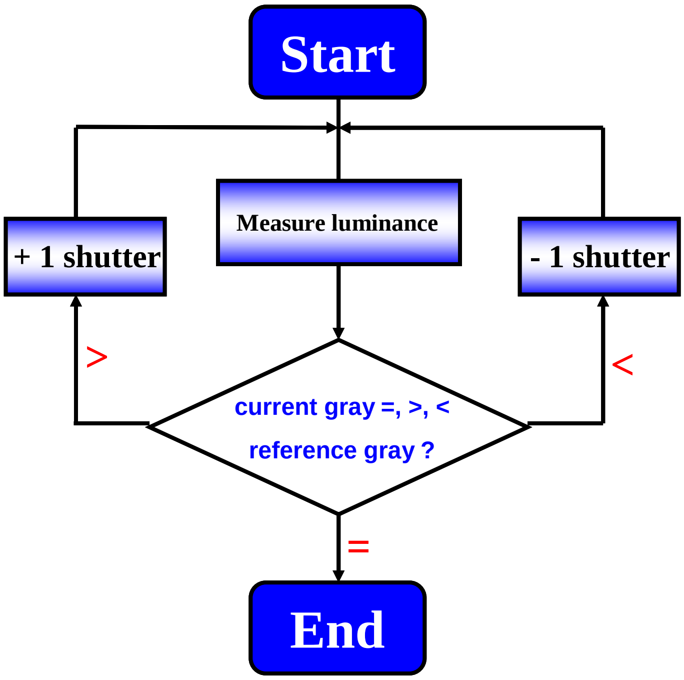


Fig. 3-2 Light metering method based on constant gray value to control the exposure time [18]

3.2.2 Method Based on Look Up Table (Kuno Model)

In order to control the exposure appropriately in different scene luminance, Kuno et al. have developed a high-precision AE system capable of controlling the exposure quickly by calculating the scene luminance directly using the Look-Up-Table (LUT) [16]. The exposure parameters for different scene luminance can be determined through LUTs, accordingly. In the proposed AE system as shown in **Fig. 3-3**, the analog imaging signal from the charge-coupled device (CCD) is fed into the signal processor before being dominated by automatic gain control circuit (AGC). Then, the AGC output signal is converted into digital one by the analog to digital converter (A/D), and the integrator integrates the digital video signal per one field as the imaging signal data within the sampling area as indicated in **Fig. 3-4**. Finally, CPU determines the exposure according to the integrated data and looks up the LUTs to obtain the scene luminance and exposure parameters.

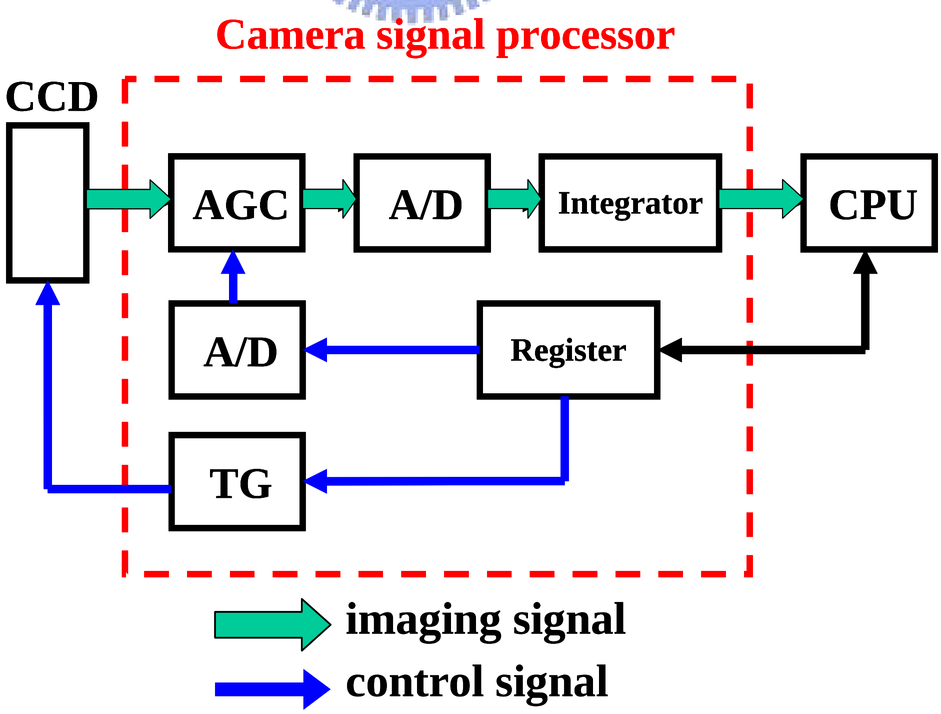


Fig. 3-3 AE system based on LUTs propose by Kuno et al. [16]

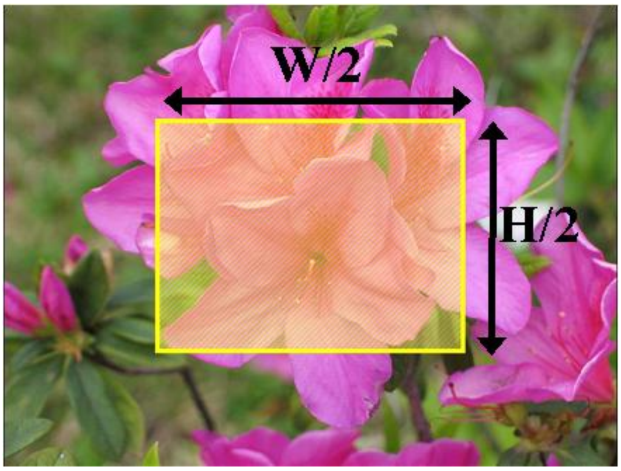


Fig. 3-4 Sampling area of the imaging sensor CCD

In Kuno method, the average integrated value of imaging signal $\sum_m$ in the sampling area can be expressed by **Eq. (3-1)**.

$$\sum_m = K \times L \times T \times G \tag{3-1}$$

Where

$\sum_m$ ：Average integrated value of imaging signal;

K ：Constant;

L : Scene luminance (cd/m^2);

T : Exposure time (sec);

G : Gain of AGC circuit;

According to **Eq. (3-1)**, the luminance of the main object L can be calculated as follows:

$$\mathrm{L} = \frac{\sum_\mathrm{m}}{\mathrm{K} \times \mathrm{T} \times \mathrm{G}} \tag{3-2}$$

Thus, the optimum exposure time and AGC gain for different scene luminance can be immediately extracted from LUTs in terms of the calculated luminance.

To implement Kuno model in DSCs easily, LUTs with the brightness of the object as the address number are set up. Due to the normal scene luminance ranges vary from the lowest luminance $L_{\min}$ to the highest luminance $L_{\max}$, the object luminance of address value n ranging from 0, 1, 2, ..., N-1, can be expressed as:

Address value n:

$$\mathrm{n} = C\log(\Sigma_m) - C\log(T_n) - C\log(G_n) - k_1 \qquad \textbf{(3-3)}$$

Where

constant $k_1 = C\log(K) + C\log(L_0)$;

constant $C = {(N-1)} \big/ {[\log(L_{\max}) - \log(L_{\min})]}$;

The LUTs use address value n to represent different luminance from dark to bright scenes, as shown in **Fig. 3-5**. The exposure time $\mathrm{T_n}$ and $\mathrm{Clog(T_n)}$, and the AGC gain $\mathrm{G_n}$ and $\mathrm{Clog(G_n)}$ corresponding to the address value n are set in LUTs 1, 2, 3 and 4. Once the address value is obtained, the exposure time $\mathrm{T_n}$ and AGC gain $\mathrm{G_n}$ can be selected from LUTs 1 and 3 to provide optimum exposure, corresponding to different luminance of objects.

Address	**LUT1**	**LUT2**	**LUT3**	**LUT4**
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
n	**$\mathrm{T_n}$**	**$\mathrm{Clog(T_n)}$**	**$\mathrm{G_n}$**	**$\mathrm{Clog(G_n)}$**
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.

Fig. 3-5 Configuration of LUTs with address value n

The advantage of Kuno method is that the calculating of exposure uses addition and subtraction only, thus reducing drastically the operational load on the CPU. Moreover, the optimal exposure parameters for different scene luminance can be extracted from LUTs immediately. However, in special lighting conditions, there are still some problems such as backlighting or strong frontlighting. To improve the light metering system in special lighting conditions, a scene analysis process is needed.

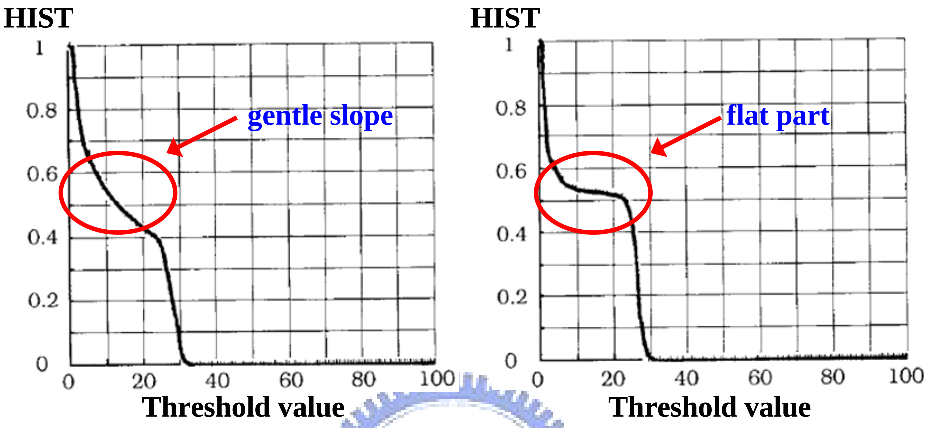
3.3 Scene Analysis Methods

The traditional methods based on average metering are failed in special lighting conditions such as backlighting, strong frontlighting due to the large luminance difference between the main object and the background. To detect the special lighting conditions, three scene analysis methods are proposed to improve the light mertering ability of AE system in DSCs [8], [9], [10].

3.3.1 Method Based on HIST Information

Shimizu et al. have defined threshold parameters of histogram (HIST) to analyze the feature of backlighting and strong frontlighting images [8]. HIST is defined as the ratio of the pixels whose brightness is higher than a threshold value to the total pixels in the whole picture. In the case of backlighting image, the luminance of the main object is much lower than that of the background. To analyze the feature of backlighting conditions through HIST information, normal and backlighting images are plotted in **Figs. 3-6 (a)** and **(b),** respectively. We can see that in the normal lighting situation, there is a gentle slope, while the backlighting one has a flat part which represents a large luminance difference (contrast) between the main object and the background. Besides, the height of the flat part represents the area ratio of the dark region to the bright region. In the strong frontlighting situation, the main object is much brighter than the background. Therefore, the height of flat part can be used to classifiy the backlighting and strong frontlighting images according to the different area ratio of the bright and dark regions. To sum up, the slope of flat part reflects the contrast between the object and the background, and the height of flat part reflects the ratio of area as shown in **Fig. 3-7**.

According to HIST information, the backlighting and strong front-lighting images can be detected and compensated, appropriately. Besides, the position of object causes no problems. However, in the detection of strong frontlighting and backlighting images, the main object need to be smaller than the background region in HIST method.



(a) **(b)**

Figs. 3-6 (a) The HIST distribution of the normal lighting state and (b) The HIST distribution of the backlighting state [8]

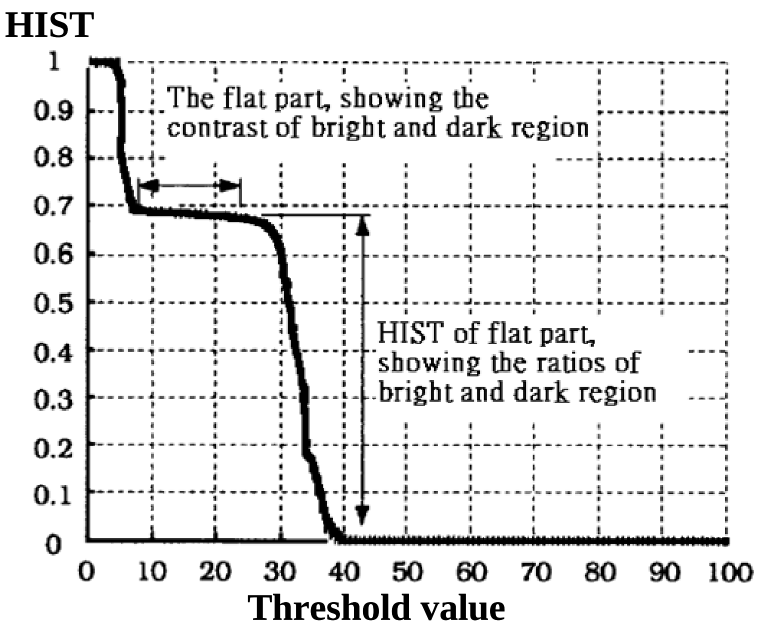
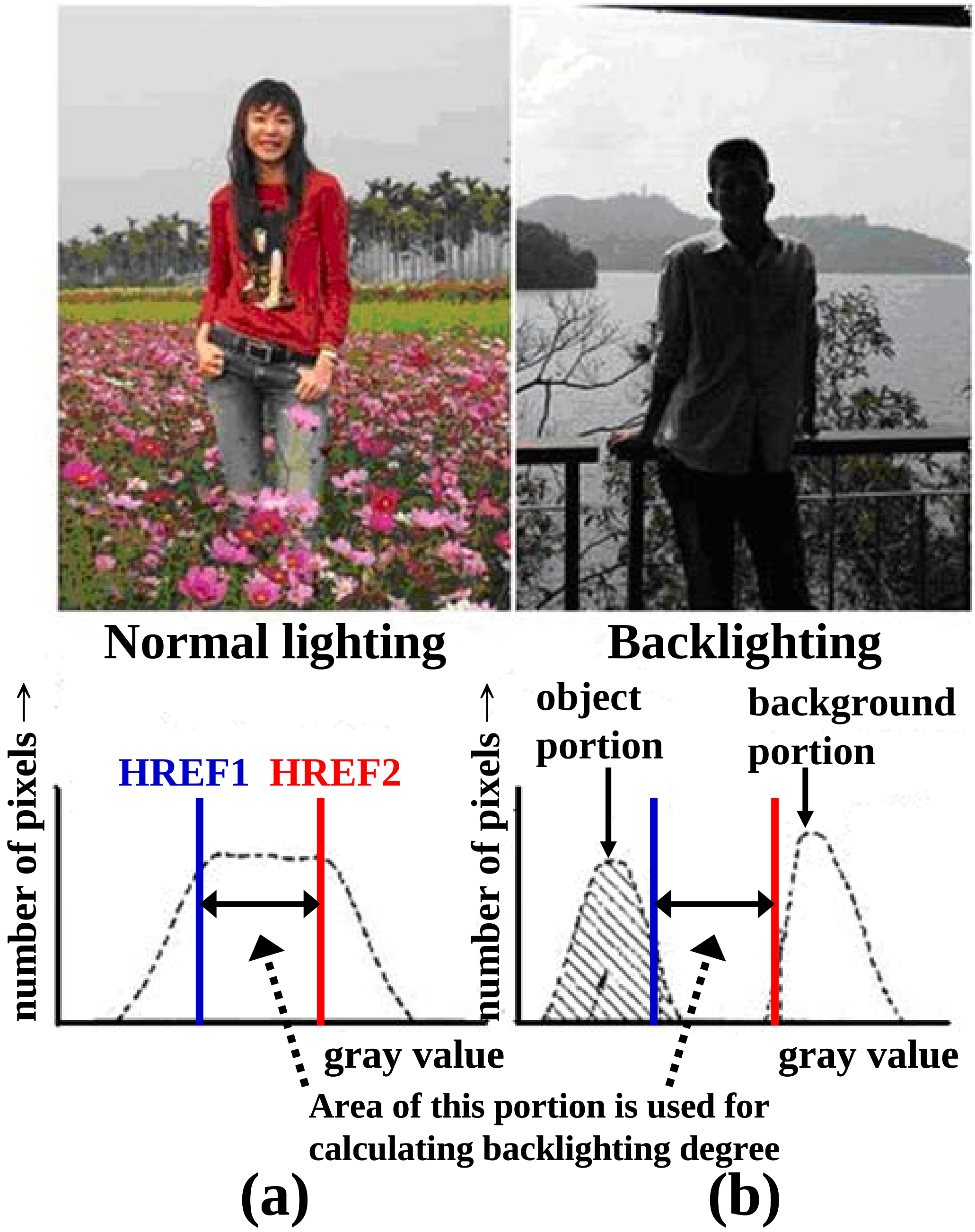


Fig. 3-7 The features of HIST information in high contrast conditions [8]

3.3.2 Method Based on Histogram Information

Hanagata et al. have proposed another scene analysis method based on "histogram" information to compensate exposure according to the "backlighting degree" [9]. The histogram is a plot of the number of pixels as a function of gray values. Through the histogram analysis method, the images of normal lighting state and backlighting states are plotted as shown in **Figs. 3-8 (a)** and **(b)**, respectively. In the backlighting situation, the feature is that there are two peaks in the high gray value and low gray value regions. The higher gray value part represents the background region, and the lower gray value part represents the main object. As the backlighting degree is increased, the contrast between the main object and the background is increased. The distance between two peaks is increased, and there are few pixels in the middle gray value region of the backlighting state compared to the normal state. Thus, the backlighting degree can be detected by calculating the number of pixels in the middle gray value region. With two threshold gray parameters as shown in **Fig. 3-8 (b)**, the degree of backlighting can be determined immediately by counting the number of pixels between HREF1 and HREF2.

The advantage of the histogram analysis method is that by calculating the number of pixels between the HREF1 and HREF2 the backlighting degree can be detected. The disadvantage is that the strong frontlighting conditions can not be recognized because few pixels in the middle gray region will confuse the calculation of backlighting degree, and error compensation will be performed.



Figs. 3-8 (a) Photography and histogram in normal lighting state and (b) Photography and histogram in backlighting state [9]

3.3.3 Method Based on Color Information

Current AE systems detect special lighting conditions such as backlighting or strong frontlighting and compensate the exposure of main object. The compensation is performed to adjust the luminance of the main object causing the background to become worse. Due to the images with high chroma as shown in **Figs. 3-9 (a)** and **(b)** are changed a lot by exposure compensation. On the other hand, the influence of the images with low chroma as shown in **Figs. 3-10 (a)** and **(b)** is small. Thus, the importance of background should be taken into consideration. To compensate exposure properly, Murakami et al. have proposed a method by using the color information where the importance of background (BI) is determined by calculating "hue" and "chroma" of pixels [10]. The larger the BI value means that the background with higher chroma, the compensation amount should be appropriate. While BI is small, the background with large white area should be overexposed, and the background with large black area should be underexposed.

According to this method, the compensation of backlighting or strong frontlighting situations can be more effective. The background with high chroma information can be preserved, and low chroma image can be compensated a lot. The disadvantage of this method is that BI is a criterion based on color information. If the function of automatic white balance (AWB) is failed, the detection of chroma and hue will be affected. While the waterfall becomes bluish as shown in **Fig. 3-11**, the detection of BI will be affected.

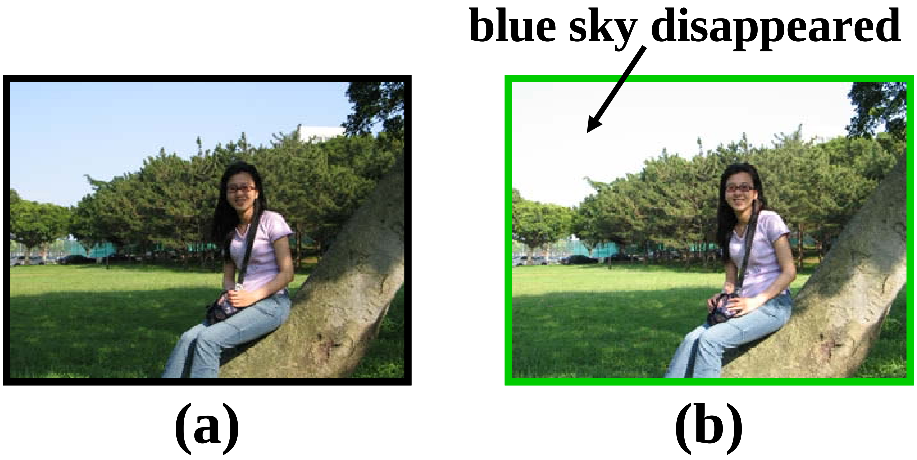


Fig. 3-9 High chroma images: (a) Background with blue sky before exposure compensation and (b) Background with white sky after exposure compensation

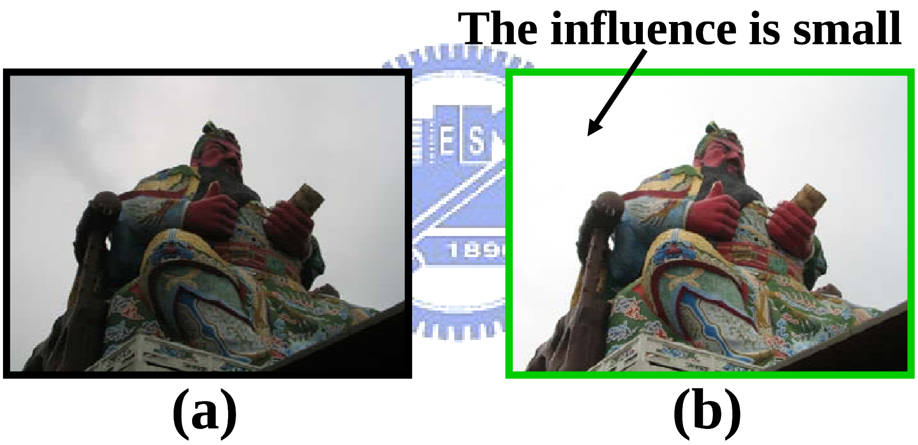


Fig. 3-10 Low chroma images: (a) Background with gray clouds before exposure compensation and (b) Background with white clouds after exposure compensation

Fig. 3-11 Low chroma images: waterfall become bluish due to wrong AWB

3.4 Summary

We have discussed five methods to perform the light metering. The comparisons of their performances in special lighting conditions are listed in **Table 3-1**. The method based on color information is useful in all conditions. However, color information is just a criterion to help for adjusting the compensation amount. To perform the light metering well in all situations, we propose a *modified* luminance detection model and a 2-D scene analysis method to improve the function of AE in DSCs. The details of our novel methods will be rendered in the next chapter.

Table 3-1 Comparisons of light metering in special lighting conditions

AE method / Lighting condition	Constant Gray	Kuno method	HIST	histogram	Color information
backlighting	X	X	O	O	V
Strong frontlighting	X	X	O	X	V
Dark environment	X	O	X	X	O
Highlight	X	V	X	X	O

X : fail
O : excellent
V : acceptable