Chapter 2

Basic Principles of Exposure Control

2.1 Introduction

The conventional exposure control principles used in the film camera can be applied to the DSCs [11], [12], [13]. In this chapter, we describe the basic principles derived from the film cameras for further usage in the DSCs. The first part gives the exposure parameters including exposure controlling factors, focal plane exposure and light sensitivity of imaging media. The second part describes the well-known exposure equations used in the film camera system. The final part presents the additive system of photographic exposure control (APEX), which is a practical exposure control system in the film cameras.

2.2 Factors of Exposure Control

The imaging system of camera can be divided into two parts. One is the optical system which controls the amount of light coming from the scene or the object, the other is the imaging media which absorbs light and records the image as shown in **Fig. 2-1**. Generally, the control of light to produce appropriate image calls exposure control. Thus, there are two factors that affect the exposure control. One is the amount of the exposure at the focal plane which is controlled by the exposure time, the aperture size of lens, the transmittance of lens, and the scene luminance. The other is the light sensitivity of the imaging media which is controlled by the size of sensing grain of the film and the gain value of the imaging sensor.

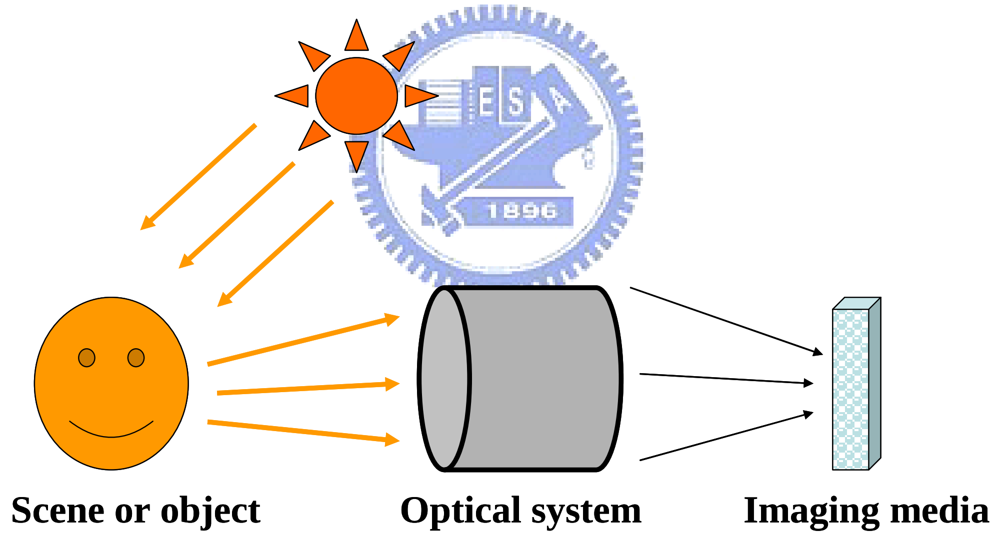

Fig. 2-1 Configuration of the major parts of the imaging system

2.2.1 Focal Plane Exposure

Focal plane exposure is the term used to refer the amount of light coming from the scene or object reaching the imaging media at the focal plane. When the arithmetic mean scene luminance is measured by the camera exposure meters, the expected value of the arithmetic mean focal plane exposure (H) can be computed by this equation:

$$H = \frac{\pi T v \cos^4 \theta \cdot L t F^2}{4A^2 t^2} + H_f = \frac{qLtF^2}{A^2 i^2} + H_f \qquad \textbf{(2-1)}$$

Where

$q = \frac{1}{4}\pi T v \cos^4 \theta$, and

A is the lens F-number;

F is the lens focal length, in meters;

H is the focal plane exposure (general), in lux.seconds;

H_f is the focal plane flare exposure, in lux.seconds;

i is the image distance, in meters;

L is the scene luminance, in candelas per meter square;

T is the transmission factor of the lens;

t is the exposure time, in seconds;

v is the vignetting factor;

θ is the angle of image point, off-axis.

When the camera is focused on infinity, H_f << H, and **Eq. (2-1)** can be simplified to:

$$H = \frac{qLt}{A^2} \qquad \textbf{(2-2)}$$

Because the optical properties of the optical system have been determined in the manufacturing process, the parameter q in **Eq. (2-1)** can be taken as a constant. The major factors which affect the focal plane exposure are the exposure time, the scene luminance and the F-number. Focal plane exposure varies linearly with the exposure time and the scene luminance and is inversely proportional to the square of the F-number.

2.2.2 Light Sensitivity of Imaging Media

ISO (International Standards Organization) speed is a numerical value related to the light sensitivity of the imaging media which is the film in film cameras or the imaging sensor in DSCs [14], [15]. The larger the ISO speed represents the higher the light sensitivity of the imaging media. The general expression of ISO speed is:

$$S = \frac{H_0}{H_m} \quad \textbf{(2-3)}$$

Where

S is the ISO speed;

H_0 is a speed constant;

H_m is the arithmetic mean focal plane exposure.

According to **Eq. (2-3),** the ISO speed is inversely proportional to the exposure for an imaging media to obtain an acceptable image.

2.3 The Exposure Equation

Exposure equation indicates minimum necessary exposure to produce acceptable results based on an assumption about the average reflectance and tone distribution of the subject. The basic equation for determining the "correct exposure parameters" is:

$$A^2/T = LS/K \tag{2-4}$$

Where

A is the lens F-number;

T is the exposure time (seconds);

L is the average scene luminance (cd/m^2);

S is the light sensitivity of the film (ISO speed);

K is a calibrated constant.

According to **Eq. (2-4)**, the film speed (S) is then determined by making a series of exposure on the test film with carefully controlled values of lens F-number (A), exposure time (T), and scene luminance (L). With the exposure equation, the exposure parameters can be calculated immediately for every given scene luminance. However, the calculation of multiplication is not suitable for the implement in the film cameras, and another exposure equation was proposed.

2.4 APEX System

The Additive System of Photographic Exposure Control (APEX system) which provides for another exposure equation in logarithmic form was developed in Germany about 1954. In this way, the calculation of the “correct exposure parameters” can be done through simple additions.

2.4.1 Exposure Value

Exposure Value (EV) is the exposure equations in logarithmic form:

$$EV = \log_2\left(A^2/T\right) = \log_2\left(LS/K\right) \tag{2-5}$$

APEX system is based on four “values,” namely, the aperture value (AV) of the diaphragm opening, the time value (TV) of the shutter, the speed value (SV) of the film, the light value (LV) of the subject. Then, EV can be expressed:

$$EV = AV + TV = \mathrm{LV} + \mathrm{SV} \tag{2-6}$$

Where

$AV = \log_2\left(A^2\right)$;

$TV = \log_2\left(1/T\right)$;

$LV = \log_2\left(L\right)$;

$SV = \log_2\left(S/K\right)$.

The aperture and time values are determined by the camera settings, while the speed and the light values are determined by the film and subject conditions. After the luminance of the photographic subject is determined, alone with the given ISO speed, the demanded aperture size and exposure time can be calculated through **Eq. (2-6)**.

2.4.2 EV Compensation

EV compensation is to change the exposure parameters for any given scene luminance. EV compensation is often useful when certain properties of the scene would frustrate the metering system's ability and cause the captured images to be underexposed or overexposed. A "plus" setting of the EV compensation is to compensate the underexposed images which are done by decreasing the EV as shown in **Fig. 2-2**. By increasing the exposure time or the aperture size, the underexposed image can be compensated to an acceptable state. As a result, the exposure compensation setting is often called the "EV offset" which forces EV to be different from what would ordinarily be put into effect by the light metering system.

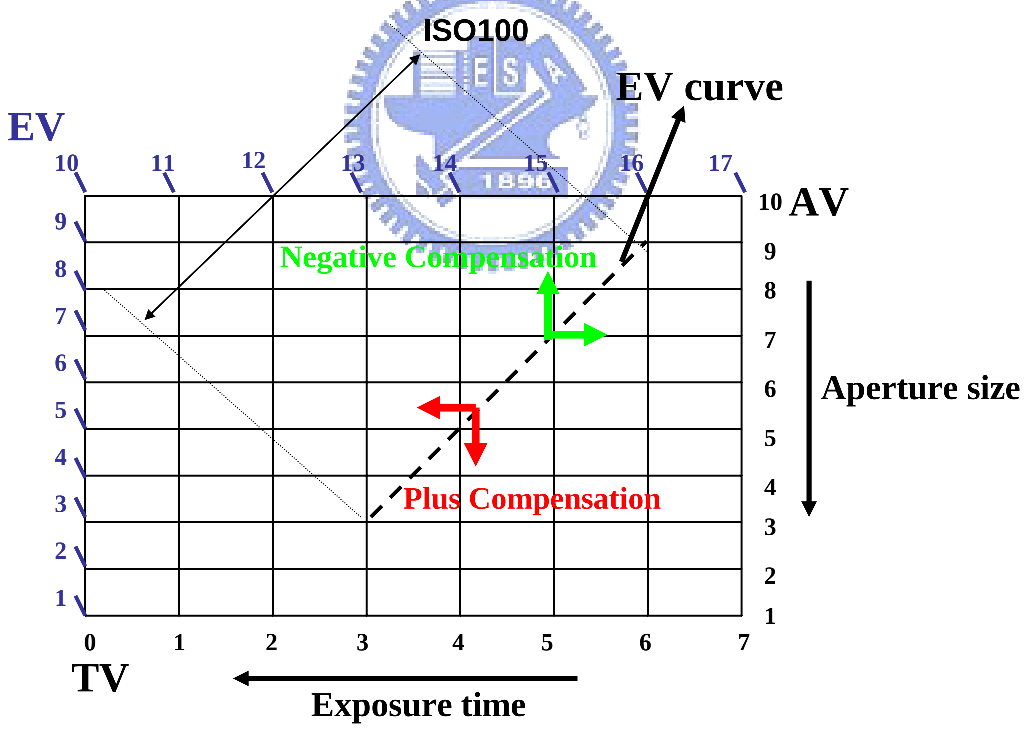

Fig. 2-2 The displacement of EV curve after EV compensation.

2.5 Summary

According to the basic exposure control principles derived in film cameras, we know how to determine the correct exposure parameters for different luminance of photographic scene. With a light meter or light metering system, the luminance of photographic scene can be detected, and the exposure parameters can be obtained immediately as shown in **Fig. 2-3**. In the DSCs, the function of AE is still determined by the light metering. We are going to introduce and discuss traditional AE methods of DSCs in Chapter 3.

Fig. 2-3 Exposure parameters are extracted from light meter