Chapter 5

Experiment

5.1 Introduction

According to the proposed AE methods as described in Chapter 4, we design the following experiments to evaluate the feasibility and robustness of the algorithms. The first part is the experiments of the *modified* luminance detection model. The second part is the experiments of the 2-D scene analysis method.

5.2 Luminance Detection Model

An experimental system has been set up to test the luminance detection model. The experimental flow is shown in **Fig. 5-1**. From the testing results of the Kuno model, we find the K value is unstable. After analyzing the experimental data, we suggest that an offset value should be added into Kuno model to stabilize the K value. Several experiments are done to verify the idea, including the relation of exposure and K value and relation of inclination angle and K value. The experimental system and method are shown in the following sections.

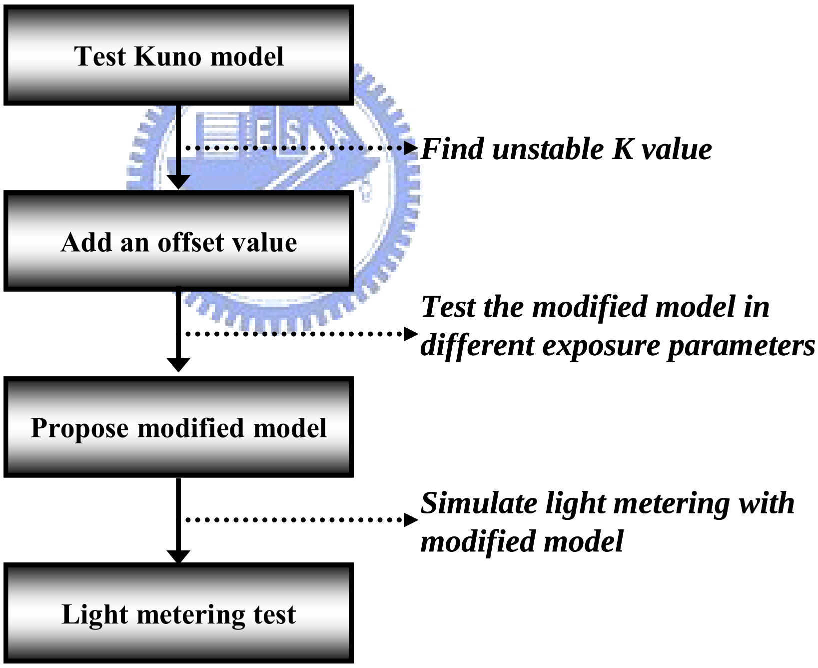

Fig. 5-1 Experimental flow chart of luminance detection models

5.2.1 Experimental System

In the light metering experiment, the simulation system is set up as illustrated in **Fig. 5-2**. A light source is used to simulate the photographic subject under different scene luminance, approximately from 10 (cd/m^2) to 10^4 (cd/m^2). A diffuser is placed in front of the light source to uniformize light distribution. The light meter, Minolta CS100, is used to calibrate the light source. A DSC, Canon G5, on the manual exposure mode is used as the platform to simulate the light metering process. The captured images are transferred into PC and analyzed through MatLab.

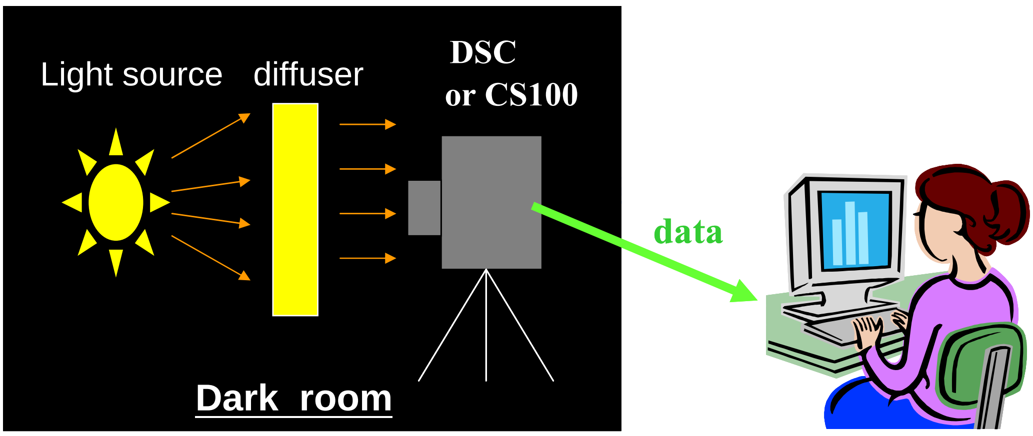

Fig. 5-2 Configuration of the light metering system in simulation

5.2.2 Experimental Methods

We use a DSC (Canon G5) in manual model to control the exposure parameters: exposure time (T), F-number (A) and ISO speed (S). Because the light sensitivity of DSC is controlled by the gain value of the AGC circuit, we take the ISO50, ISO100, ISO200 and ISO400 as gain values (G) of 1, 2, 4 and 8.

To avoid the image gamma effects, we take pictures with raw data format which is the original digital signal from imaging sensor. For the calculation of pixel luminance (y), we choose NTSC standard formula that is as follows:

$$y = 0.229r + 0.587g + 0.114b \qquad \textbf{(5-1)}$$

Where r, g, b are digital gray values in the R, G and B pixels. The following sections are experimental procedures for examining the modified light metering model.

✧ **Kuno Model Evaluation**

The procedures for evaluating the Kuno model ($\sum_m = K \times L \times T \times G$) are outlined as follows:

(1). Measure the light intensity with CS100 and take pictures with fixed exposure time, fixed gain value. (in this experiment, aperture size is fixed as a constant)

(2). Repeat procedure (1) several times but change the gain value.

(3). Repeat procedure (1) several times but change the exposure time.

(4). Calculate the average luminance values of the images which are obtained from above steps and estimate the K value of Kuno model.

✧ Modified Kuno Model Evaluation

The procedures for evaluating the modified Kuno model ($\sum_m = K \times L \times G \times T/A^2 + offset$) are outlined as follows:

(1). Measure the light intensity with CS100 and take picture with fixed exposure time, fixed gain value, and fixed F-number. (in this experiment, aperture size is a variable)

(2). Repeat procedure (1) three times but change the light intensity.

(3). Calculate the image data which is obtained from procedure (2) and calculate the slope (m) and offset values after the linear regression of the average luminance signal and scene luminance as shown in **Fig. 5-3**. Then the slope m and offset value are deduced.

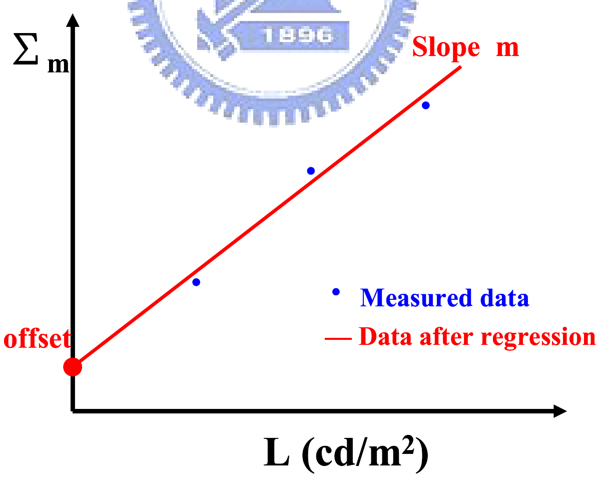

Fig. 5-3 Linear regression of the experimental data

(4). Calculate the experimental K value of the modified model by this equation:

$$K = m \times A^2 / G \times T \tag{5-1}$$

(5). Repeat procedures (1) ~ (4) several times but change the exposure time.

(6). Repeat procedures (1) ~ (4) several times but change the gain value.

(7). Repeat procedures (1) ~ (4) several times but change the F-number.

(8). Plot the calculated K and offset values as a function of exposure time, gain value and F-number.

✧ Examining the Small Angle Inclination of the Optical Axis

The experiments of camera inclination are made in the angles of 0°, 5° and 10°, as shown in **Fig. 5-4**. The procedures are outlined as follows:

(1). Measure the fixed light intensity with CS100 and take picture with fixed exposure time, fixed gain value, and fixed F-number.

(2). Repeat procedure (1) several times but change the exposure time or F-number.

(3). Repeat procedure (2) but change the optical axis of camera in 5°.

(4). Repeat procedure (2) but change the optical axis of camera in 10°.

(5). Plot the experimental K and offset values in different inclination angle.

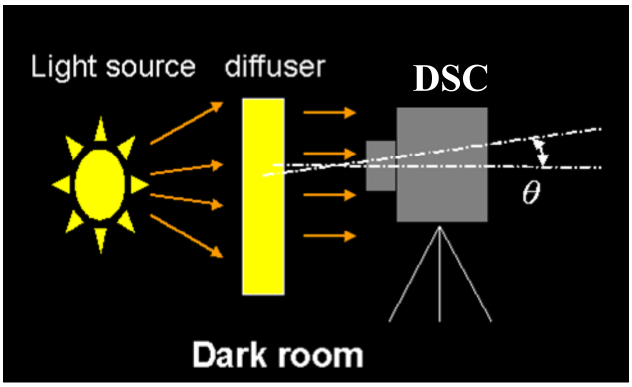

Fig. 5-4 Small angle inclination of the optical axis

✧ Examining the Light Metering Experiments

To examine the light metering accuracy of the proposed model, we use the calibrated light source to simulate the photographic scene. The procedures of light metering experiments are outlined as follows:

(1). Measure the fixed light intensity by CS100 and take picture by G5.

(2). Repeat procedure (1) several times but change the light intensity.

(3). Calculate the luminance of photographic scene with image data and compare with CS100.

5.3 2-D Scene Analysis Method

To implement our scene analysis method in the practical application, the simulations for optimized results are performed. The flows of the experimental process are shown as **Fig. 5-5**. In the beginning, we collect a lot of pictures for different lighting conditions. A simulation system is set up to find the optimal threshold values by the learning via the classified image data. The fuzzy rules of scene analysis process are defined by the optimized database. The performance of the proposed algorithm is tested through the simulation of AE process on PC and compared with other light metering methods.

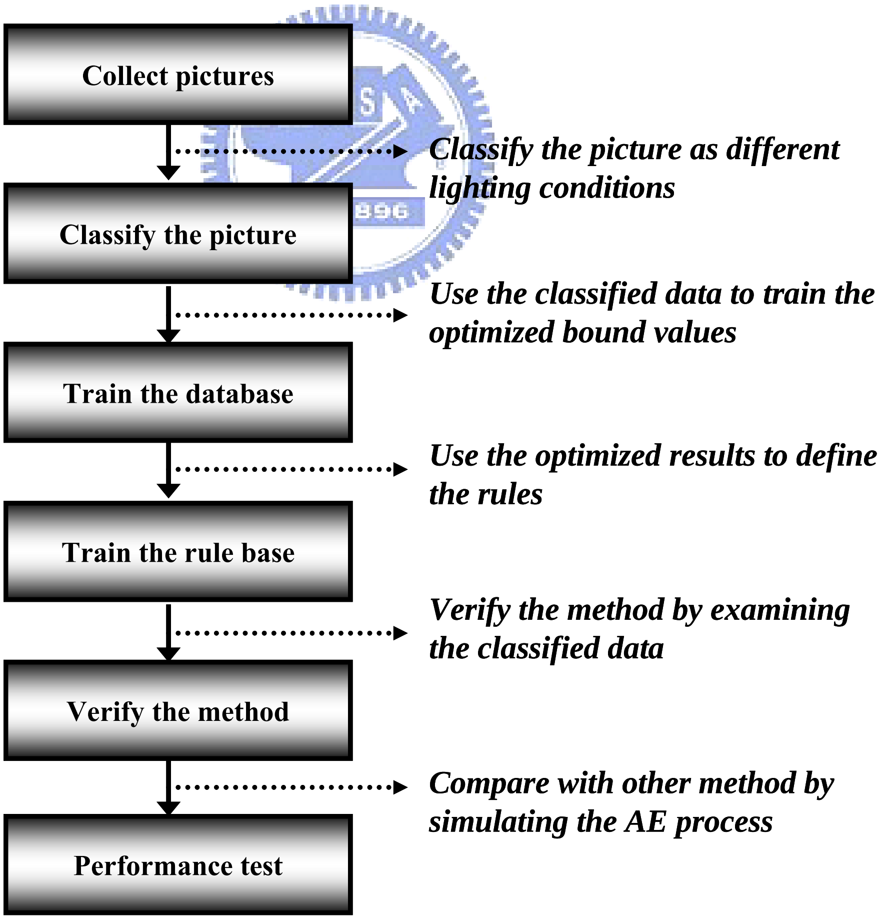

Fig. 5-5 Experimental flow chart of scene analysis method

5.3.1 Experimental System

A simulation system has been set up to test the proposed scene analysis algorithm that is based on two threshold parameters. The configuration of this simulation and experimental system is shown in **Fig. 5-6**. First, the collected pictures are classified into normal, backlighting, strong backlighting, strong frontlighting, highlight or dark environment categories through the checking of pictures one by one on a PC monitor. According to the classified pictures, the training of database and fuzzy rules are performed. The knowledge system to judge the special lighting conditions is built by the training of data and rule bases. Finally, the test of the 2-D scene analysis method is performed by rechecking image data after fuzzy scene analysis process [19].

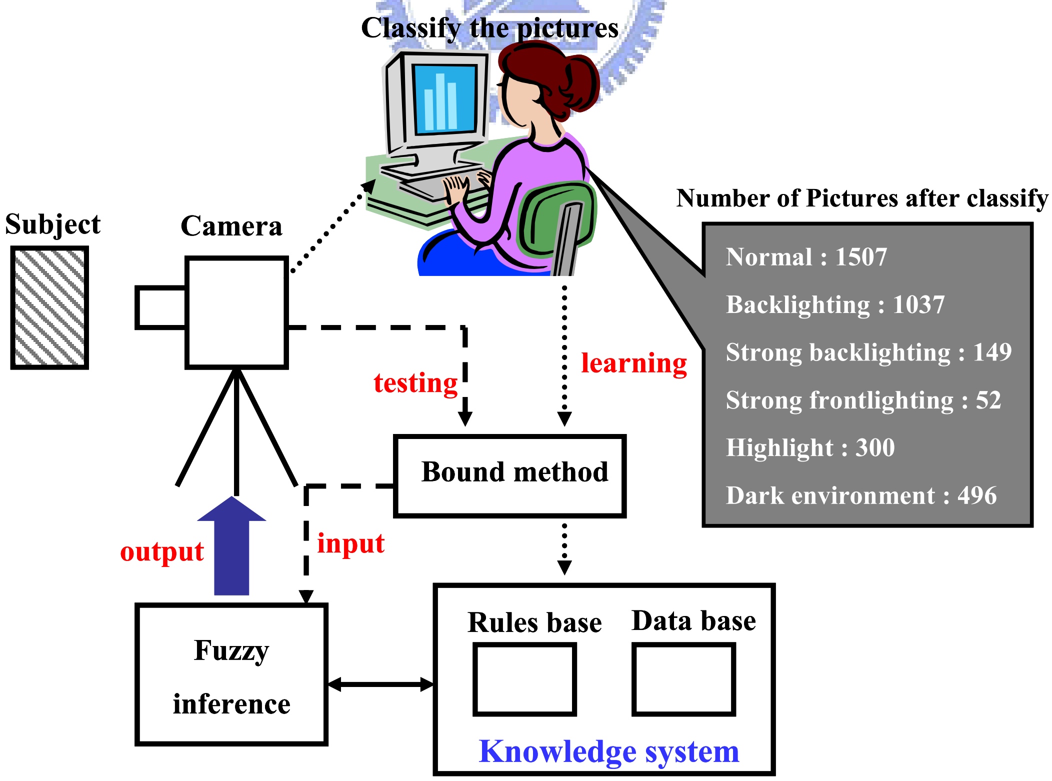

Fig. 5-6 Block diagrams of experiment and simulation configuration

5.3.2 Optimization Methods

The optimized procedures can be divided into three parts: first, the simulation of optimal bound values is performed to find the overlapping region of the database is the smallest. Then, optimized threshold parameters are chosen according to the examination of the database with the best performance. Finally, the fuzzy rules base can be determined according to the partition results.

✧ Optimization of the Database

To reduce the overlapping of database, we define two criterions to find the optimal threshold values. The basic assumption is that all kinds of image database are symmetric with the gravity. According to the adjustment of location of gravity, the overlappingping regions of the database can be reduced.

One is the maximum distance between the gravities of different kinds of image database as shown in **Fig. 5-7**. Because the backlighting image data are always in the center part of the database, we use the gravity of the backlighting image database as the pivot to calculate the maximum total distance.

The other criterion is to find the maximum distance both in the angle and distance directions as shown in **Fig. 5-8**. Because we want the overlapping regions of the image data with different ratios of dark to bright regions can be smallest in the angle direction, we define the distance of the gravities in the angle direction are total dx. Therefore, the overlapping regions of highlight, backlighting, strong frontlighting and dark environment can be reduced. Besides, we want the overlapping regions of the image data with different backlighting degree can be smallest in the distance direction, we define the distance of the gravities in the distance direction are total dy.

Then, the overlapping region of normal lighting, backlighting and strong backlighting can be reduced. According to the two criterions, the simulations of optimal threshold values are performed.

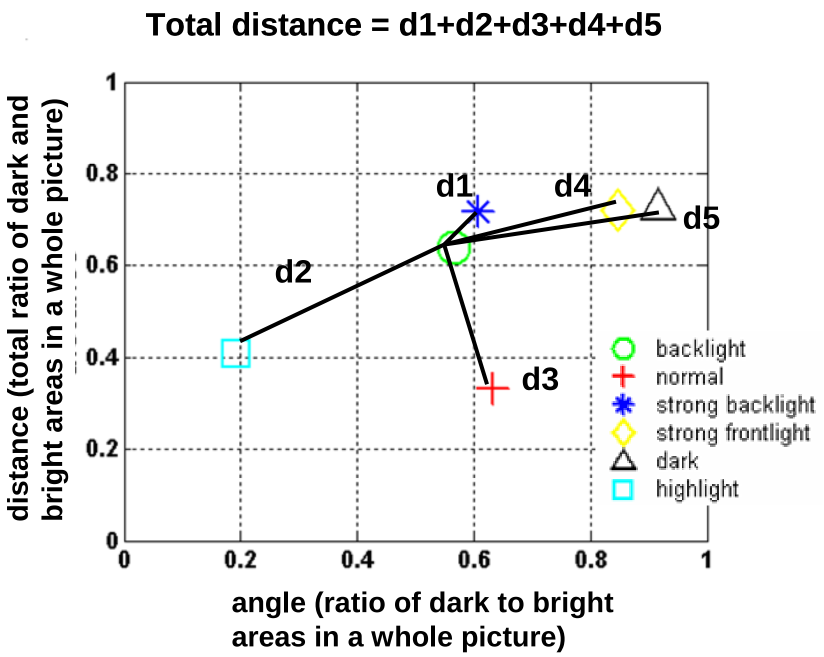

Fig. 5-7 Total distance of the gravities in different kinds of database

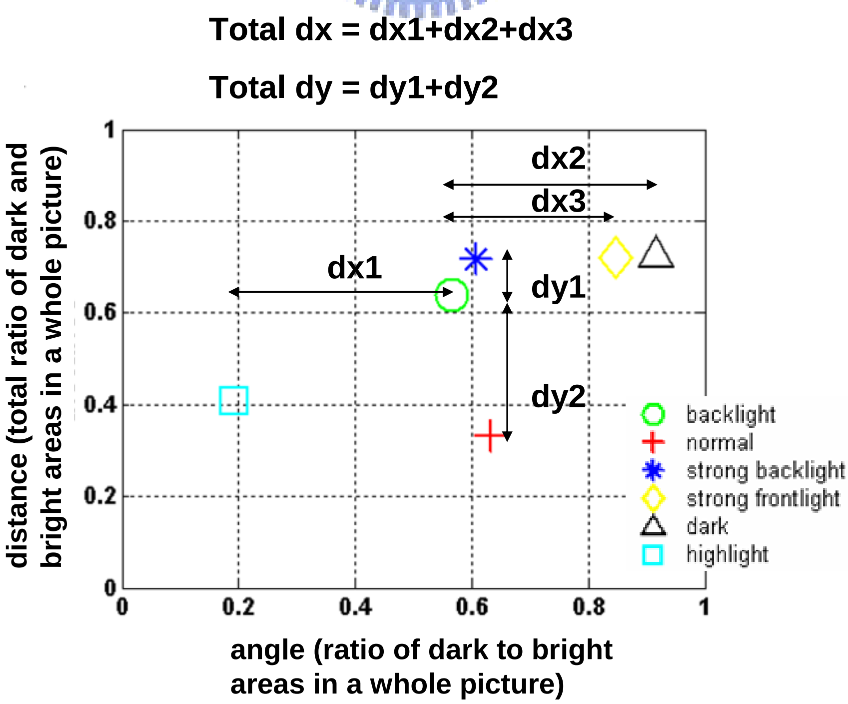

Fig. 5-8 Total distance of the gravities of database in angle and distance directions

✧ Examination of the Database

To examine the optimal threshold parameters, the partition of database is performed. The partition lines are determined according to the percentage of image data in the angle and distance direction as shown in **Figs. 5-9** and **5-10**. The percentage is defined as the ratio of database is smaller than the angle (or distance) value. According to the plots of percentage as a function of angle and distance, we choose percentage equal to 0.1 and 0.9 as partition lines. With careful adjustment of the partition lines, we decide the optimal partition with 4×4, 5×5 and 5×7. After the partition of database, the partition regions are classified as different lighting conditions. Then, the examination of optimal threshold values is performed by the partition results.

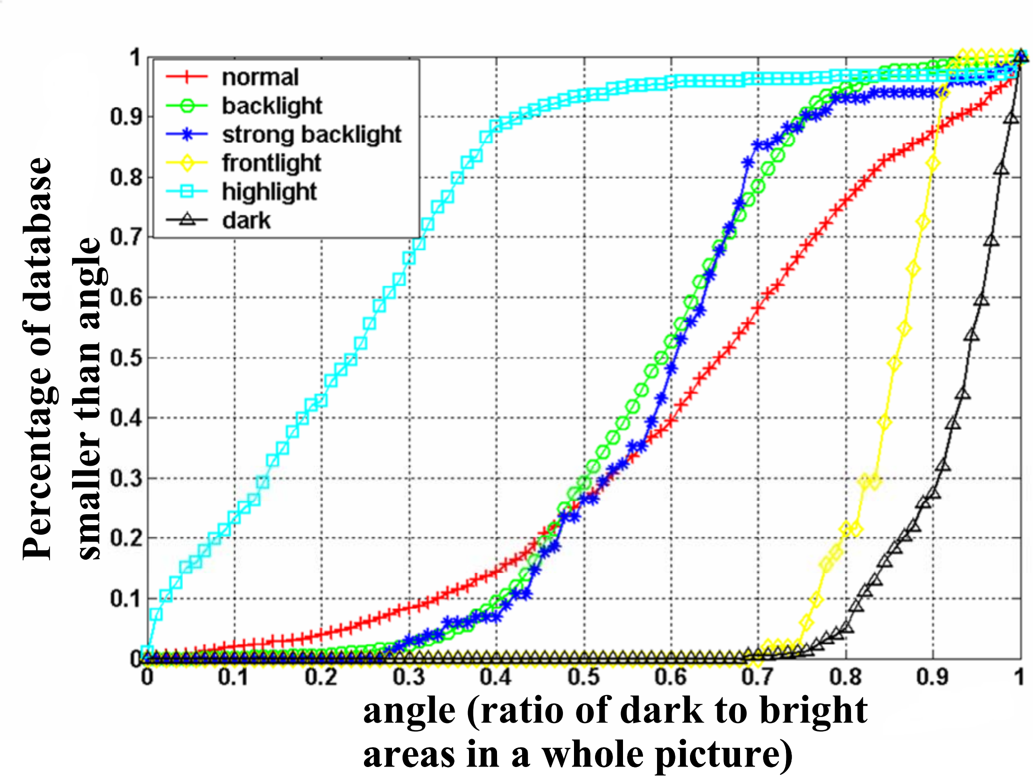

Fig. 5-9 Plot of the percentage of image database as a function of angle

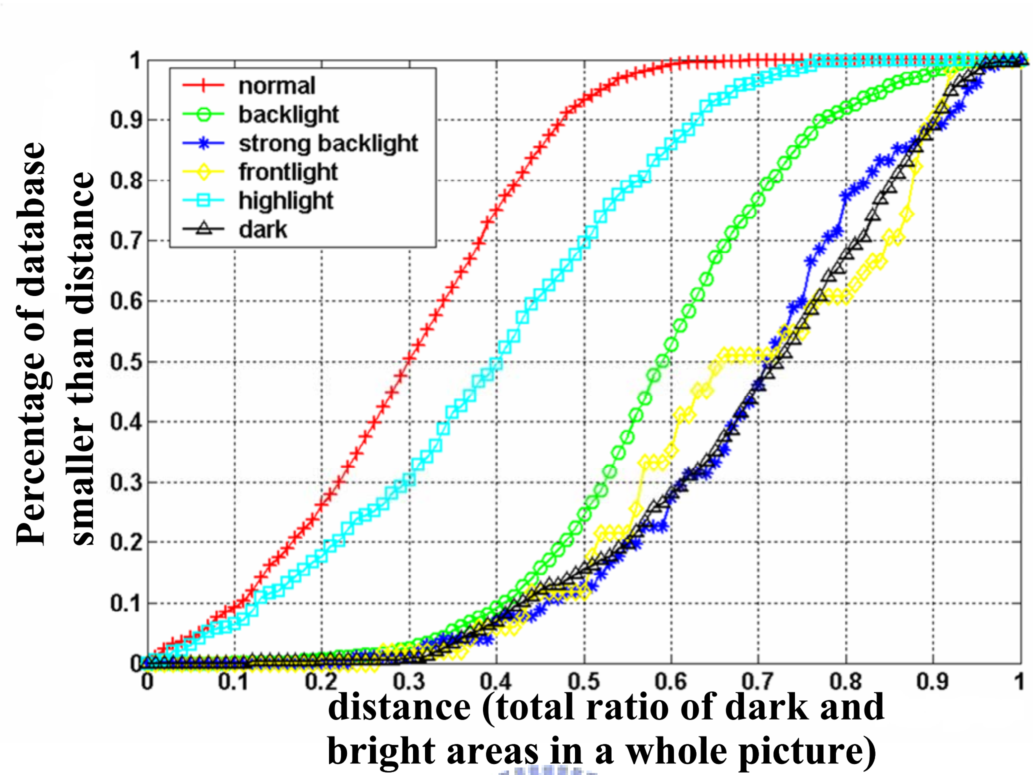

Fig. 5-10 Plot of the percentage of image database at as a function of distance

✧ Fuzzy Rules Base

To compensate the exposure smoothly, we use the fuzzy membership functions. In each partition region the degree of membership is 1. In the overlapping region, the degree of membership varies linearly from 1 to 0. Therefore, the shape of membership functions is chosen as trapezoid. With trial and error, the compensation amount of each region is determined. The positive compensation amounts are set in backlighting, strong backlighting and dark environment regions. The negative compensation amounts are set in strong frontlighting regions. In the normal and highlight region, we do not give any compensation amounts.

5.3.3 Performance Test

To examine the performance of our scene analysis method, we simulate the AE process by using a DSC (Canon G5) to take picture in different lighting conditions. The schematic diagram of the simulation system is shown as **Fig. 5-11**.

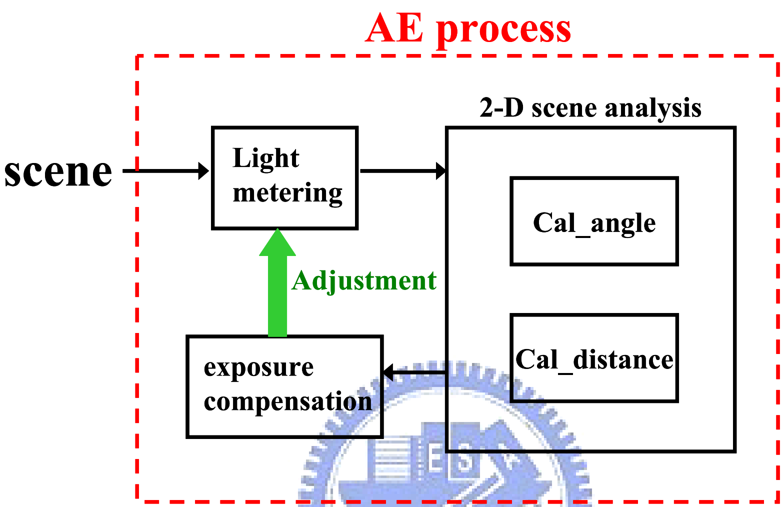

Fig. 5-11 Schematic diagram of the AE simulation system

In the simulation, we use center-weighted metering model of Canon G5 as the basic light metering method. Then, each scene is pictured with a serial exposure values from under to over the exposure which is determined by the basic light metering method. We use the basic light metering method to take picture, and the captured images are analyzed by our scene analysis method to evaluate the compensation amount. The compensation amounts are determined by the fuzzy analysis process and used to adjust the exposure parameters verified by basic light metering method. By using the pictures with a serial exposure values, the simulation of AE process is performed. The output compensation amounts after the scene analysis process are listed in **Table 5-1**. The light metering methods for comparisons are listed in **Table 5-2**. The evaluative metering mode is an intelligent light metering algorithm of Canon G5. The HIST analysis method is a traditional algorithm proposed by Shimizu et al [8].

Table 5-1 Output δEV values in different δEV range after deffuzify

δEV range	-1~ -0.85	-0.85~ -0.5	-0.5~ -0.15	-0.15~ 0.15	0.15~ 0.5	0.5~ 0.85	0.85~ 1.15	1.15~ 1.5	1.5~ 1.85	1.85~ 2.0
output δEV	-1	-0.7	-0.3	0	+0.3	+0.7	+1	+1.3	+1.7	+2

Table 5-2 Comparisons of different metering methods and their picture settings, Center-Weighted = CW, Multi-Region = MR, Automatic white balance = AWB, Automatic Focus = AF, test camera = Canon G5

Method	Metering mode	Scene analysis	Picture setting
Center-Weighted	CW		AWB, AF, flash off, aperture priority, fixed ISO speed
Evaluative	MR		AWB, AF, flash off, aperture priority, fixed ISO speed
CW+ HIST method	CW	HIST	AWB, AF, flash off, aperture priority, fixed ISO speed
CW+ Our method	CW	Our method	AWB, AF, flash off, aperture priority, fixed ISO speed

5.4 Summary

In this chapter, we have presented the experimental systems and experimental methods of luminance detection models and 2-D scene analysis method. The experimental results and discussions will be given in next chapter.