Chapter 4

Luminance Detection Model and 2-D Scene Analysis Method for Improvement of AE

4.1 Introduction

In order to resolve the drawbacks of traditional methods, we propose two methods to improve the function of AE. One is a luminance detection model to improve the light metering accuracy under different scene luminance. The other is a 2-D scene analysis method based on the histogram information to improve the analysis of the photographic subject in special lighting conditions.

4.2 Luminance Detection Model (Modified Model)

To examine the Kuno model used in AE, we have done the light metering experiments. We find that K value of Kuno model indicated in **Eq. (3-1)** has a “tumbling” effect which means that K value of Kuno model can not converge to a constant value. According to the experimental results, we add a constant offset value into Kuno model, and more constant K value can be obtained. In addition, the average integrated value $\sum_m$ has a linear relation with the inverse square of the aperture size. Thus, we propose a *modified* Kuno model in which we add an offset value and another exposure parameter F-number. In our proposed model, the average integrated value of the imaging signal $\sum_m$ is:

$$\sum_m = K \times L \times G \times T/A^2 + offset \qquad \textbf{(4-1)}$$

Where;

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

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

T : Exposure time (sec);

A : Lens F-number;

G : Gain of AGC circuit;

K and $offset$ ：Constant.

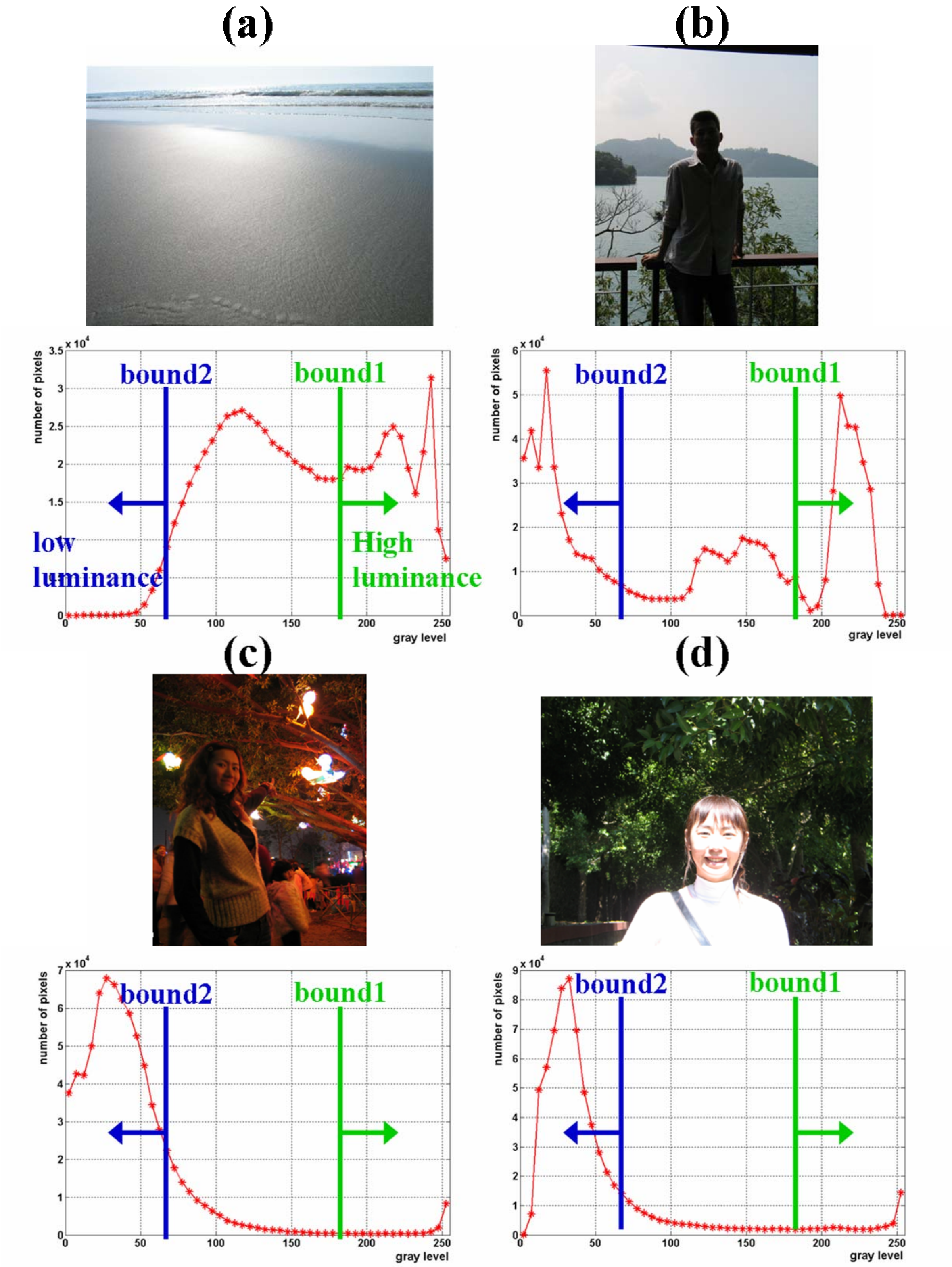
The proposed model can improve the light metering system under different scene luminance in DSCs. Furthermore, to improve the light metering in special lighting conditions, we propose a *new* scene analysis method, which will be discussed in the next section.

4.3 2-D Scene Analysis Method

According to the traditional AE methods, we know that the special lighting conditions can be classified as backlighting, strong frontlighting, highlight, and dark environment. After analyzing the special lighting images on the histogram, we propose a 2-D scene analysis method. To implement the proposed method, the learning via examples approach is performed by a lot of images. In this section, we shall present the use of the proposed scene analysis method.

4.3.1 Features of the Special Lighting Images

In the digital video system, the image brightness is digitalized as gray values. In our proposed method, the features of special lighting images are analyzed by histogram which is a plot of the number of pixels as a function of gray values. With two threshold gray values, bound1 and bound2, we sort the histogram into the high luminance (bright) and the low luminance (dark) regions as plotted in **Figs. 4-1 (a)**, **(b)**, **(c)** and **(d)**. In the highlight situation, there are more pixels in the high luminance region compared to the low luminance region. In the backlighting situation, there are two almost equal sizes of peaks in the high and low luminance regions. In the dark environment and strong frontlighting conditions, there are more pixels in the low luminance region compared to the high luminance region. The different feature between the images in the strong frontlighting and dark environment is the ratio between high and low luminance regions. After analyzing a lot of images, we know that the special lighting images usually have large dark or bright regions. To implement the *new* scene analysis method in practical application, we collect a lot of image data in normal and special lighting conditions to build the image database.



Figs. 4-1 Photographs and histograms in special lighting conditions: (a) Highlight, (b) Backlighting, (c) Dark environment and (d) Strong frontlighting

4.3.2 Collection of the Database

According to the proposed scene analysis method, the special lighting images are analyzed by detecting how many pixels in a whole picture are too dark or bright. The detecting method is based on two parameters:

$$over\_bound1 = {number\ of\ \ pixels\ over\ than\ bound1} \Big/ {total\ \ number\ of\ \ pixels} \quad \textbf{(4-2)}$$

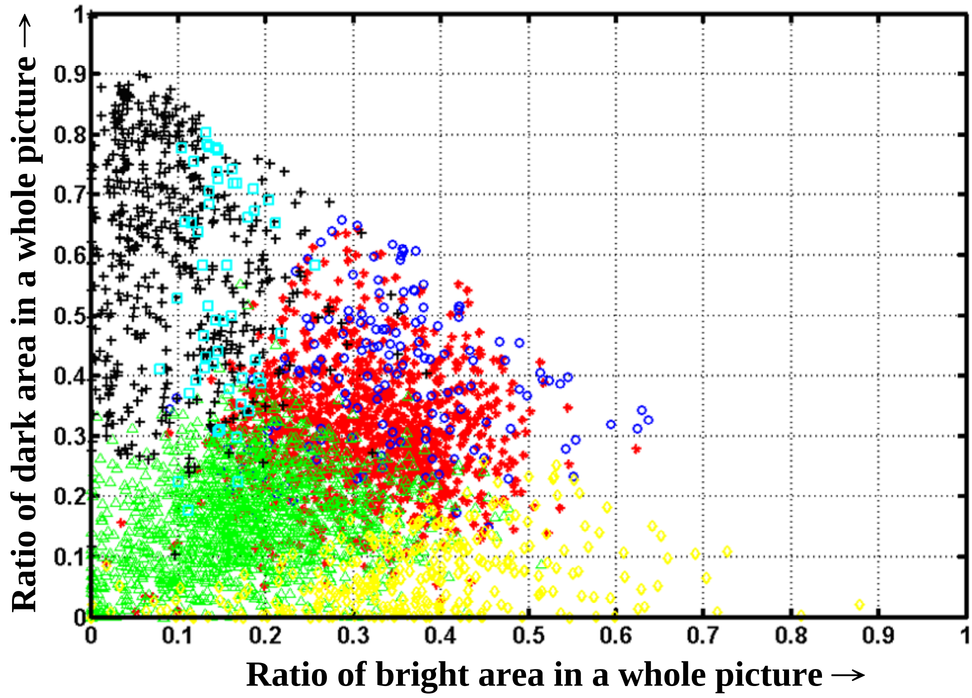
$$lower\_bound2 = {number\ of\ \ pixels\ lower\ than\ bound2} \Big/ {total\ \ number\ of\ \ pixels} \quad \textbf{(4-3)}$$

Where $over\_bound1$ and $lower\_bound2$ represent the ratio of bright and dark areas in a whole picture; bound1 and bound2 are threshold gray values used to separate the bright and dark regions. With the two parameters: over_bound1 and lower_bound2, the collected pictures in different lighting conditions such as: normal, backlighting, strong backlighting, strong frontlighting, highlight and dark environment are built into the database as shown in **Fig. 4-2**. The higher the over_bound1/lower_bound2 value represents the larger the bright/dark region in a whole picture. According to the database as shown in **Fig. 4-2,** we known that the backlighting degree can be detected by the total ratio of bright and dark areas in a whole picture, and the images in highlight, dark environment and strong frontlighting conditions can be separate by the ratio of dark to bright areas in a whole picture. Accordingly, for the convenience of analyses, the bound database is transformed into another domain by two new parameters:

$$angle = \frac{\tan^{-1}\left(lower\_bound2 / over\_bound1 \right)}{\left(\pi / 2 \right)} \quad \textbf{(4-4)}$$

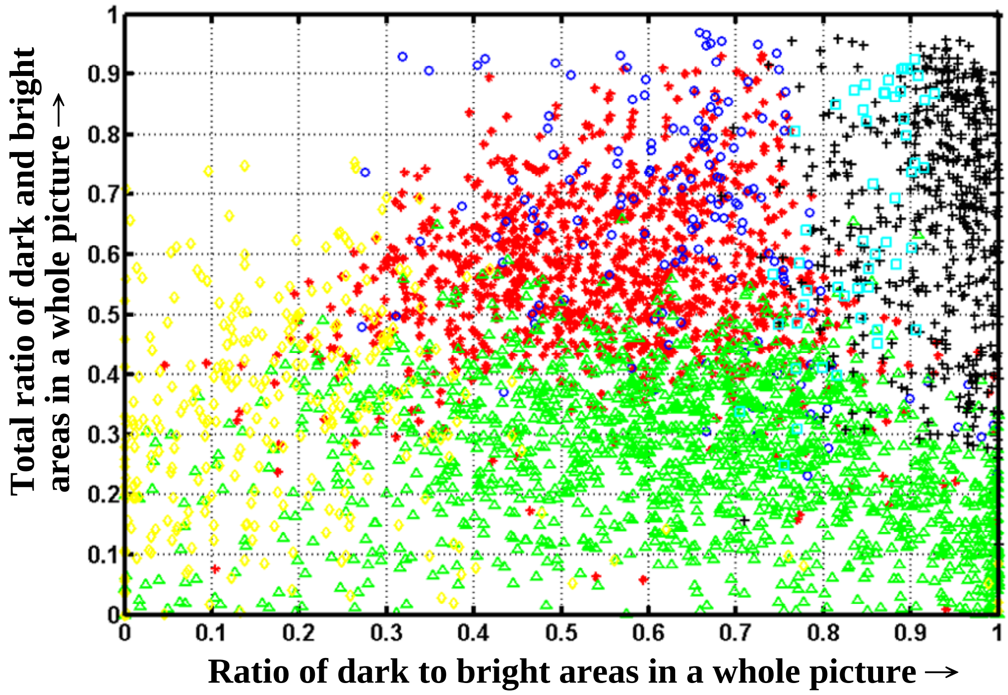
$$distance = over\_bound1 + lower\_bound2 \quad \textbf{(4-5)}$$

Where the parameter of angle is the angle relative to original x axis; the parameter of distance is the summation of x and y indices. After the coordinate transformation, the image database with different lighting conditions is classified by the parameters of angle and distance as shown in **Fig. 4-3**. The images in the highlight, strong frontlighting and dark environment situations can be separated by the parameter of angle (ratio of dark to bright areas in a whole picture). The degree of backlighting which represents the luminance difference between the main object and the background regions can be detected through the parameter of distance (total ratio of bright and dark areas in a whole picture). In the database, there are small overlap regions in the boundary. To make the judgment of lighting conditions in the overlap regions smoothly, a well-known method based on “fuzzy logic” is applied to solve this issue. [19]



△ : Normal ∗ : backlighting ○ : strong backlighting □ : strong frontlighting ◇ : highlight + : dark environment

Fig. 4-2 Image database in the over_bound1 and lower_bound2 plane



△ : Normal ∗ : backlighting ○ : strong backlighting □ : strong frontlighting ◇ : highlight + : dark environment

Fig. 4-3 Image database in the angle and distance plane

4.3.3 The Fuzzy Rules Base

When the calculated values are located in the transition regions, the judgment of the lighting conditions will have an unstable phenomenon which causes that the gray values of an image in the DSCs will switch back and forth of the reference gray values. To make the judgment of the lighting situations near the boundary smoothly, we simulate the human fuzzy mechanism by fuzzy membership functions. The membership functions which indicate the probability of the lighting situation are created for the fuzzy variables: angle and distance. Five membership functions: VS (Very Small), S (Small), M (Medium), B (Big) and VB (Very Big) are created and adopted for each of angle and distance as indicated in **Fig. 4-4.** The compensation amounts "C" of all rules are determined empirically and shown in **Fig. 4-5.** Corresponding to these membership functions, twenty-five rules are introduced and defined as follows：

$Rule(1,1) =$

$$\textit{if}\ \text{angle}\ \textit{is VS and}\ \text{distance}\ \textit{is VS},\ \textit{then C is}\ C(1,1) \qquad \textbf{(4-6)}$$

$Rule(1,2) =$

$$\textit{if}\ \text{angle}\ \textit{is}\ \text{S}\ \textit{and}\ \text{distance}\ \textit{is}\ \text{VS},\ \textit{then C is}\ C(1,2) \qquad \textbf{(4-7)}$$

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$Rule(5,5) =$

$$\textit{if}\ \text{angle}\ \textit{is VB and}\ \text{distance}\ \textit{is VB},\ \textit{then C is}\ C(5,5) \qquad \textbf{(4-8)}$$

To defuzzify this system, the well-known method is used. Generally, the "If" part is written in the following expression：

$$u(i, j) = Min(U(i),\ U(j)) \qquad \textbf{(4-9)}$$

$$1 \le i \le 5,\ 1 \le j \le 5$$

Where;

$u(i, j)$ is the degree of membership of $Rule(i, j)$;

$U(i)$ and $U(j)$ are membership functions of angle and distance, respectively.

In the "If" part of equations, the degree of membership of the two variables are obtained from membership functions, and the smaller one is chosen. In the "then" part, the compensation value is weighted by the degree of membership chosen in the "If" part. The defuzzified compensation value which can be applied to the exposure control is defined by：

$$C = \sum_{i=1:5}\sum_{j=1:5}(u(i, j)\times C(i, j)) \Big/ \sum_{i=1:5}\sum_{j=1:5}u(i, j) \qquad \textbf{(4-10)}$$

Then, the target compensation values for each lighting conditions are calculated.

The advantage of this 2-D scene analysis method is that the photographic subject in special lighting conditions: backlighting, strong backlighting, strong frontlighting, highlight and dark environment can be detected and compensated through simple calculation and fuzzy inference. After the fuzzy analysis process, the compensation amount will be continuous in the transition of lighting states.

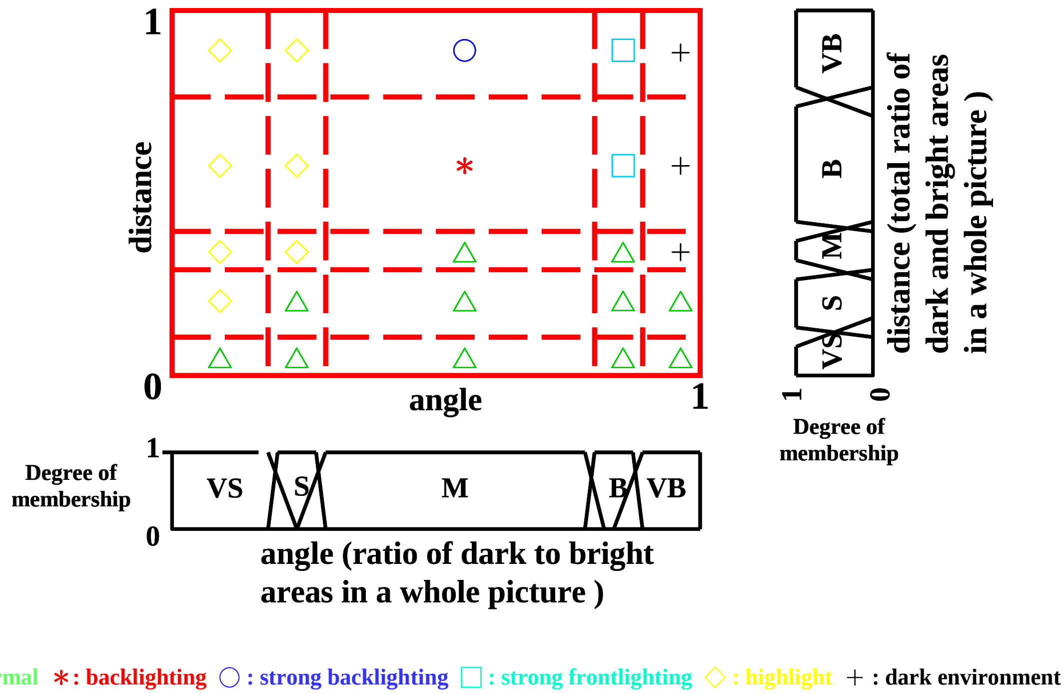

Fig. 4-4 Image database and membership functions of proposed 2-D scene analysis method

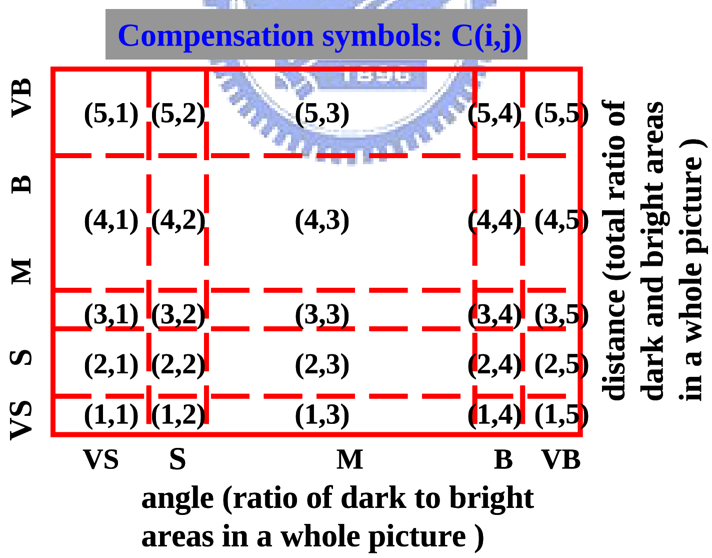

Fig. 4-5 The compensation amounts of different lighting regions.

4.4 Summary

We have proposed two methods to improve the light metering system of AE. One is the *modified* luminance detection model which can improve the light metering accuracy under different luminance of photographic scene. The other is the 2-D scene analysis method which can improve the light metering system in special lighting conditions: backlighting, strong backlighting, strong frontlighting, highlight and dark environment.