Chapter 1

Introduction

1.1 Introduction

As many parts of industry have been digitalized in the recent decade, the tendency of digitalization is also required for camera. Although the digitalization caused the image quality of past digital still cameras (DSCs) interior to that of the film cameras, the image quality of DSCs are continuously improved due to the development of CCD/CMOS imaging sensors. In addition, DSCs are much more convenient for users than film cameras due to the advanced function of previewing images on an LCD panel, and other attractive features. Generally speaking, DSCs have three important system functions including automatic focus (AF), automatic white balance (AWB) and automatic exposure (AE) which mainly influence the quality of camera as shown in **Fig. 1-1**.[1]

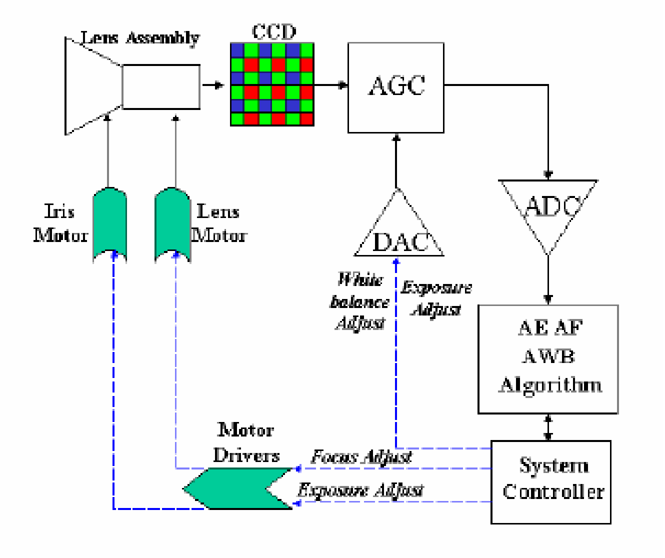

Fig. 1-1 Image pipeline stage of DSC

Due to the continuing decline in the cost, the digital cameras are becoming increasingly popular. Affordability is need for the continued expansion of the digital camera market, but the quality of digital color images is also the important consideration for the consumers. There are many key factors that have a great effect upon the quality of digital cameras. White balance is one of the keys to the quality of digital cameras. Let us depict all details below.

1.2 White balance

What is white balance? It begins with the concept of color temperature. Color temperature is a way of measuring the quality of a light source. It is based on the ratio of the amount of blue light to the amount of red light, and the green light is ignored. The unit for measuring this ratio is in degree Kelvin (K). A light with higher color temperature (*i.e.*, larger Kelvin value) has "more" blue lights than a light with lower color temperature (*i.e.*, smaller Kelvin value). Thus, a cooler (*resp.*, warmer) light has a higher (*resp.*, lower) color temperature. The Table 1-1 shows the color temperature of some light sou**rces.**

Table 1-1. Color temperature of some light sources

Light Sources	***Color Temperature in K***
Clear Blue Sky	10,000 to 15,000
Overcast Sky	6,000 to 8,000
Noon Sun and Clear Sky	6,500
Sunlight Average	5,400 to 6,000
Electronic Flash	5,400 to 6,000
Household Lighting	2,500 to 3,000
200-watt Bulb	2,980
100-watt Bulb	2,900
75-watt Bulb	2,820
60-watt Bulb	2,800
40-watt Bulb	2,650
Candle Flame	1,200 to 1,500

Note that Kelvin values listed in the table are approximate rather than exact ones. Moreover, a new light bulb and new flash have higher color temperature than their old and used equivalents, and an electronic flash is designed to have a color temperature comparable to that of average sunlight.

Human brain can quickly adjust to different color temperatures. More precisely, our eyes, with the help from the experience we learned, see a white paper as a white paper no matter it is viewed under strong sunlight or in a room illuminated with incandescent lights. Unfortunately, color films can only correctly record the colors in certain range of color temperatures. Therefore, films are used to compensate color shift induced by daylight and tungsten light sources. On the other hand, digital cameras are very different! Digital cameras usually have built-in sensors to measure the current color temperature and use an algorithm to process the image so that the final result may be close to what we see (with our eyes, of course). But, the algorithm(s) being used may not be accurate enough to make every situation correct. Under some difficult situations when the in-camera algorithm is not able to set the color temperature correctly or when some creative and special effects are needed, we can instruct the camera to use a particular color temperature to fulfill our need. This adjustment that makes sure the white color we view directly will also appear white in the image is referred to as white balance.

Setting white balance incorrectly may cause a color shift in the image. For example, suppose the camera is told to use a color temperature of sunlight to take an image of an indoor environment illuminated mainly by incandescent lights, the camera will expect excessive blue light and less red light, and set its algorithm to be more sensitive to the blue light. However, in an environment illuminated with incandescent lights, color temperature is low with excessive red light rather than the blue one. As a result, we shall see a reddish or yellowish image. An example is exhibited in Fig.1-2.

Correct white balance **Reddish/Yellowish image**

(a) (b)

Fig 1-2. An example for setting white balance incorrectly in digital camera. A watch on the table with incandescent light (a) camera white balance setting in incandescent light and (b) camera white balance setting in the sunlight.

On the other hand, suppose we set the camera to a low color temperature (*e.g.*, that of incandescent light) and take a photo under sunlight, the camera will expect excessive red light and less blue light. Because the white balance is set to incandescent light, the processing algorithm is more sensitive to the red light rather than the blue one. Hence, the resulting image will be bluish as shown in the following images.

Correct white balance **Bluish image**

Fig 1-3. An example for setting white balance incorrectly in digital camera. It's sunny outdoor scene . (a) white balance setting in sunlight. (b) white balance setting in incandescent light.

1.3 Motivation and Objective of this thesis

The mechanism employed in digital cameras to compensate the color difference caused by various light sources to solve color constancy is an objective for this thesis research. The algorithm being used may not be accurate enough to make every situation correct. And most of this algorithms are too complex, in order to apply to digital still camera, we would like to modify a simple algorithm to implement Auto-white balance.

The image recorded by a camera depends on three factors: the physical content of the scene, the illumination incident on the scene, and the characteristics of the camera.

The goal of computational color constancy is to account for the effect of the illuminant, either by directly mapping the image to a standardized illuminant invariant representation, or by determining a description of the illuminant which can be used for subsequent color correction of the image. Computational color constancy has important applications such as object recognition and scene understanding, as well as image reproduction and digital photography.

We analyze illuminant classification algorithms designed to group images by illuminant color temperature. To classify the illumination color temperature, a version of the correlation method suggested by Finlayson and colleagues is used. The original algorithm uses spectral distribution to classify the illumination, and does not use the fact that bright image regions contain more information about the illuminant than dark regions. Using calibrated images with known illuminants, we find that the original correlation method can be improved by using a simple Gaussian model to have less parameter in hardware memory. When applied to these quantities, the algorithm is more sensitive to differences in illuminant color temperature.

The color correction method is based on summarizing the ratio of R, G, and B sensor responses under different illuminants. Both of R and B gains are defined as a function of color temperature. The color correction can be performed in a simple way using a lookup table. The proposed method can be applied to a variety of real scenes.

1.4 Organization

This thesis is organized as follows. In **Chapter 2**, the details of traditional methods for white balance and their corresponding theories are described. In **Chapter 3**, we discuss issues we meet and present the solutions. Moreover, we propose a new method for white balance. In **Chapter 4**, experimental flows and experimental systems are presented. In **Chapter 5**, experimental results and summaries are given. In **Chapter 6**, concluding remarks and future works are presented.