A method determining tone conversion characteristics of digital still camera from two pictorial images

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Introduction

The tone conversion characteristics of a digital still cameras are one of the most important characteristics of the camera and are also used for the transformation of raw red *R*, green *G* and blue *B* digital values to colorimetric values *X*, *Y* and *Z* or *L**, *a** and *b**. They are determined from measured digital values as a function of known luminance of an object from a gray scale included in the scene. They are called the characteristic curve in photography, the gamma characteristic in television, and the opto-electronic conversion function (OECF) in ISO 14524 [1].

There are many problems with the capture of images of gray scales such as the use of more gray patches to get precise tone conversion characteristics, non-uniform illumination and the decrease of the surrounding illumination with the 4^{th} power of the cosine law and the vignetting factor.

We have developed a new method based on the exposure to the CCDs. The values are calculated on the basis of the digital values of two images of the same subject captured at two different levels of exposure whose ratio is known[2,3]. The obtained characteristic is a relationship between the relative exposures and the digital values, not an OECF. This is a relationship between luminance and digital values.

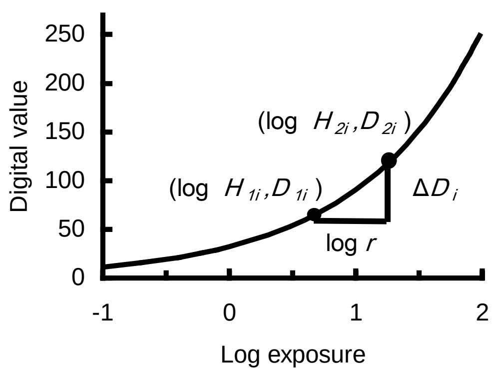

Fig. 1. Tone conversion characteristic curve and variables used in this study

Method of determining tone conversion characteristics

The gradient of a tone conversion characteristic curve of a digital still camera is defined as

$$g = \frac{\mathrm{d}\,D}{\mathrm{d}\log H} \qquad (1)$$

where *D* is the raw digital value of the camera, *R*, *G*, or *B*, and *H* is the exposure to the CCD. Integrating this equation, the log exposure is expressed as

$$\log H = \int \frac{\mathrm{d}\,D}{g} + C \qquad (2)$$

where *C* is the constant of integration.

In application of Eq. (2), assume that there are two images of a gray scale, images 1 and 2, and that each image has been produced under identical conditions except for exposure. If *r* expresses the exposure ratio of image 2 to image 1, then

$$H_{2i} = r\,H_{1i} \qquad (3)$$
$$(i = 1,2,3,---,n)$$

where *i* is the step level and *n* is the number of steps. The variables are shown in Fig.1.

Digital values of the images corresponding to exposures H_{1i} and H_{2i} are D_{1i} and D_{2i}, respectively. An average gradient between these digital values is expressed as

$$\bar{g}_i = \frac{D_{2i} - D_{1i}}{\log r} \qquad (4)$$

A digital value D_i, at which the gradient is equal to the average gradient g_i, must exist in the range between D_{1i} and D_{2i}, and is expressed as

$$D_i = \frac{w_{1i}\,D_{1i} + w_{2i}\,D_{2i}}{w_{1i} + w_{2i}} \qquad (5)$$

where w_{1i} and w_{2i} are weighting coefficients. These coefficients are determined from the following equations.

$$w_{1i} = 2\Delta D_{1i} + \Delta D_{2i} \qquad (6)$$

(7)

$$w_{2i} = \Delta D_{1i} + 2\Delta D_{2i}$$

The weighting coefficients are used in order to shift the digital value D_i slightly from the midpoint of D_{1i} and D_{2i} towards the section of the curve having the higher gradient, since the gradient at the midpoint is virtually always slightly different to the average gradient g_i [4]. The log exposure for step i, log H_i, is then calculated from the following equation.

$$\log H_i = \log H_{i-1} + \frac{D_i - D_{i-1}}{\bar{g}_i} \qquad (8)$$

The digital value vs. log exposure curve can be calculated from the set of digital values from Eq. (5) and the log exposure from Eq. (8). In most cases, the constant C in Eq. (2) can not be determined. It should be noted that, in turn, the actual values of log H also can not be determined because log H here has relative, but not absolute, significance.

For simplicity, the above explanations are based on stepwise images, such as images of a gray scale. In order to apply the method to pictorial images, digital values of corresponding pixels in images 1 and 2 may be used as the digital value pair D_{1i} and D_{2i} mentioned above. However, there may be several million pairs and these values contain noise. To avoid the problems associated with the identification of conjugate pairs of pixels, the digital values of images 1 and 2 corresponding to the same cumulative frequency are used as the digital value pair D_{1i} and D_{2i}. Then log relative exposures log H_i and corresponding digital values D_i are calculated, i.e. tone conversion characteristics are obtained without a gray scale.

Experiments and results

Two different exposure images for a scene including a GretagMacbeth Color Checker DC were captured using a Minolta Dimage RD-3000 digital still camera. Exposure time was changed to obtain two images of different exposure, because of the accuracy of the exposure time. Repeatability of the diaphragm was taken into consideration, and the full open diaphragm was used. Images were captured indoors because daylight is unstable with respect to both illuminance and color temperature. Tungsten lamps, not fluorescent lamps, were used for illumination to avoid oscillation based on voltage frequency.

Cumulative frequency distributions for digital value R of the two images are shown in Fig. 2. The calculated tone conversion characteristics of digital value R is shown in Fig. 3. As the calculated log exposure is relative, the curve was shifted arbitrarily to pass the point (2.0, 100). The tone conversion characteristics of digital values G and B were also calculated. These approximate the digital value R.

In Fig. 3, the relationship between luminances and digital values is plotted as dots. They were determined from the gray scale of the Color Checker DC in the scene.

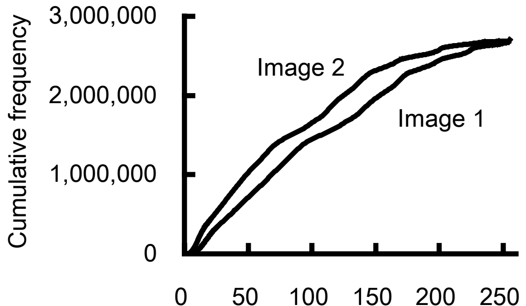

Fig. 2 Cumulative frequencies of digital value R for two images

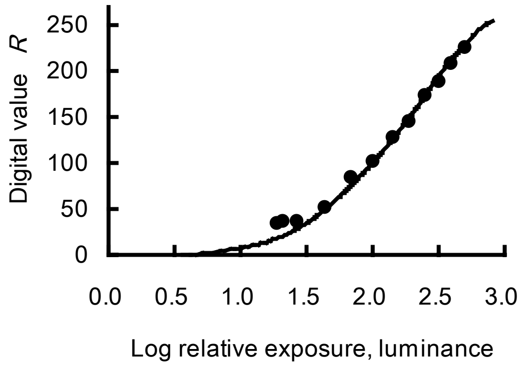

Fig. 3 Calculated tone conversion characteristics for digital values R and measured digital values from a gray scale

The relationship is one of the tone conversion characteristics obtained conventionally. The luminance of the gray scale is also a relative value that is based on tristimulus value Y, and the dots were shifted to overlap the region of higher luminance of the curve. A comparison of the two tone conversion characteristics demonstrates that they are almost identical except in the region of lower luminance where flare is effective.

Summary

A new method for determining the tone conversion characteristics of a digital still camera has been described. Digital values of two images of the same subject formed at two different exposure levels whose ratio is known are used and there is no need for a gray scale. The tone conversion characteristics can be applied to a color reproduction model of a digital still camera and used to not only convert digital values to exposures but also to eliminate flare.

References

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