PCD 042
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PHOTO CD INFORMATION BULLETIN

Fully Utilizing Photo CD Images

Using Information Beyond 100% White

Article No.1

Introduction

This article is the first of a series in which we will discuss some of the unique imaging-science attributes of Photo CD disc images. These articles are intended to help you to understand and utilize these attributes. our goal is to provide you with the information you need to achieve the maximum quality from each Photo CD image.

One of the key imaging-science attributes of the Photo CD System is its encoding of color (luminance and chrominance) information. This color encoding contains some unique features which, if fully leveraged, will produce high-quality images when appropriately rendered on virtually any additive (RGB) or subtractive (CMY or CMYK) output device or medium. One of these unique features of the Photo CD color encoding (PhotoYCC) is its extended dynamic range.

Photo CD Dynamic Range

The color-encoding basis of the Photo CD system, as explained in the Planning Guide for Developers[1], is the **reference image-capturing device.** All Photo CD images, regardless of their actual mode of capture, can be thought of as having been captured and encoded by a specially defined reference image-capturing device**.** This conceptual device provides a consistent colorimetric definition and specification for the encoding of all Photo CD images.

Among the features of this reference device is its ability to capture and encode original scene information corresponding to linear RGB image signals from -0.20 to 2.00, where RGB values of 1.00 are defined as the signal levels that would result from the capture of a perfect, non-fluorescent, white-reflecting diffuser in the original scene. This extended dynamic range allows the Photo CD system to:

@ Encode colors that are beyond the color gamut of the CCIR 709 reference primaries of the system.

@ Encode fluorescent colors, which can sometimes produce signals that are above 1.00.

@ Provide latitude for balance adjustments and other image manipulations subsequent to encoding.

@ Encode original scene luminance information that results in RGB values greater than 1.00. This last feature is the subject of this article.

Luminance Information Beyond 100% - the Original Scene

Although it would seem logical that there should be no luminance information in an original scene beyond that corresponding to a perfect (100%), non-fluorescent, white-reflecting diffuser, many scenes actually do have a considerable amount of visually important information beyond this white point.

Specular highlights, such as those produced by sunlight reflecting from water or polished surfaces, are one source of such information. Diffuse highlights, such as those produced by some areas of a wedding dress illuminated from above the camera angle, represent another important source of scene information beyond the 100% white point. In addition, areas outside of the principal area of a scene (the area controlling the overall exposure) may be lit to higher levels of illumination than the principal area itself, thus resulting in luminances beyond those produced by a 100% white within the principal area of the scene. Similarly, a cloudy sky may contain areas of luminance well beyond those produced by a 100% white in the principal area of the scene. In all of these cases, this above-white luminance information must be captured in order that optimum reproductions can be made.

Luminance Information Beyond 100% - photographic originals

Photographic materials (negatives and reversal transparencies, in particular) are designed to capture and reproduce information from well beyond the 100% white point. Figure 1, for example, shows the location of a properly exposed 100% white on a typical photographic transparency greyscale characteristic curve (Dmin-subtracted Density vs Log Exposure). The film shown has the ability to capture and render luminance information to about 0.30 Log Exposure beyond the 100% point, which corresponds to about 200% of the scene white. Photographic negatives also have an extensive exposure-capturing range. In order to produce images of photographic quality, then, the Photo CD system must have the capability to extract and encode this extensive range of luminance information from scanned photographic inputs.

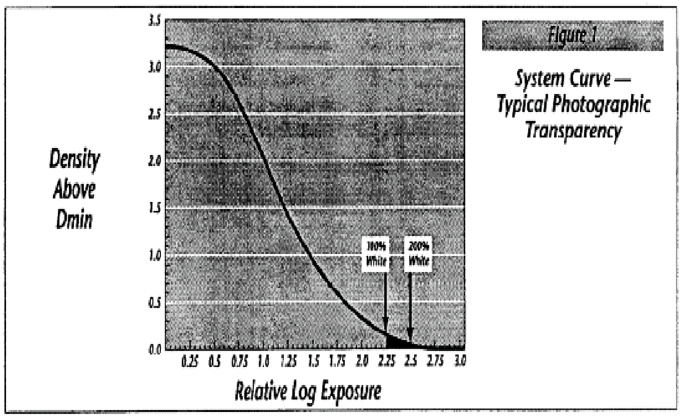

Table 1

% Reflectance	Y Code Value
1	8
2	16
5	34
10	53
15	67
20	79
30	98
40	114
50	128
60	141
70	152
80	163
90	173
100	182
107	188
120	199
140	215
160	229
180	243
200	255

Luminance Information Beyond 100% - Photo CD

As explained in the Planning Guide for Developers, the Photo CD color encoding metric, PhotoYCC, consists of a luma channel (Y) and two chroma channels (C1 and C2), which are derived from nonlinear transformations of RGB linear signals equivalent to those from the reference image-capturing device. In order to provide for the production of optimum output images from photographic originals, and also to provide some additional latitude for subsequent balance adjustments, the Photo CD color encoding is designed to encode luma information corresponding to 200% of the white of the principal area of an original scene.

This extended luminance range can be seen in Table 1, which relates the reflectances of a neutral scale of an original scene to the corresponding code values of the Y channel of Photo CD.

Using Photo CD Information beyond 100% white

In order to prevent the loss of the visually important encoded information from beyond the 100% white point, which would compromise final output image quality, encoded Photo CD data must be properly mapped or transformed for each type of output device and medium. An analogy to this is that many high-end scanning systems require the user to compress highlight information and to otherwise adjust data scanned from an original film to fit within the display capabilities of the output devices and media used in those systems. Photo CD images are similar in that there can be a broad range of original scene luminance data encoded on the disc. Therefore Photo CD image data must be transformed properly for output, based on the capabilities and limitations of the output device and medium. In order to produce optimum results, a different transformation should be used for each type of output.

In the Kodak Photo CD players, for example, the Photo YCC values are processed in a series of digital and analog operations to produce analog RGB voltage signals that are compatible with broadcast TV specifications. This ensures that players can be used along with other video sources such as broadcast, cable, VCRs, laser discs, etc. **When the player signals are sent to a typical home TV, where they pass though further analog signal processing, a resulting overall system output characteristic is produced which, like a photographic film, can display a significant amount of information encoded on the disc from above the 100% scene white point.**

The following equations, used in many Photo CD compatible products, represent a corresponding conversion of Photo YCC values to video RGB digital values. The equations are based on the SMPTE 240M digital specifications for broadcast TV.

$$Y' = 1.3584 \times Y$$
$$C1' = 2.2179 \times (C1 - 156)$$
$$C2' = 1.8215 \times (C2 - 137)$$
$$R = Y' + C2'$$
$$G = Y' - 0.194 \times C1' - 0.509 \times C2'$$
$$B = Y' + C1'$$

A scale factor of 1.3584 has been used in these equations so that the code values on the disc representing a 90% white are mapped to a code value of 235, 235, 235, in accordance with the SMPTE digital specification. When these conversions are used, the RGB video digital code values shown in Table 2 are obtained. When these digital code values are in turn sent directly to a typical computer monitor, using an 8-bit per color channel video drive board, the overall system greyscale characteristic curve shown in Figure 2 is obtained. (The monitor output of this figure is expressed in terms of -Log Luminance relative to the monitor full-drive white. The output values can therefore be compared to the photographic density values shown in Figure 1).

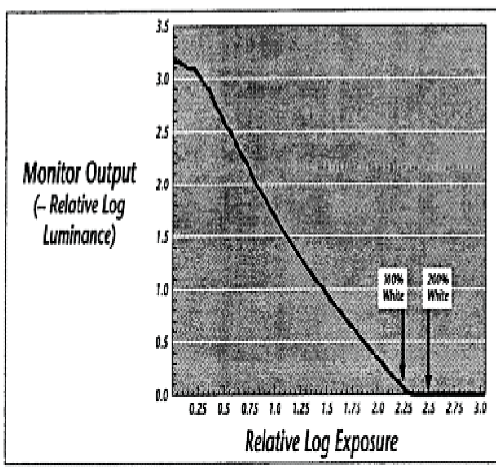

Figure 2

System Curve —
YCC to Typical
Computer Monitor

Table 2

% Reflectance	Y	R	G	B
1	8	11	11	11
2	16	22	22	22
5	34	46	46	46
10	53	72	72	72
15	67	91	91	91
20	79	107	107	107
30	98	134	134	134
40	114	156	156	156
50	128	175	175	175
60	141	192	192	192
70	152	207	207	207
80	163	221	221	221
90	173	235	235	235
100	182	247	247	247
107	188	255	255	255
120	199	271	271	271
140	215	292	292	292
160	229	311	311	311
180	243	330	330	330
200	255	347	347	347

As you can see from the table and the figure, information beyond 107% white produces video code values greater than 255, and this information is clipped to the monitor full-drive level. In order to retain information beyond this 107% point, it is necessary to map the original RGB code values such that they remain within the available range of the display code values.

Remapping Photo CD Information Beyond 100% White

In order to determine a mapping of the above RGB code values, it is first necessary to determine the desired greyscale for the overall system, i.e., from the scene input to the displayed output of the output device. Figure 3 is an example of such an overall system greyscale curve; it represents a system greyscale that has produced excellent results in our tests using a wide variety of video monitors. The shaded area indicates the additional encoded information, above 107% white, that can now be displayed.

The code-value mapping table required to produce this system greyscale will depend on the characteristic response (output luminances vs. input code values) of the particular monitor being used. Once this characteristic response is measured, the mapping table required to produce the desired system greyscale can be calculated. Different mapping tables are required in order to produce the same system greyscale on monitors of different setups.

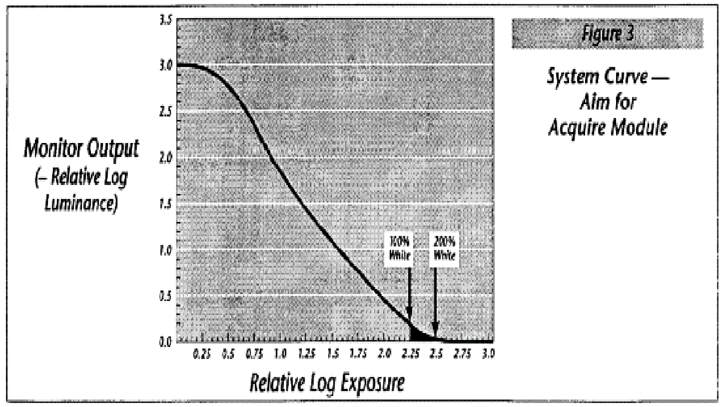

Table 3 lists some representative data points for an example code-value mapping table, derived for a monitor set to Kodak PIW (Photo CD Imaging Workstation) specifications, that would produce the system greyscale curve shown in Figure 3. The table shows the mapping of the previous RGB video code values of Table 2 to the new set of video code values, R'G'B'.

Table 3

% Reflectance	Y	R	G	B	R’	G’	B’
1	8	11	11	11	13	13	13
2	16	22	22	22	23	23	23
5	34	46	46	46	47	47	47
10	53	72	72	72	71	71	71
15	67	91	91	91	88	88	88
20	79	107	107	107	102	102	102
30	98	134	134	134	126	126	126
40	114	156	156	156	145	145	145
50	128	175	175	175	161	161	161
60	141	192	192	192	176	176	176
70	152	207	207	207	188	188	188
80	163	221	221	221	201	201	201
90	173	235	235	235	213	213	213
100	182	247	247	247	223	223	223
107	188	255	255	255	229	229	229
120	199	271	271	271	240	240	240
140	215	292	292	292	249	249	249
160	229	311	311	311	253	253	253
180	243	330	330	330	254	254	254
200	255	347	347	347	255	255	255

KODAK Photo CD Mapping Tables

The KODAK Photo CD Acquire Module for Adobe Photoshop plug-in offers the flexibility to load different mapping tables so that a system greyscale similar to that shown in Figure 3 can be obtained from any of a number of different monitor setups (gammas). The lower number tables are designed to be used on higher gamma monitors, and the higher number tables are designed for lower gamma monitors. These mapping tables, which will also be available in future releases of the KODAK Photo CD Access and the KODAK Photo CD Toolkit, and some suggested uses are listed below. The table that works best for your situation will depend not only on your monitor setup, but also on other factors such as your monitor viewing environment.

- @ Monitor Setup 1 -
- @ Monitor Setup 2 - for typical Apple 13" monitors, uncalibrated*
- @ Monitor Setup 3 -
- @ Monitor Setup 4 - for Kodak PIW, other monitors calibrated to gamma 2.2
- @ Monitor Setup 5 -
- @ Monitor Setup 6 -
- @ Monitor Setup 7 -
- @ Monitor Setup 8 - monitors calibrated to 1.8 gamma
- @ Monitor Setup 9 -

*(Note: many Apple systems automatically load in a "hidden" curve shaper into the video drive board when the system is booted. When this occurs, the monitor gamma is effectively reduced to about 1.8, so Monitor Setup 8 should be used. Because the Apple shaper reduces the available output dynamic range of the monitor, our recommendation is to remove it and to then use Monitor Setup 2.)

As an alternative to using these Kodak developed mapping tables, you can create your own tables. Most software packages allow you to access YCC data. This data can be processed, using customized mapping tables, to retain the extended luminance information of Photo CD images. The principles and examples described in this article should help you to construct tables appropriate for your application.

Conclusions and Recommendations

Photo CD color encoding contains an extended range of luminance information that is important to the production of high-quality output images. Most currently available Photo CD display packages do not fully utilize the capabilities of Photo CD images. As a result, images from wide dynamic range scenes may be reproduced with washed out or clipped highlights. Optimum output images can be produced by appropriately mapping Photo YCC values to output device code values.

Future releases of KODAK Photo CD Access and the KODAK Photo CD Toolkit will incorporate the video mapping capabilities currently available in the KODAK Photoshop Plug-In. When using applications that do not have this capability, the YCC data should be accessed and processed to obtain the best quality output images.

References

1. *KODAK Photo CD System – A Planning Guide for Developers*, Eastman Kodak Company, Part No. DCI200R, (1991).

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