PCD 043
July, 1993

PHOTO CD INFORMATION BULLETIN

Fully Utilizing Photo CD Images

Universal Film Terms for Reversal Films
Article No. 2

Introduction

This article is the second in a series in which we will discuss selected topics concerning the imaging science of Photo CD. The goals of this series are to further your understanding of the Photo CD system and to provide you with information helpful to producing the maximum quality for each Photo CD image.

In our first article, which dealt with the extended luminance range of Photo CD images, we stated that one of the features of Photo CD is its unique encoding of color (luminance and chrominance) information. In this article, we will explain more about this color encoding. In particular, we will discuss an important encoding feature called *input compatibility*. We will also describe the relationship of color encoding to the use of product-specific input signal processing (film terms) and to a new set of "universal" film terms that can be used for encoding transparency images.

Photo CD Color Encoding and Input Compatibility

Perhaps the most distinctive feature of Photo CD color encoding is that it allows each output device (such as a home player, a computer monitor, or a thermal printer) to produce images from *any* Photo CD data file, regardless of the type of input imaging medium that was scanned to produce that file. This feature results from the use of a proprietary input encoding technique[1] that achieves *input compatibility* of Photo CD images scanned from a variety of types of input media.

By input compatibility we mean that the fundamental differences among the various types of input images, such as negatives and positives, are eliminated.

Without input compatibility, each output device requires multiple output data-processing paths (transforms) in order to properly produce images encoded from different types of inputs. *With* Photo CD's unique input compatibility, the data-processing path for each output device is *independent* of the original input source of the Photo CD encoded image. Each output device therefore requires only a single transform to produce output images from *any* image encoded on any Photo CD disc.

Photo CD input compatibility also allows for the cutting-and-pasting of elements of Photo CD images that originated from different types of input media into composite images. For example, portions of images scanned from negatives can be readily edited together with images scanned from transparencies to form an homogeneous-appearing composite. The composite image can then be sent to any output device, where the *entire* image will then be reproduced in a way that has have optimized for that particular device. In addition, input compatibility allows all images to be adjusted and manipulated, during and after encoding, by the use of a common set of application software tools.

In the next sections of this article, we will explain why input compatibility is difficult to achieve for the photographic negative, transparency, and reflection print inputs of the system. We will then show that, nevertheless, compatibility *has* been achieved by the unique features of the Photo CD color encoding, and we will explain how that encoding relates to product-specific and universal film terms used in the Photo CD Imaging Workstation (PIW).

The Problem of Input Incompatibility

None of the photographic products currently used for input to Photo CD (Figure 1) is designed specifically to be scanned and digitized. Instead, each is designed for other purposes; either for direct viewing by a human observer or for printing onto other photographic materials. Because each type of input product is designed for a different purpose, each is physically (and colorimetrically) different from the others. As a result, unprocessed data from scanned images on different types of input products, such as negatives and transparencies, are not compatible. Unlike Photo CD image data, this non-compatible scanned image data from different input types cannot be:

@ adjusted or modified using a single set of software user tools, transforms, etc.

@ merged to produce composite images

@ processed by an output device, without requiring knowledge of the origin of each image.

There are two principal causes of incompatibility of scanned input data. The first is that most positive transparency and reflection print imaging media are designed to be viewed by a human observer under a specific set of viewing conditions. Reflection prints, for example, are designed to be viewed in a normal environment where the illumination of the image is similar to the illumination of the rest of the viewing environment. Transparencies, on the other hand, are generally designed to be projected in a darkened room or illuminated by back-light.

Because differences in the viewing environment will change an observer's perception of an image, reflection and transparency imaging media must be designed very differently from each other. Each must properly account for the perceptual effects that its intended viewing environment will induce in the observer. For example, projecting an image in a darkened room will lower its *apparent* luminance contrast. In order to compensate for this perceptual effect, projection slide films are built with physical contrasts that are higher than those of reflection prints.

A measuring device, such as an input scanner, is of course not subject to the perceptual effects of the human observer. As a consequence, scanned data from images on different types of positive media will not directly correspond to the visual appearances of images on those media. For example, transparencies and reflection prints that *look identical* to an observer, when each is viewed in an environment appropriate for each respective medium, will produce very *different* scanned values. Likewise, if by some chance the scanned values were identical, the transparencies and reflection prints would look different. Image data scanned from a transparency is therefore incompatible with image data scanned from a reflection print (or scanned from any other form of image designed to be viewed in a normal viewing environment).

Note: A conversion of the scanned data to standard CIE colorimetry, often described as "device-independent color", will *not* solve this incompatibility problem. CIE colorimetry measures certain characteristics of colors, but it does not include perceptual factors. It therefore does not specify the appearance of measured colors, which would be required in order to produce compatibility of data scanned from positive transparencies and reflection prints.

The second cause of incompatibility among input image types relates to photographic negatives. Negatives do not contain rendered output imaging information, i.e., information relating directly to an image to be viewed by an observer. Scanned data measured from a photographic negative corresponds more to the appearance of the negative itself rather than to that of a rendered positive image that would result if, for example, the negative were to be optically printed. Image data scanned from negatives is therefore fundamentally incompatible with image data from reflection prints, transparencies, and other forms of positive rendered images.

As a result of these two sources of input image incompatibility, image data scanned from photographic negatives, transparencies, and reflection prints cannot share a common output data path, cannot be merged to form composite images, and cannot be manipulated by common tools unless such data are first appropriately transformed to achieve input compatibility. In the next section, we will show how the unique color-encoding of Photo CD provides this compatibility-producing transformation.

Photo CD Input Compatibility

As explained in the Planning Guide for Developers[2], the color-encoding basis of the Photo CD system is the reference image-capturing device (Figure 2). All Photo CD images, regardless of their actual mode of capture, can be thought of as having been captured and encoded by the reference image capturing **device.** This conceptual device provides a consistent colorimetric definition for the Photo CD system.

Moreover, the concept of this reference image-capturing device **p**rovides the basis for achieving compatibility among the various types of media that are input to the Photo CD system. Figure 3 represents a somewhat idealized illustration of this concept where output values from the reference device go directly to the Photo YCC color encoding and where scanned data from each photographic input medium are processed on the Photo CD Imaging Workstation (PIW) to produce values corresponding to those from the reference device. Compatibility is achieved by the transformation of data from each input medium to a common ***meaning*** and a common ***numerical encoding.*** This meaning and the numerical encoding are defined, **in the most strict sense**, as follows:

> ***The meaning of each Photo CD disc image is:*** *The colorimetry of the original scene which caused the image to form on the input imaging medium being scanned.*
>
> ***The numerical values that are used to encode this original-scene colorimetry are:*** *Those values which would have been measured by the Reference Image-Capturing Device had it captured the same original scene.*

These two definitions form the basis for Photo CD color encoding. What is unique about Photo CD encoded images is that they all have a common *meaning* - the colorimetry of the *original scene*. This is very different from encoding the colorimetry of the input *images* themselves which, as explained previously, would produce incompatible image data from different types of input media. Having this common meaning is much more significant than simply having a single color-encoding *metric.* A single data metric is operationally convenient; but a single data metric, without a single meaning of the data, contributes nothing to achieving input compatibility.

We will see later on that there is a considerable amount of flexibility within the scope of the definition of the "original scene". But it is important for all PIW users to understand that any image they are *writing* to a Photo CD disc *must* be fundamentally consistent with this common meaning and that they are actually recording the colorimetry of the original scene. They are not recording the colorimetry of the scanned image itself, nor are they recording the colorimetry they would ultimately like to produce on any particular output device.

One of the unique features that results, in part, from input compatibility is the flexibility that is created for *output.* Photo CD image data can be transformed in the output process to correspond to either of the above colorimetric objectives, or to virtually any other desired color-reproduction objective. But it is important that, during the encoding process, the basic original-scene-colorimetry interpretation is fundamentally maintained in order to ensure that all recorded images are consistent and compatible with all other Photo CD images.

Achieving Input Compatibility in Practice

As we have explained, all Photo CD images can be thought of as original scenes that have been captured by thereference image-capturing device. To achieve that end, which would result in the maximum compatibility among input image types, *all* input-film-specific properties of *each* input film would have to be eliminated and replaced with the properties of the reference device. Is this technically feasible?

There is a theoretical limit to how exactly the values scanned from a given input film can be transformed into the values that would have been produced by the reference device. Each input film has a somewhat different theoretical limit.

Under laboratory conditions, we can essentially reach this theoretical limit. Doing so requires careful control over the entire process, calibration of the actual film and equipment being used, and other measures that are not available in ordinary usage. In practice, this limit can be approached by the use of product-specific PIW film terms for each input film. However, there are many factors which these film terms cannot account for, such as:

- @ variations in film manufacturing
- @ changes in the film after manufacturing
- @ exposure of the film under non-standard conditions
- @ changes in the unprocessed image after exposure
- @ variations and/or deliberate alterations of film processing
- @ changes in the film image after processing
- @ variations in scanning

In practice, then, it is unlikely that any given image scanned from an actual photographic film and transformed using the film terms of that product will have values exactly equal to those of thereference image-capturing device. Is that a problem? Have we lost the compatibility of the inputs? No, not really. What will happen is that differences of the film being scanned from the reference film used to derive the film terms for that product will be encoded as alterations of the "original scene"; however, the basic input compatibility would not be lost.

For example, if a particular piece of film were chemically processed to a higher contrast, use of the product-specific film terms would simply result in encoded values representative of a "higher contrast original scene". The image would not be identical to that from the reference film, but it would still be compatible with it. Also, the automatic balance algorithms and the operator adjustments provided in the PIW are designed to help compensate for unwanted variations in the scanned images caused by input film variations. Proper use of these adjustments enhances the consistency of the scanning/encoding process which in turn enhances input compatibility.

Degrees of Input Compatibility

We have discussed the data manipulation and interchange advantages of input compatibility. But how much compatibility is really necessary? Certainly the fundamental incompatibility of negatives, transparencies, and reflection prints *must* be eliminated for the system to work at all. But should all images of the same original scene, recorded on a wide variety of input media, produce *identical* Photo CD image files?

There is really no "right" or "wrong" answer to this question. For some advertising and scientific applications, it may well be desirable to produce image files that are accurate colorimetric records of the original scenes, regardless of the actual film (or films) used to record those scenes. Similarly, it would probably be preferable for a Photo CD produced from slides taken of museum paintings to represent the colors of the paintings themselves rather than the colors of the slides. For other applications, however, an accurate record of the photographic image itself might be more desirable. What we have then is a range of differing needs to consider, from:

@ achieving original scene colors and complete input compatibility, but with no retention of the particular characteristics of the input film, to

@ achieving complete retention of the particular characteristics of the input film, but with no input compatibility.

These two possibilities represent extremes of what is really a continuum of possible trade-offs between input compatibility and retention of individual film characteristics. The point that is reached on the continuum depends on the correspondence between the actual image being scanned and the film terms being used in the PIW input processing. For example, using film terms calibrated for each and every individual frame of film could achieve virtually complete input compatibility. On the other hand, using less specific film terms would result in somewhat less compatibility while retaining more of the particular characteristics of the input film.

The product-specific film terms currently available on the PIW represent a point on this continuum where the product-to-product differences among films of the same type have been minimized. The use of these terms produces results that favor input compatibility; their primary purpose is to produce consistent discs for applications such as home players, photofinisher thermal printers, etc.

We have recently developed a more general set of film terms for use with photographic transparencies. These terms favor a greater retention of the characteristics of the input film, while at the same time producing image files that are generally compatible with files produced from negatives and reflection prints. These new terms are called "universal" transparency film terms.

"Universal" Transparency Film Terms

Our goal in developing "universal" film terms was to provide a Photo CD encoding path for transparencies which would retain the distinctive characteristics of each input film, while producing image files that are reasonably compatible with each other and with files produced from negatives and reflection prints.

This goal was achieved by developing film terms which account for the fundamental differences between transparencies and other forms of input media but which do not remove the visual differences among transparency products. When these terms are used with films that are above average in contrast, for example, the resulting Photo CD images files reflect that higher contrast. Similarly, films with other particular characteristics, such as high or low color saturation, or a tendency to reproduce reds as orange-reds or magenta-reds, will produce Photo CD images files that reflect these characteristics.

How can this be done without sacrificing the fundamental input compatibility of the system? One way to think of this is that while we have retained the basic definition of Photo CD color encoding - original scenes, captured by the reference image-capturing device - we have allowed the encoding of these scenes to be somewhat altered according to the particular characteristics of each input film. It is as if we now have some scenes with somewhat higher or lower contrast, higher or lower color saturation, more orange or more magenta reds, and so on. Photo CD files created using the "universal" film terms are therefore still fundamentally compatible with files created using product-specific terms.

Other Features of the "Universal" Transparency Film

There are other features provided by these "universal" terms. One that has proven to be popular in our trials is that it is not necessary to identify the specific transparency product being scanned (not an easy task with mounted slides). At the time of this writing, we have just two sets of "universal" transparency film terms. One set is for KODAK Kodachrome films (which can be readily identified by the relief image that can be seen on the emulsion side of the film); the other can be used for all Process E6 products.

The transforms used for the "universal" terms have been designed to avoid clipping highlight (low density) information in the encoding of transparencies that have been severely overexposed or that have been push-processed. The transforms have also been designed to improve the encoding of information from very high densities on the transparencies. In addition, improved techniques for optimizing the color matrices of the film terms have been incorporated into the "universal" terms. As a result, you should see improved color saturation and blacker, richer blacks.

Finally, the new "universal" terms eliminate the image data adjustments of the automatic Scene Balance Algorithm (SBA). This algorithm is normally used to adjust the overall density and color balance of the Photo CD image, based on the information measured during the pre-scan of the transparency. With the SBA effectively disabled, the encoded images retain more of the original look of each input transparency.

We recommend that you use "universal" transparency film terms for scanning transparencies for most applications. These terms incorporate several improvements which are not yet part of the product-specific PIW film terms. In addition, the "universal" terms are operationally simpler to use (the exact film type does not have to be determined), and they are somewhat more forgiving of film variations and scanner/operator errors.

The "universal" terms automatically set the Scene Balance Algorithm (SBA) to 0% correction. While this helps to retain more of the original look of each input transparency, there are situations where there may be unwanted density and color-balance variations in the original transparencies. In such cases, it may be desirable to re-enable the SBA by setting the correction level to a higher percentage, perhaps as high as 70%. The instructions for changing the correction level are contained in the Kodak Photo CD Products publication *Managing the KODAK PCD Imaging Workstation,* Edition 3, Chapter 3, Managing Film Terms.

Summary and Recommendations

In this article, we have explained the concept of input compatibility. Input compatibility allows the data-processing path for each output device to be independent of the original input media, it allows for the production of composite images from various media, and it allows for the adjustment and manipulation of images using common application software tools. We have shown how the input compatibility of the Photo CD system results from the use of proprietary input encoding techniques.

We have also described the relationship of the encoded data to the use of product-specific PIW film terms and to "universal" film terms. While the use of product-specific film terms can produce results that are closer to the theoretical concept of the Reference Image-Capturing Device, the use of "universal" terms results in images that retain more of the individual characteristics of each input film.

In a subsequent article, we will provide recommendations for the use of product-specific film terms in applications where the colorimetry of the objects in the original scene takes precedence over the colorimetry of the transparency itself.

References

1. U.S. Patent Application Serial No. 931889 METHODS AND ASSOCIATED APPARATUS FOR FORMING IMAGE DATA METRICS WHICH ACHIEVE MEDIA COMPATIBILITY FOR SUBSEQUENT IMAGING APPLICATIONS

2. Kodak Photo CD Products, *A Planning Guide for Developers*, Eastman Kodak Company, Part No. DCI200R

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PCD043
July 1993
Consumer Imaging
Eastman Kodak Company Rochester, NY 14650