Progress Towards a New Test Method Based on CIELAB Colorimetry for Evaluating the Image Stability of Photographs

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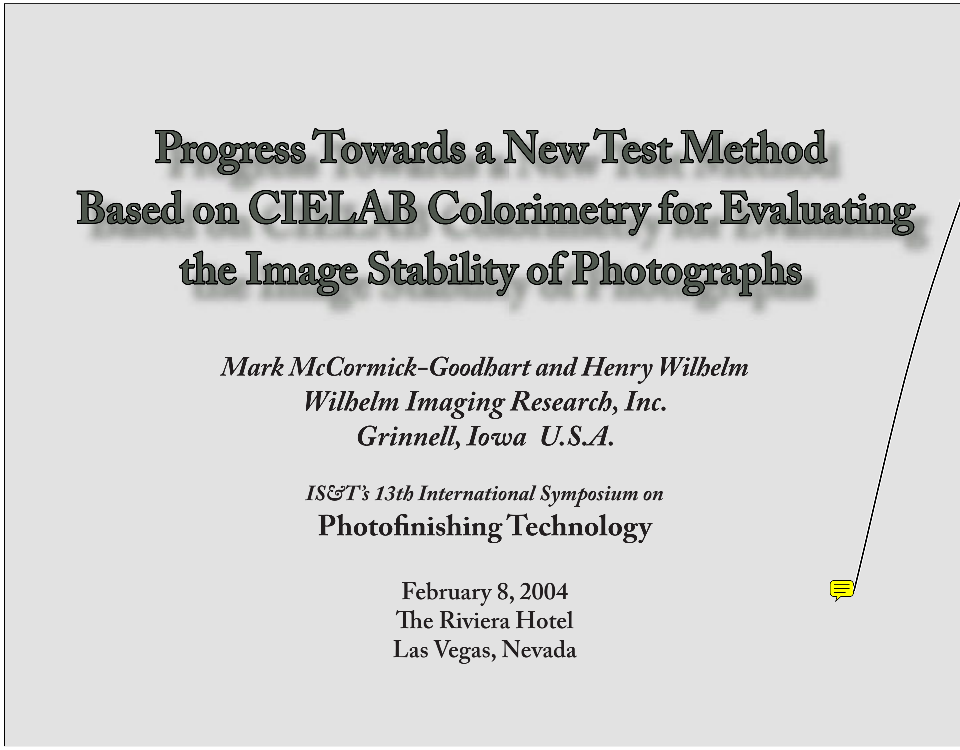

Summary of Comments on IS&T_Photofinishing_2004_ Presentation slides

Title Slide

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 9:30:50 PM

Title slide -

This PDF file contains all of the “slides” I presented at IS&T’s13th International Symposium on Photofinishing Technology, which took place Las Vegas, Nevada on February 8 and 9, 2004 (the presentation was given on February 8). The IS&T conference was co-located the with Photo Marketing Association International trade show held at the Las Vegas Convention Center. I have added comments about each slide on a following page to convey the essence of the remarks made during the talk. My remarks are similar but not verbatim since the presentation was not recorded. For optimum display of the photos on a computer, I recommend viewing the presentation on an sRGB calibrated monitor using the latest version of Adobe Reader (available for free at the adobe.com website).

The presentation was accompanied by a paper in the IS&T Final Program and Advanced Printing of Paper Summaries book: Mark McCormick-Goodhart and Henry Wilhelm, "Progress Towards a New Test Method Based on CIELAB Colorimetry for Evaluating the Image Stability of Photographs," pp. 25–30. It is also available on the WIR website <www.wilhelm-research.com> with the file name: <WIR_ISTpaper_2004_02_MMG_HW.pdf>

Factors Influencing the Determination of Print Life

1). *Materials/Construction/Processing*
2). *Environmental Conditions (e.g., light, heat, humidity, air quality, physical handling,etc.)*
3). *Endpoint Criteria*

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Slide #1

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 7:13:57 PM
Slide #1 -

When attempting to predict the print life of a particular print system using accelerated image stability tests, there are three major factors which influence the test results. The first, of course, is the materials and components comprising the imaging technology. The second contributor is the identification of the important environmental factors that influence the outcome. Typically, researchers create elevated but steady-state environmental conditions designed to accelerate the aging process, and then the results under these conditions are extrapolated to more real world “averaged” environmental conditions. These first two aspects of image permanence testing are well recognized and have been the subject of considerable research. Surprisingly, the third contributor to print life determination, namely, the choice of an endpoint criterion (or multiple criteria) for failure, can easily affect the outcome by more than an order of magnitude. Yet to date endpoint criteria have received little attention by researchers. WIR currently uses a weighted densitometric criteria set that was originally designed to evaluate the performance of traditional color photographic materials processed in standardized photographic processing chemistry. Because these traditional photographic color materials change in a fairly uniform manner, the monitoring of just one or two density levels for cyan, magenta, and yellow dyes plus neutral CMY patches was sufficient to characterize the response. However, today we recognize that in this modern era of digital output, diverse colorant sets, and widely varying printing procedures (for example, use of UCR, GCR and spot colors), we must adopt a colorimetric approach that will rank different printing systems in a more uniform and impartial way.

How Long Will My Print Last?

When will I notice a change in appearance?

When will I object to the change in appearance?

Slide #2

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 7:22:58 PM

Slide #2 -

When researchers try to correlate objective parameters such as changes in density or colorimetric values with the subjective responses obtained from focus group studies where participants are asked to judge changes in image quality or appearance, the way that the questions are phrased has a large impact on the outcome. In our paper that was published in the conference proceedings we discussed these issues at length. I invite you to read the companion paper to this presentation published in the IS&T Photofinishing Conference proceedings book. It is also available on the WIR website <www.wilhelm-research.com> with the file name <WIR_ISTpaper_2004_02_MMG_HW.pdf>

We were about to embark on a significant parametric study. Psychophysical tests are time consuming and expensive and our initial plan was to ask participants in the study to judge perhaps four or five levels of "noticeability" (i.e., no noticeable difference, just noticeable, noticeable, very noticeable, extremely noticeable). When a good statistical correlation can be achieved, the results should relate to the chosen levels. At the end of the study, if all went well, we would have identified colorimetric properties in typical photographs that correlate with perhaps four or five levels of change as they pertain to perceived levels of noticeable difference between the control prints and their aged counterparts. Such results are prescriptive, and not predictive of the true end of functional life for many people. Indeed, while an individual can be very consistent in noticing change, his or her tolerance for the observed change varies depending on the circumstances (e.g., professional portrait, amateur snapshot, sole surviving print of an important event, size of print, etc.).

Faded chromogenic color print, circa 1965. Total loss of color information but some lightness channel data (L) is retained.*

Faded chromogenic color print, circa 1965. Total loss of color information but some lightness channel data (L) is retained.*

Slide #3

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 10:40:34 PM

Slide #3 - Henry and I have seen many faded color photos like this one over the course of our photographic careers. Yet the circumstances under which we experienced this photo catalyzed an important concept for us: the concept of “retained image appearance”. It has led to a different path in our research, towards a new test method based on CIELAB colorimetry.

One day in December 2003, Henry stopped by the office of Mr. Charles Manly, a lawyer in Grinnell, Iowa. Henry saw this photograph framed and hanging on the wall but did not recognize the lovely house in the picture. Because Grinnell is a small town and the home appeared as if it might be a local home, or perhaps located near the town of Grinnell, Henry asked about the house. Mr. Manly immediately started recounting memories of the home, which belonged to his grandfather and where he had spent a great deal of time as a child, and pointed out many architectural details of the house.
Unfortunately, the house was demolished in the early 1970's which is why Henry didn’t recognize the home in the photo! The house had been located only a few blocks from where Henry and his family now live in Grinnell. In their conversation, Mr. Manly did not even mention that fact that the circa 1965 Kodak color print was now severely faded.

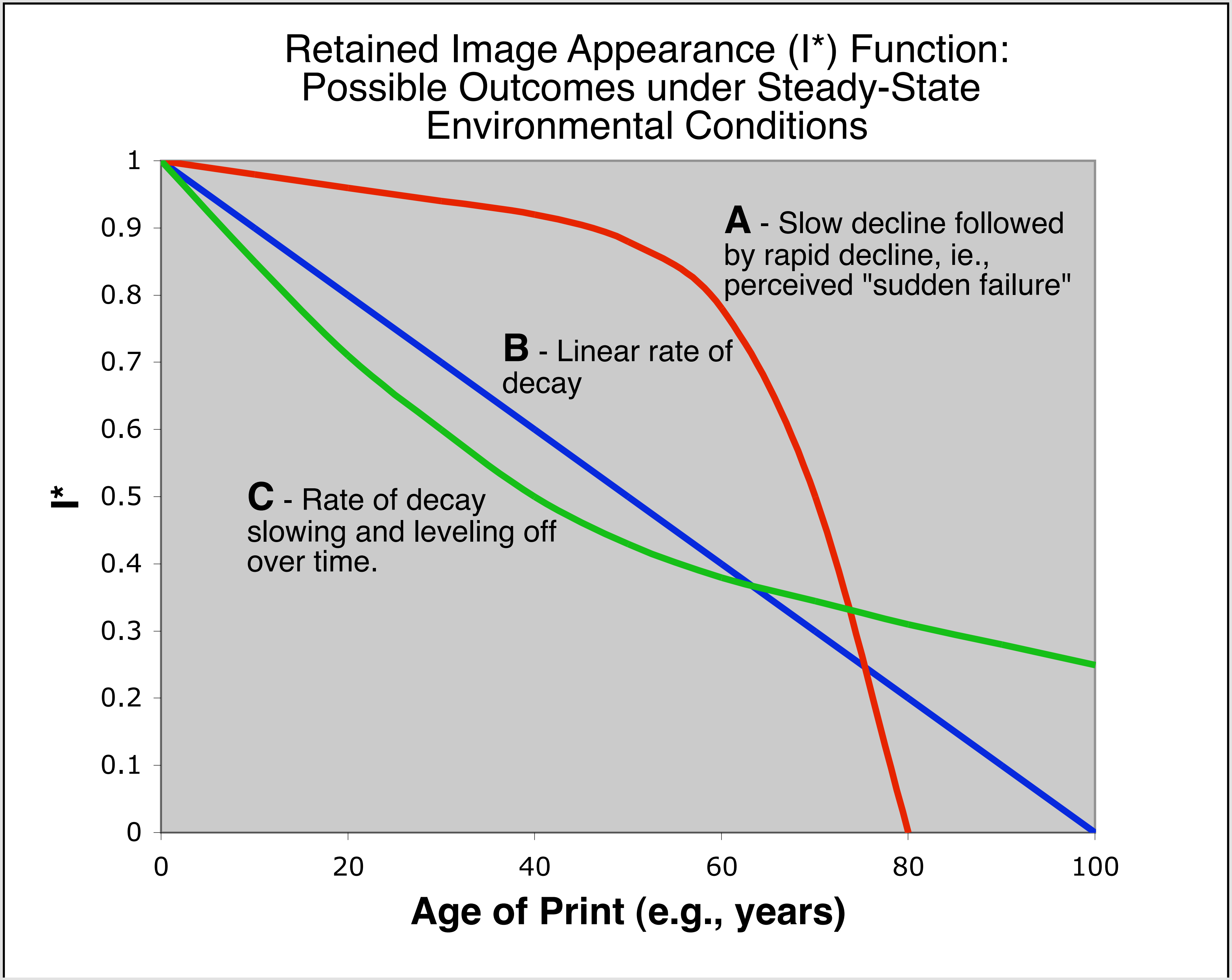
Henry later asked to borrow the faded photo since it would make a good example to show in future talks given on the subject of image permanence. Mr. Manly kindly lent Henry the photo so he could scan it, indicating to Henry how important the photo still was to him and that he wanted it back. The day I first saw the photo Henry began to relate to me the conversation he had had with Mr. Manly. Our casual discussion soon revealed the technical significance of the photo’s provenance to both of us. I said to Henry “It’s amazing that the color information is completely lost and the contrast is probably less than 20% of the original, but it is still a photograph that Mr. Manly wants to display in his office!”

I realized just then that we should reconsider the full “life cycle” of a photograph in terms of loss in information content, not just a fractional decrease in visual aesthetic to some preset endpoint. So did Henry. He replied to my comment, “Yes, it is now an L channel-only photograph and, recalling his conversation with Mr. Manly, "I think this was my first purely L-channel discussion with another person about what at one time was a full-color photograph!” Indeed, the image is still a valuable photograph for Mr. Manly and functionally capable of conveying a historical scene to new observers despite the fact that it has long passed the point in its life cycle where color and contrast would be rationally judged as acceptable by a focus group on image quality. It clearly has not yet reached its undisputed end of life.

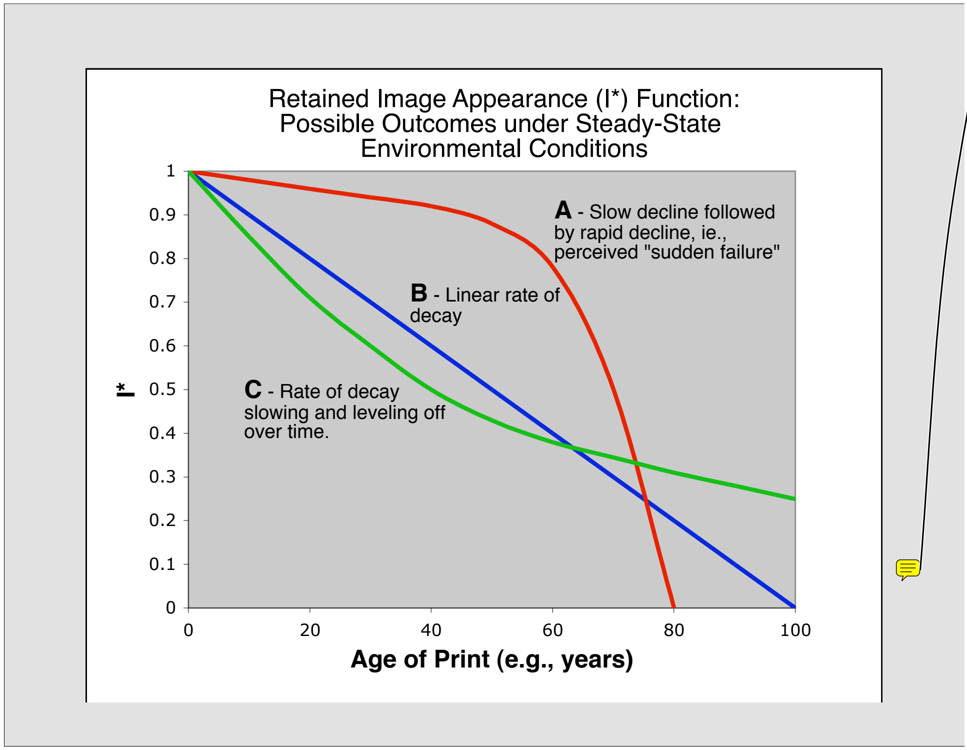
Comments on slide #3 continued on next page

Faded chromogenic color print, circa 1965. Total loss of color information but some lightness channel data (L) is retained.*

In the context of information content, Henry and I quickly understood the significance of separating lightness from hue and chroma information, that the black-and-white signal is meaningful – and in fact black and white photography can often be quite beautiful – to humans who otherwise see the world in color. It is why people not only accept, but genuinely treasure the black-and-white photographs by Ansel Adams, Edward Weston, and many other photographers. That day we began to envision a more comprehensive way to describe the boundary conditions for the life of a photograph. A photograph begins its life with a retained image appearance value of 100% and its functional life ends when the retained image appearance is 0% of the original state. A photograph's aging process is one of ongoing loss of information content. To a fine artist, critical information content may be lost with just noticeable changes in color. To an archivist or historical researcher, important information content may still be retained in the very faintest signals emanating from the deteriorated remnants of an old photograph. The very faded photograph of this house is a good example.



Retained Image Appearance (I*) Function:
Possible Outcomes under Steady-State
Environmental Conditions
A - Slow decline followed by rapid decline, ie., perceived "sudden failure"
B - Linear rate of decay
C - Rate of decay slowing and leveling off over time.
I*
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
Age of Print (e.g., years)



Slide #4

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/18/2004 3:41:44 PM

Slide #4 –

How might a Retained Image Appearance function which we denote as I* be plotted? In this slide we postulate three general curve shapes that could occur as a photograph ages under steady-state environmental conditions. Curve A represent a photographic print that holds its original fidelity reasonably well for a long time and then begins to deteriorate more rapidly. Curve B is a process with linear decay over time. Curve C represents a process that deteriorates more rapidly in the beginning but slows down over time. All of these pathways are possible and this slide serves to illustrate that at a given point in time two different photographs could have very similar I* values but at another point in time show markedly different retention of image appearance. It is our opinion that when consumers ask the question “How long will this photograph last” they intuitively are thinking about a process that follows path A. They tend to envision a photo that looks pretty faithful to its original print quality until one day they conclude it looks very bad. While such a pathway to failure is possible, we anticipate that modern photographic processes are more likely to follow path B or C. Thus, the whole story of the aging process cannot be told with a single endpoint criterion. I view this situation analogously to the image sharpness concept of the modulation transfer function (MTF) versus resolution. An MTF plot indicates the total frequency response of an imaging system whereas a resolution number reports only how the system does at its high frequency limit.

The "Retention of Image Appearance" function, I^*, can be thought of as having two components, I^*_{color} and $I^*_{B\&W}$, where I^*_{color} represents the retained color information and $I^*_{B\&W}$ represents the retained black and white [lightness channel (L^*)] information:

$$I^* = \frac{I^*_{color} + (I^*_{B\&W} + w)}{1+w}$$

The term, w, is a weighting factor that proportions the relative importance of the color versus the black and white information.

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Slide #5

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 10:24:38 PM

Slide #5 –

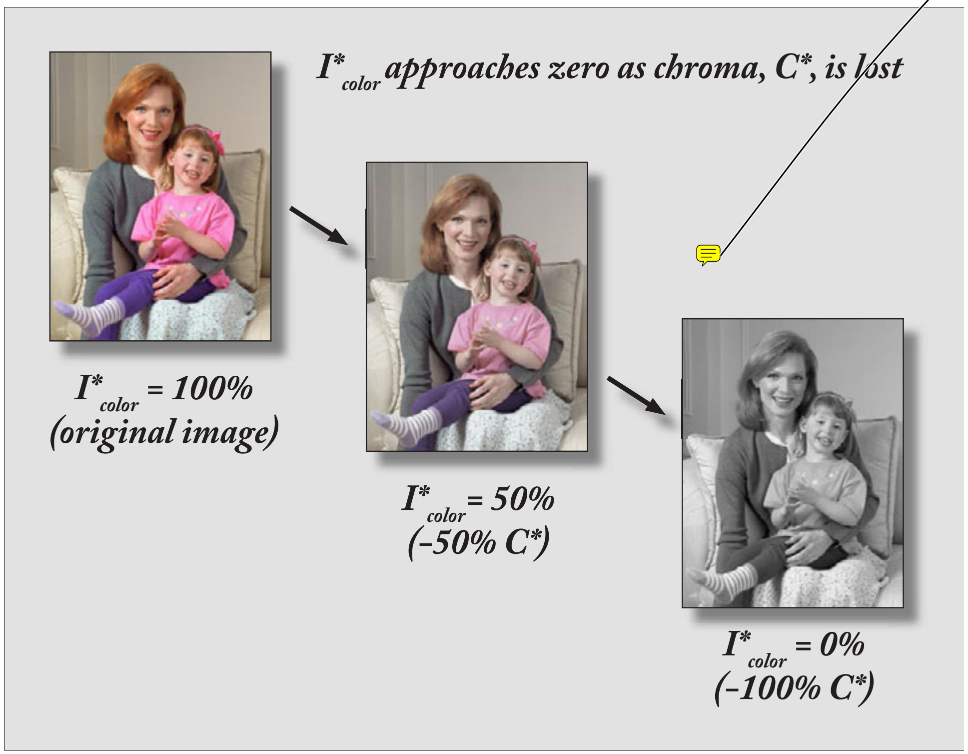
In attempting to define information content, we must first think about what kind of information is extracted from a photograph. If it is a color photograph, then accurate rendition of color is very useful information. While we can deduce certain memory colors from other spatial clues in a scene (e.g., green grass, human skin tones, etc.), we rely on the color photographic process to authenticate most colors in the scene, for example, a red automobile, yellow shirt, etc. On the other hand, black and white photographs brilliantly convey spatial information in the form of modulated scene lightness values without presenting any color information (A notable exception being subtle hues characteristic of the process itself, not of the scene, and often prized by printmakers.). Thus, I* can be divided into components as shown in the math in this slide. Note: I was asked a good question after the talk about incorporating image sharpness into the equation. For example, an I* component for image sharpness would be very useful to characterize certain dye-base inkjet media that can suffer line bleed and subsequent loss of sharpness upon exposure to high humidity environments. I replied that, yes, I can conceive of an additional I* component for image sharpness derived from MTF data that would then be weighted into a total I* metric similarly to what has been shown here. Future research to keep us busy!

I^*_{color} approaches zero as chroma, C^*, is lost

$I^*_{color} = 100\%$
(original image)

$I^*_{color} = 50\%$
($-50\%\ C^*$)

$I^*_{color} = 0\%$
($-100\%\ C^*$)



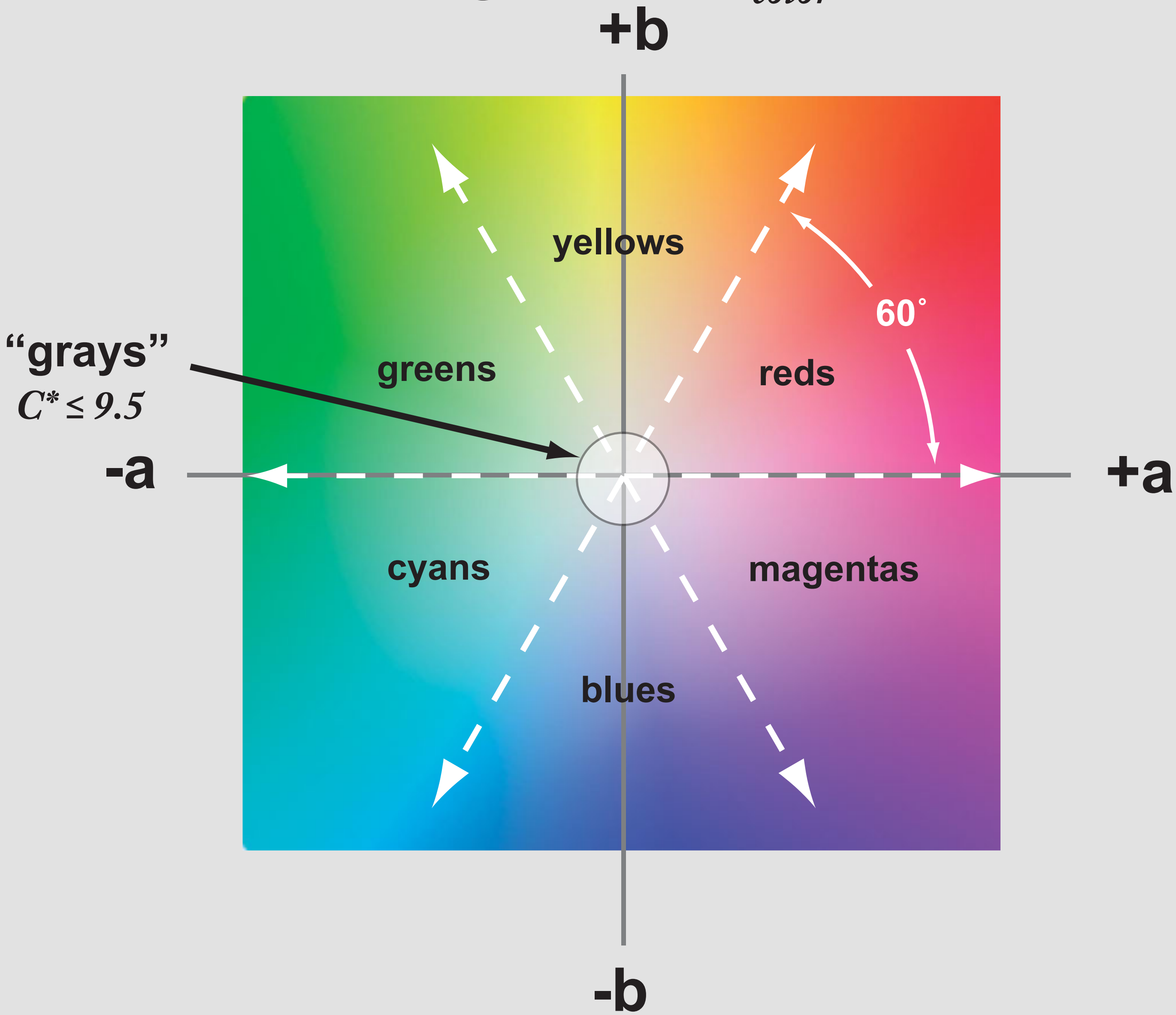
Slide #6

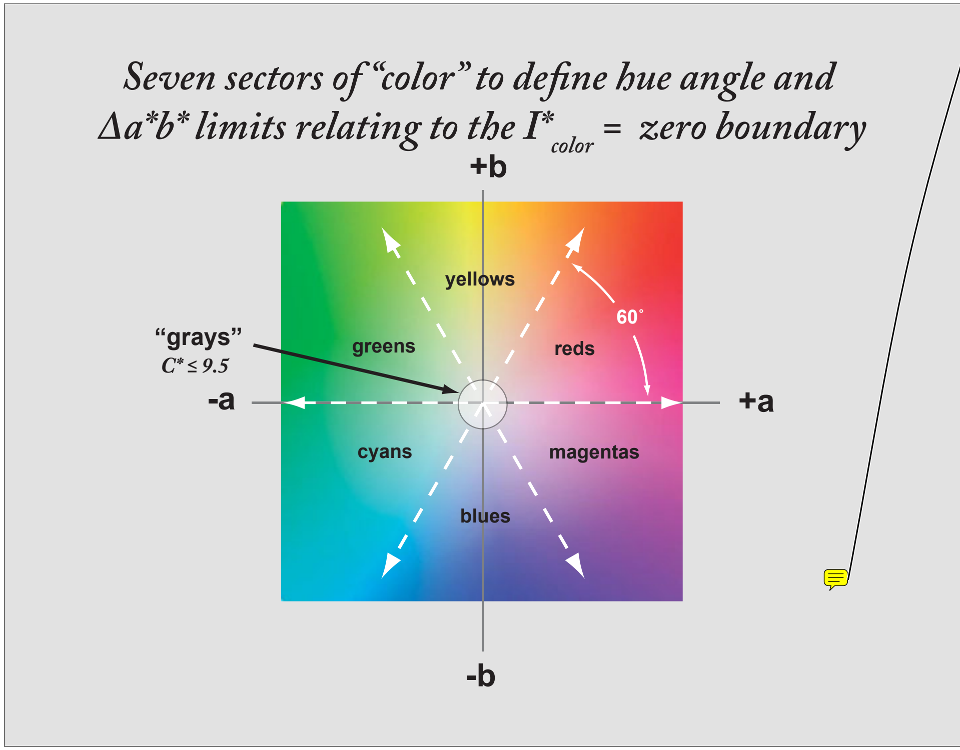
Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 8:13:00 PM

Slide # 6 –

Slides 6 – 10 will show how we can derive the I* color component based on objective colorimetric measures of the retention of color information in the print. Understanding the boundary conditions is the key to deriving the I* math. This slide shows an example, digitally simulated, of chroma loss and the linear visual impact on I* color.

Seven sectors of "color" to define hue angle and Δa^*b^* limits relating to the I^*_{color} = zero boundary





Slide #7

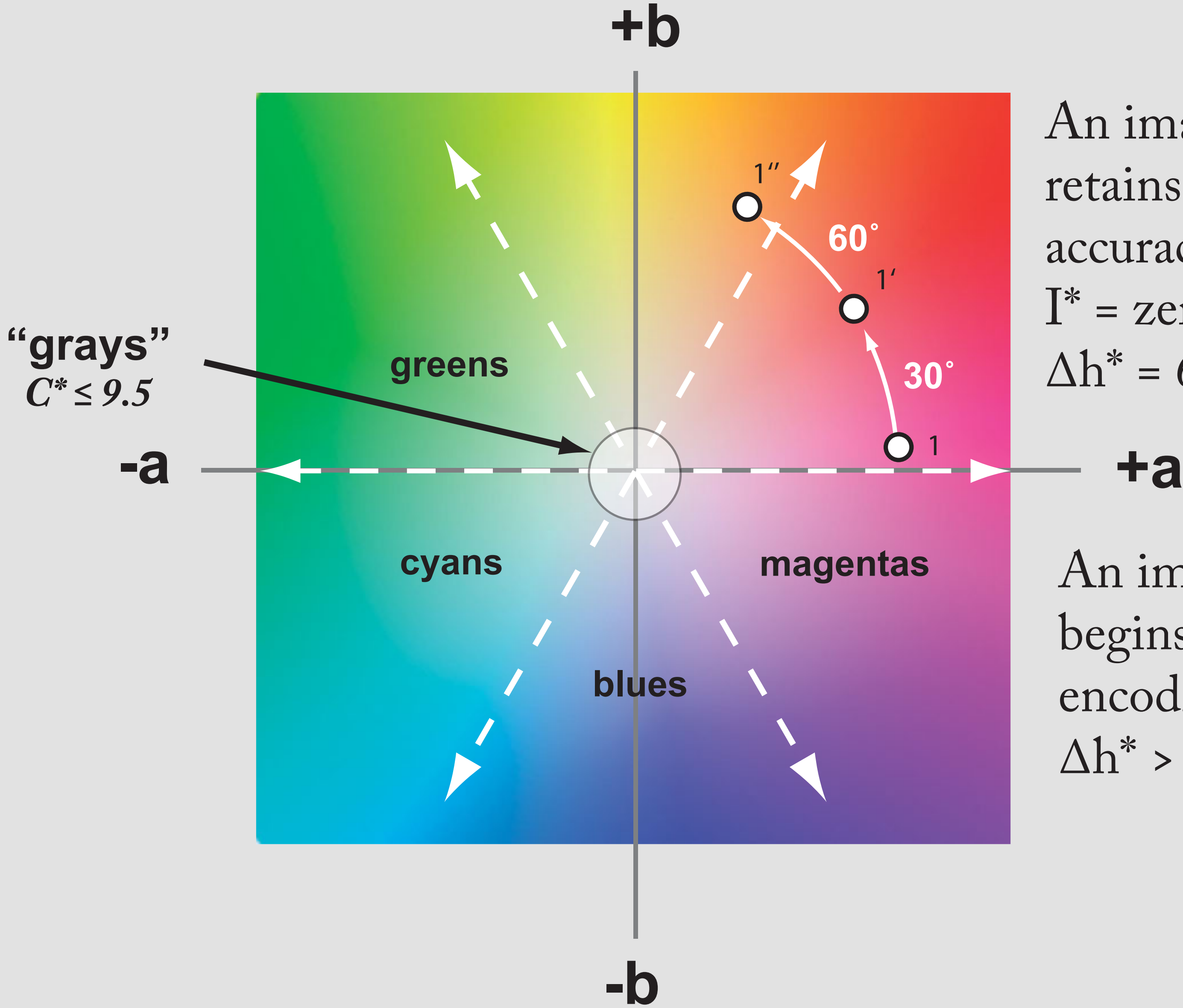
Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 8:13:09 PM

Slide # 7 –

Now we must consider hue. In the LCH color space of CIELAB math, hue is calculated as a ratio of a* and b* values. As a* and b* collapse to zero, chroma decreases, but another consequence is that the determination of hue angle becomes increasingly less accurate, and as we approach perfect gray the hue angle becomes undefined (i.e. division by zero). We must think in terms of retained color accuracy rather than just retained color. Some color scientists classify only four unique or primary hues; blue, green, red, and yellow, preferring to think of cyan as a mixture of blue and green and magenta as blue-red.

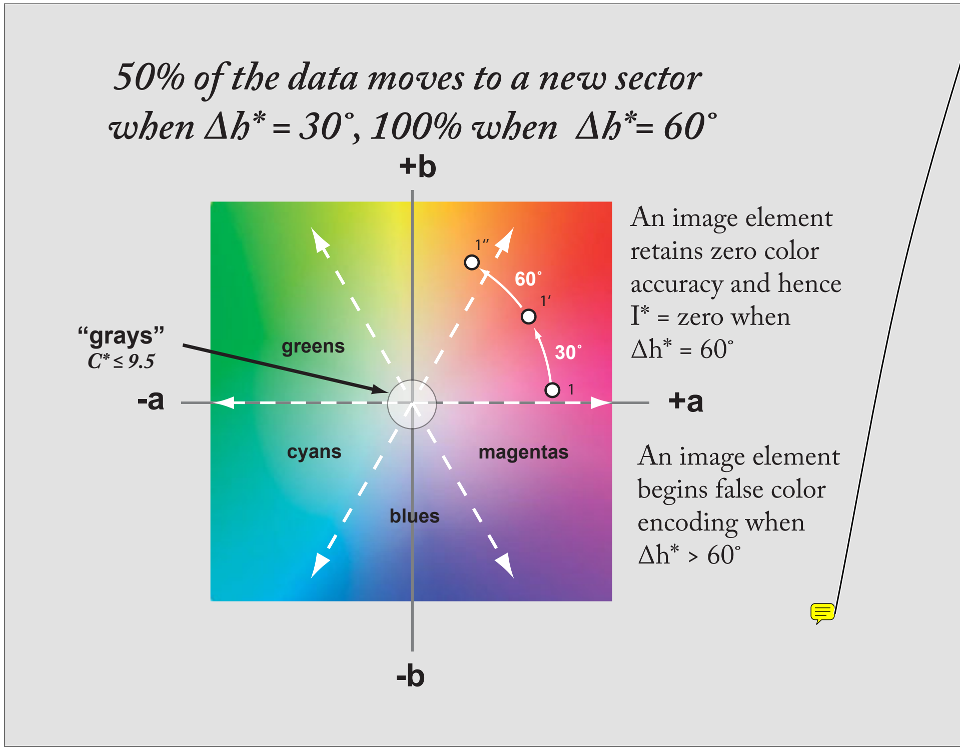
However, color photography is so fundamentally built on the principles of additive and subtractive color, that we choose to elevate cyan and magenta to equal status and then include a gray (i.e, near gray) sector to complete the mathematics. Thus, we define seven sectors of color as shown in this slide. These sectors categorize hue into seven zones, cyan, magenta, yellow, blue, green, red, and "gray". Defining the gray sector as colors with initial chroma equal to 9.5 or less was not entirely arbitrary. It was derived by considering the CIELAB concept of just noticeable differences for the standard human observer, then setting chroma large enough so that a standard observer can accurately identify the hue of a given color patch (with precision for colors differing by approximately 3 degrees in hue angle). Therefore in given sector other than gray, a standard observer will be able to observe hue shifts as little as 3 degrees with satisfactory repeatability. This structuring of the gray sector thus relates to the precision that will achieved when calculating I* color.

50% of the data moves to a new sector when $\Delta h^* = 30°$, 100% when $\Delta h^* = 60°$



An image element retains zero color accuracy and hence I^* = zero when $\Delta h^* = 60°$

An image element begins false color encoding when $\Delta h^* > 60°$



Slide #8

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 8:13:16 PM

Slide #8 –

Consider hue shifts for the scene colors 1, 1 prime, and 1 double prime. As an initial color element in a photograph shifts from 0 degree error, to 60 degree error the original hue accuracy is lost. For example, what was originally observed to be a red color element in the print now appears to be a yellow or magenta color element, depending on the direction of the shift. Thus color accuracy is totally lost as the shift reaches 60 degrees. We can use this information to rationally set retained image appearance for I* color as it relates to hue, and we can also conclude that hue shifts greater than 60 degrees give rise to false color encoding. If a picture element in a photograph is originally printed at one hue value and it shifts greater than 60 degrees over time, color accuracy is not merely lost. The picture element is now falsely colored. Thus, I* color can take on negative values.

Example of hue shift without chroma loss

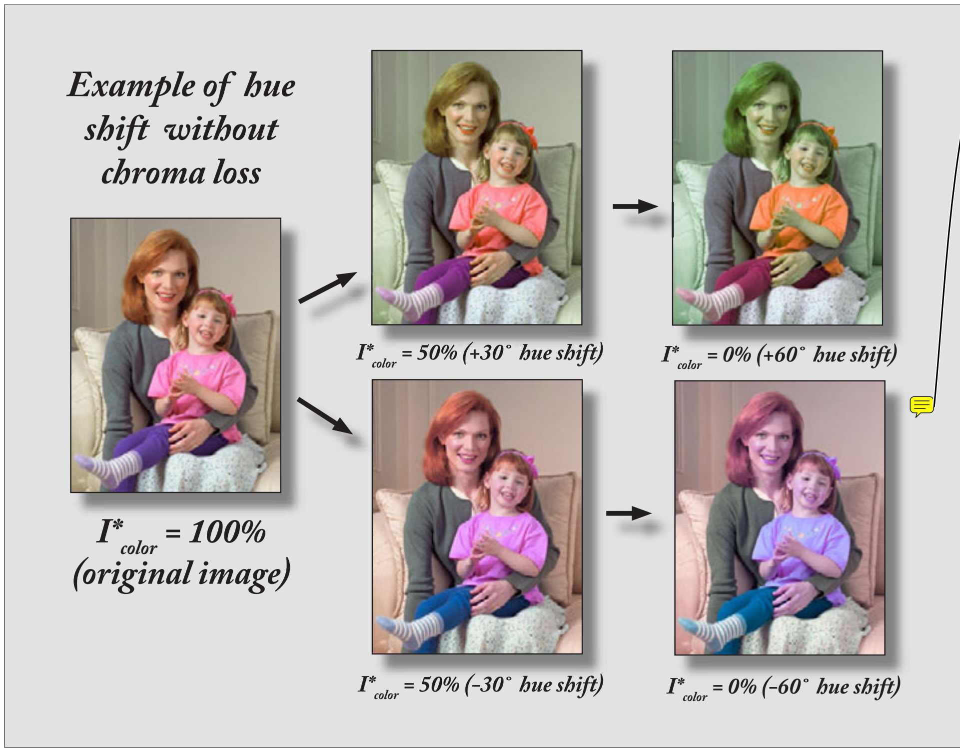
I^*_{color} = 100% (original image)

I^*_{color} = 50% (+30° hue shift)

I^*_{color} = 0% (+60° hue shift)

I^*_{color} = 50% (−30° hue shift)

I^*_{color} = 0% (−60° hue shift)



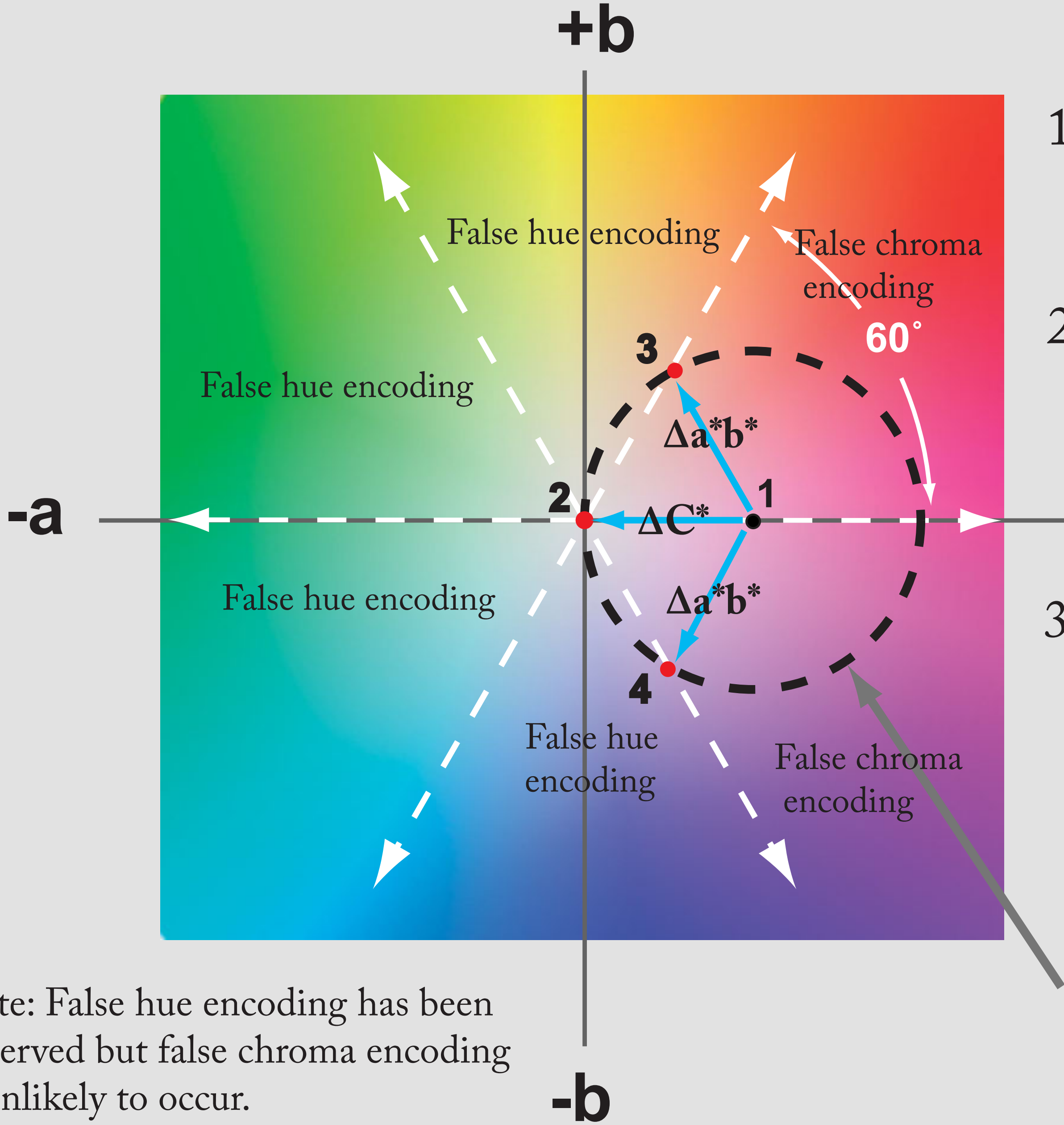
Slide #9

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 10:26:49 PM

Slide #9 –

This slide shows the simple case where all colors in the original scene shift by 30 degrees, and then by 60 degrees. The photograph still has color, but I* color is reduced to zero as the color accuracy diminishes.

The I^*_{color} = zero boundary



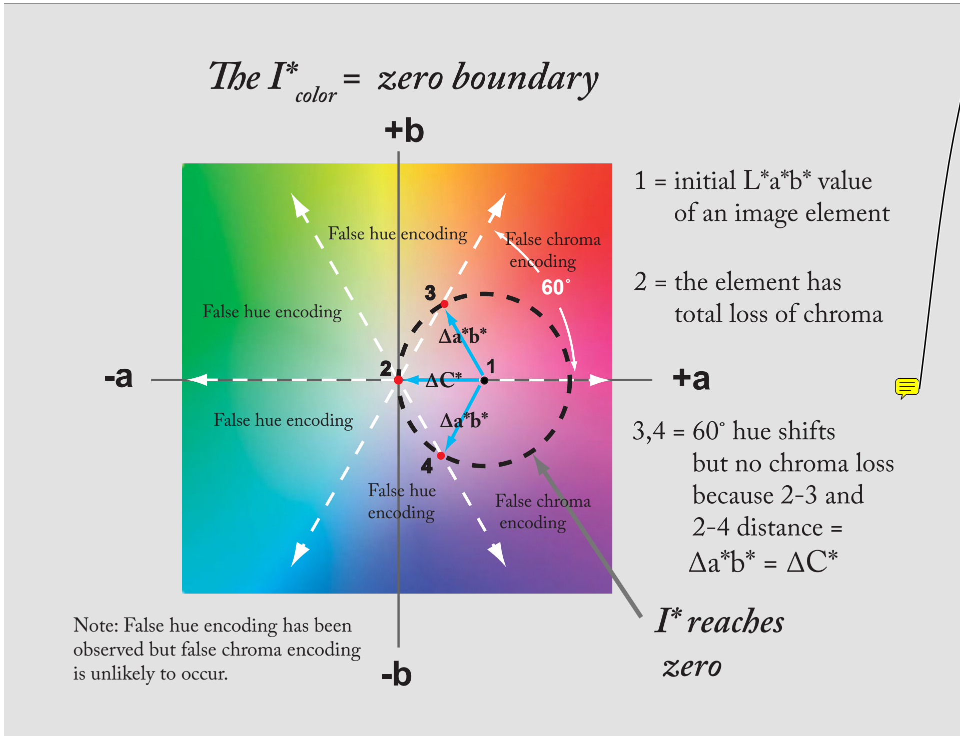
1 = initial L*a*b* value of an image element

2 = the element has total loss of chroma

3,4 = 60˚ hue shifts but no chroma loss because 2-3 and 2-4 distance = Δa*b* = ΔC*

I reaches zero*

Note: False hue encoding has been observed but false chroma encoding is unlikely to occur.



Slide #10

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/18/2004 3:43:24 PM

Slide #10 –

We can now combine the math to describe the relationship between the loss of chroma, and the loss of hue accuracy as it relates to I* color. The I* color = 0 boundary for a picture element with initial L*a*b* value at the point labeled "1" is plotted on an a*b* plot as shown in this figure.

I^*_{color} *Equations*

$$I^*_{color} = \frac{\sum_{1-n} \left[1 - \frac{(\Delta a^* b^*)_n}{(C^*_i)_n} \right]}{n}$$

for $(C^*_i)_n > 9.5$

where $(C^*_i)_n$ is the initial chroma value of the n^{th} sampled color patch

or

$$I^*_{color} = \frac{\sum_{1-n} \left[1 - \frac{(\Delta a^* b^*)_n}{9.5} \right]}{n}$$

for $(C^*_i)_n \leq 9.5$

I^*_{color} *Equations*

$$I^*_{color} = \frac{\sum_{1\text{-}n} \left[1 - \frac{(\Delta a^* b^*)_n}{(C^*_i)_n} \right]}{n} \quad \text{for } (C^*_i)_n > 9.5$$

where $(C^*_i)_n$ is the initial chroma value of the n^{th} sampled color patch

or

$$I^*_{color} = \frac{\sum_{1\text{-}n} \left[1 - \frac{(\Delta a^* b^*)_n}{9.5} \right]}{n} \quad \text{for } (C^*_i)_n \leq 9.5$$

Slide #11

Author: Mark McCormick-Goodhart
Subject: Note
Date: 5/2/2004 7:34:50 PM

Slide #11 –

We now derive the I* color metric that incorporates chroma changes, hue changes, and changes in gray sector picture elements. Note the seamless mathematical transition that occurs in the way a picture element is treated right at the boundary of the gray sector as the color moves into one of the other six hues. There is no discontinuity in the math calculation at this transition point, and this feature is a notable result of having defined a 60 degree hue angle shift as one pathway to reach an I* = 0 condition.

$I^*_{B\&W}$, the retention of lightness (L^*) channel information

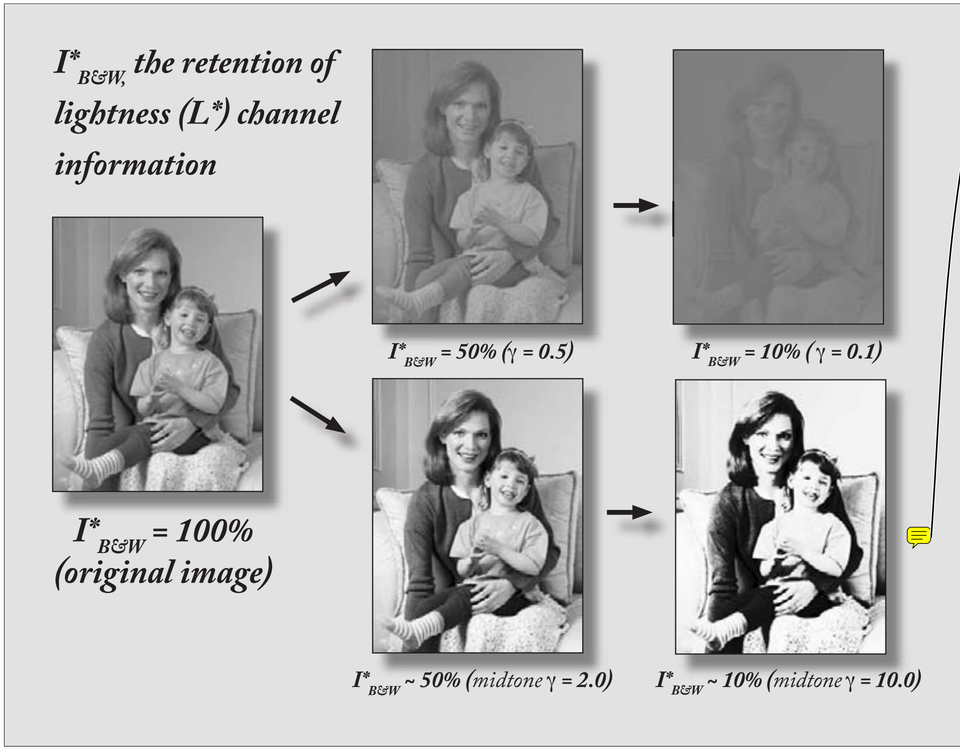
$I^*_{B\&W}$ = 100% (original image)

$I^*_{B\&W}$ = 50% (γ = 0.5)

$I^*_{B\&W}$ = 10% (γ = 0.1)

$I^*_{B\&W}$ ~ 50% (midtone γ = 2.0)

$I^*_{B\&W}$ ~ 10% (midtone γ = 10.0)



Slide #12

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 8:00:46 PM

Slide #12 –

The retention of the spatial information is a function of contrast. If contrast between all picture elements diminishes to zero there is no more image left. Thus, when a contrast function (traditionally denoted as gamma) goes to zero, I* B&W should also go to zero. Conversely, as gamma approaches infinity, a photographic image becomes a silhouette image or in digital terms, a 2 bit black-and-white image. Although the information content is not completely lost, for all practical purposes it is 99.9% lost, and we can again equate the condition with an I* B&W value of zero. What about a contrast inversion when the gamma function becomes negative the tonal relationship becomes inverted? If this situation were to occur as a photograph aged, then it can logically be defined as false luminance signal encoding in the same way that hue angle shifts greater than 60 degrees produce false color encoding.

$I^*_{B\&W}$ *Equations*

$$I^*_{B\&W} = \frac{\sum_{1-n} \gamma_n}{n}$$

for $-1 \le \gamma_n \le 1$

where $\gamma_n = \frac{(\Delta L_f)_n}{(\Delta L_i)_n}$

and $(\Delta L_i)_n$ is the initial lightness difference between the n^{th} pair or ordered combination of color patches at time $t = 0$ and $(\Delta L_f)_n$ is the final lightness difference at time, t.

or

$$I^*_{B\&W} = \frac{\sum_{1-n} \left[1/\gamma_n \right]}{n}$$

for $\gamma_n \ge 1, \gamma_n \le -1$

$I^*_{B\&W}$ Equations

$$I^*_{B\&W} = \frac{\sum_{1-n} \gamma_n}{n}$$

for $-1 \leq \gamma_n \leq 1$

where $\gamma_n = \frac{(\Delta L_f)_n}{(\Delta L_i)_n}$

and $(\Delta L_i)_n$ is the initial lightness difference between the n^{th} pair or ordered combination of color patches at time t = 0 and $(\Delta L_f)_n$ is the final lightness difference at time, t.

or

$$I^*_{B\&W} = \frac{\sum_{1-n} \left[1/\gamma_n \right]}{n}$$

for $\gamma_n \geq 1, \gamma_n \leq -1$

Slide #13

Author: Mark McCormick-Goodhart
Subject: Note
Date: 4/28/2004 5:08:59 PM

Slide # 13 –

Based on the preceding discussion about B&W information content, we propose this preliminary set of I* B&W equations. At this stage of our research on the I* concept, one aspect remains to be sorted out; how to best extract the gamma data from a pictorial print or test target. Clearly, it takes a minimum of two picture elements to derive a gamma value. If combinatorial analysis is used, one could derive a single number from all picture elements in the aged test target. However, we are inclined at this point to consider a near neighbor sampling method that averages the result over more than just two patches but allows us to extract a percentage value of picture element pairs or groups that exceed certain limits (e.g., become falsely encoded or less than a threshold value). Also, a threshold technique is needed to limit contrast calculations for conditions where initial or final delta L values are near or less than a just noticeable difference (JND). Work continues on this aspect of the I* metric.

Real world example of false color encoding. Hue shift > 60° due to catalytic fading of the magenta/yellow dye mixture.

Real world example of false color encoding. Hue shift > 60˚ due to catalytic fading of the magenta/yellow dye mixture.

Slide #14

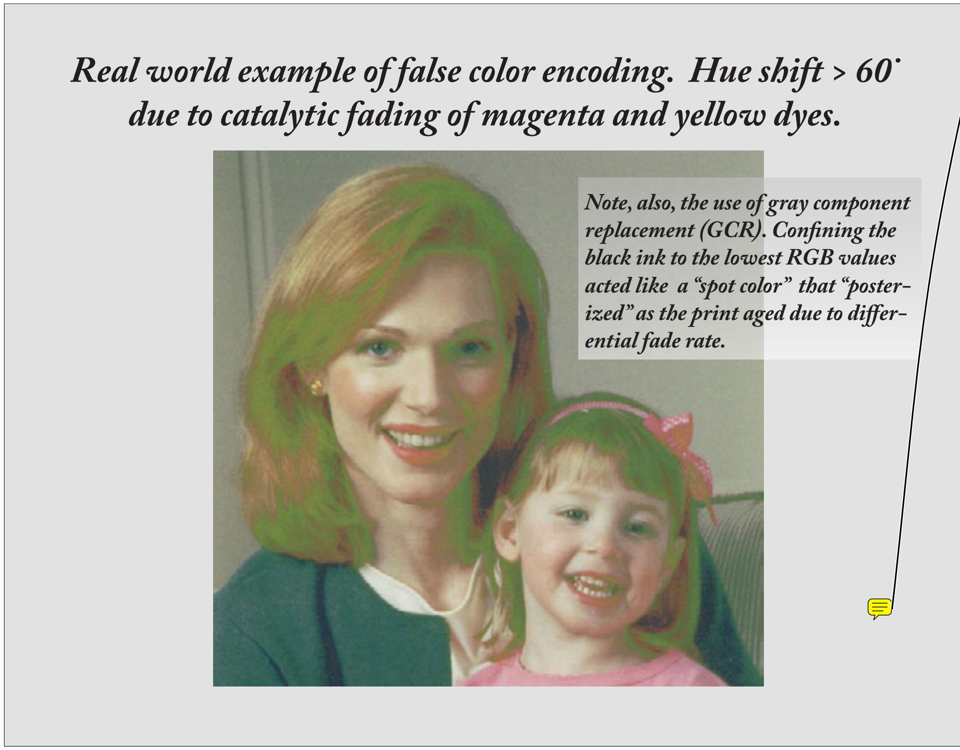
Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 8:14:06 PM

Slide # 14 –

The derivation of I* predicts that false encoding is to be expected when the changes occurring in a photograph exceed certain colorimetric limits. These limits are real, not imaginary. Thus, we should expect to see false encoding in real world examples. Indeed, we have seen these anomalies in image permanence tests that we conduct. It is especially noticeable in modern print systems that have novel ink formulations (e.g., 6 color or hexachrome sets) and inking methods that alter colorant levels (e.g. spot color black or GCR printing techniques). This slide shows a real example of an inkjet system where false encoding clearly has been reached. The test sample was light faded under accelerated aging conditions equivalent to 60 years of display at 450 lux for 12 hours per day.

Real world example of false color encoding. Hue shift > 60° due to catalytic fading of magenta and yellow dyes.

Note, also, the use of gray component replacement (GCR). Confining the black ink to the lowest RGB values acted like a "spot color" that "poster-ized" as the print aged due to differ-ential fade rate.



Slide #15

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 10:29:02 PM

Slide #15 –

This slide shows a more magnified view of the previous slide. Here we can also see locations in the print where the printing system swapped out black ink in place of the CMY colorants when the RGB data in the digital file approached 0,0,0. Thus the deepest shadows in the resultant prints made with this system include black ink that fades at a different rate compared to dark tones that are still comprised of c, m, and y colorants. Traditional chromogenic color photographs only contained three dyes. Each dye tended to fade linearly across the full tonal scale.

Preferential fading of one or more of the dyes tended to manifest itself as a broad color balance shift that the human brain could attempt to discount until it was very severe. Thus, an aged chromogenic photograph can have a disturbing color imbalance, but photographers tend not to interpret this phenomenon as decidedly false colors, merely a veiled color filtration that can be corrected by making a copy print of the faded original. Clearly, new digital output systems such as inkjet technology do not always exhibit uniform color balance shifts over time the way traditional silver-halide color photographs did. Thus, the visual appearance of the new media over time as the prints age can be far more confusing. This issue of false color encoding underscores the need for a more comprehensive test method, one that evaluates full tonal scale and color gamut behavior over time in an even-handed and impartial way in order to fairly rank the behavior of one system with respect to imaging systems using other technologies.

Another real world example of false color encoding. Differential fading caused by lower light-fastness of full concentration magenta ink in a six-ink photo system.

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Slide #16

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 10:29:47 PM

Slide #16 –

This is another real world example of false color encoding. The control print (i.e., not aged) is shown on the left side. In this example, the problem occurred on a six-ink color inkjet printer because the high concentration magenta ink was less stable than the low concentration magenta on the particular paper used to make this print. The problem is manifested in various hues at the blend points where the high concentration magenta began to displace the low concentration magenta ink in printer driver's output algorithm. Note, also, the color balance and tonal changes occurring in other parts of the print.

Close-up detail of false color encoding. Differential fading caused by lower light-fastness of full concentration magenta ink in a six-ink photo system.

Close-up detail of false color encoding. Differential fading caused by lower light-fastness of full concentration magenta ink in a six-ink photo system.

Slide #17

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/18/2004 3:45:24 PM

Slide #17 –

This slide is a close-up view of the aged print shown previously in slide #16.

Retained Image Appearance, I, can be applied to specific images as well as standardized test charts.*

Original Print

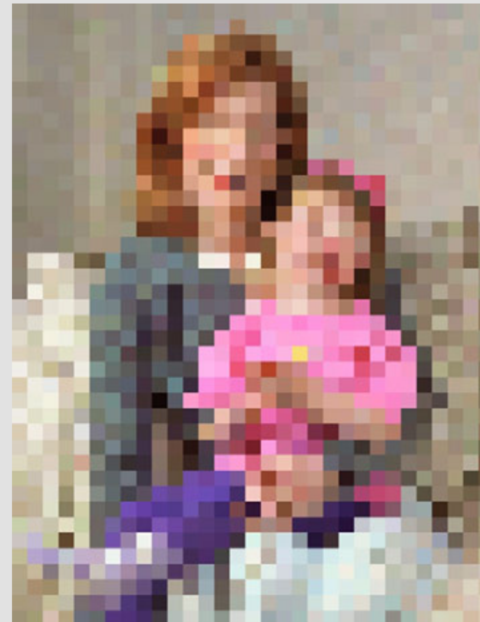
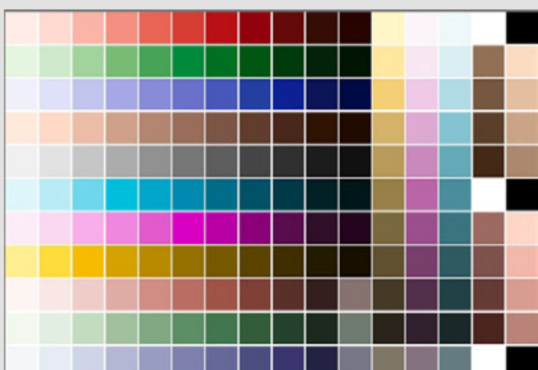
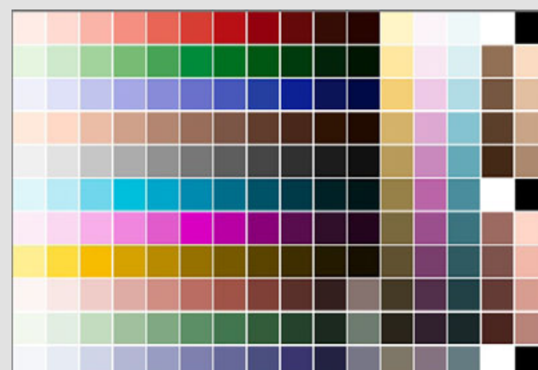


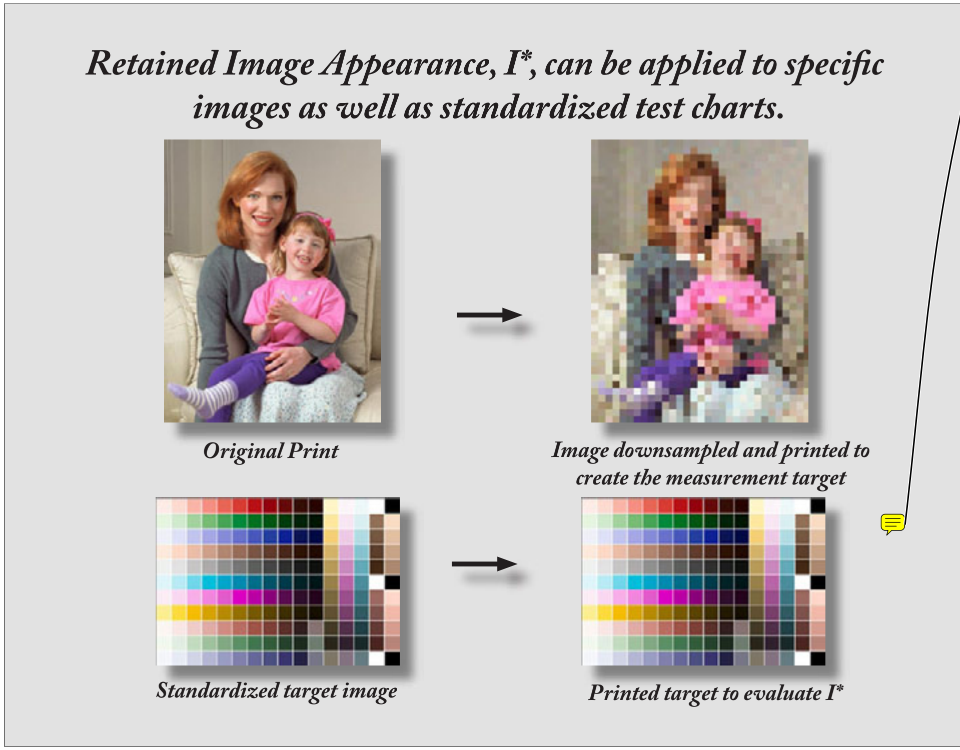
Image downsampled and printed to create the measurement target



Standardized target image



*Printed target to evaluate I**



Slide #18

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/18/2004 3:45:42 PM
Slide # 18 -

An interesting feature of the I* metric is that it can account for image dependence. There is a visual appearance interaction between the way a particular print process ages and the original information content in the photograph. The magnitude of color and tonal changes as well as the amount of physical area in the print that is affected by these changes both influence the observer response. This slide illustrates how the I* concept can be applied to specific images as well as standardized test targets typically used in image permanence testing. Calculating the I* values on an individualized pictorial print basis should bring about a higher correlation result when we undertake a psychometric study to determine the correlation of I* with the perceptual response of human observers. Using those results, we should then be able to design a better generic test target.

Print sample A

Print sample A, aged

Print sample B

Print sample B, aged

Consider, for example, a print process that is prone to staining and yellowing in highlights.

Image A would be more sensitive to this system behavior than image B. I analysis of the two prints would rank the I* value higher for image B.*

Print sample A

Print sample A, aged

Print sample B

Print sample B, aged

Consider, for example, a print process that is prone to staining and yellowing in highlights.

Image A would be more sensitive to this system behavior than image B. I analysis of the two prints would rank the I* value higher for image B.*

Slide #19

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/20/2004 8:12:27 PM

Slide #19 –

This slide is a specific example to show how the aging characteristics of a print process can either be emphasized or masked depending on the nature of the pictorial image. In this example, a print process that shows high yellowing and staining of the paper base as it ages is mostly masked by a dark scene that contains little important highlight detail. The problem is more easily observed in a scene that has important highlights, and thus the observer will more readily respond to the changes taking place.

Summary

The Retained Image Appearance function, I is based on objective measures of information content in a photographic print. These parameters are derived from the perceptually uniform psychophysical scaling features of the CIELAB colorspace.*

I^*_{color} *and* $I^*_{B\&W}$*, the color information and black and white information (L*) respectively, can be evaluated separately or combined into a comprehensive I* value by using a weighting factor.*

I deals with falsely encoded results which is necessary in order to fairly rank new digital output processes that may generate such picture artifacts over time.*

ΔE and other color difference equations, although useful metrics for print process variability, are inadequate to identify and separate the color content, brightness and contrast information of a photographic image.

I analysis can be applied to a standardized test target image or to a specific photographic image. The aging characteristics of an imaging material can become more or less noticeable over time depending upon the initial image appearance attributes of the photograph.*

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I analysis can be applied to a standardized test target image or to a specific photographic image. The aging characteristics of an imaging material can become more or less noticeable over time depending upon the initial image appearance attributes of the photograph.*

Slide #20

Author: Mark McCormick-Goodhart
Subject: Note
Date: 3/18/2004 3:46:08 PM

Slide # 20 –

We have summarized some of the important aspects of the I* concept in this slide. The presentation concludes. Our research continues…