

METHOD OF COLOR ACCENTUATION

BACKGROUND AND SUMMARY OF THE INVENTION

5 The present invention relates generally to color processing systems and more specifically to a color accentuation system and a component of a color processing system.

10 Color processing falls into two general categories, namely light projections or displays which are known as additive color systems and pigment or printing systems which are known as subtractive color systems. Color correction systems have been developed to correct for errors in the reader or scanner of the original material, signal transmission or limitations of the display or printing process. In the printing process, the correction can be directed to ink migration and physical color discontinuity. In an image or a video display, color correction can be for errors in the processing system and/or for changing the quality or color of the picture to meet certain criteria and/or tastes.

15 Examples of prior art systems include US Patents 4,674,963; 5,883,984; 6,053,609; 6,057,931 and 6,097,501.

25 In video and television, there are continuous developments of new formats. The present color accentuation system will help improve digital cameras, TV, video, and HDTV picture quality in both large and small formats. Digital still cameras and digital video cameras would have a button or command that triggers various levels of accentuation that would improve the picture quality. For example, one might take a picture on a dull, overcast day. When the accentuation button is pressed, the image will look like it was taken on a bright day.

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The present invention is directed to the concept of accentuating the ultimate color image to be more vivid, color diverse, interesting to the eye and having higher color contrast. The present invention would be compatible with almost any video or print media. This patent description translates well to the CMYK color space, which is the system generally associated with the printing industry. CMYK stands for Cyan, Magenta, Yellow, and Black. These colors are related to the primary colors, red, yellow and blue, with black being considered by this invention as the absence of color. TV's and video use the RGB (Red, Green, and Blue) color space. The color accentuation system described herein can be converted into any known or new color space or system, whether additive (light) or subtractive (ink , paint, etc.)

The primary colors are red, yellow, and blue, and combinations thereof. Rainbow colors are generally considered the vivid, bright colors and are either a primary color or two primary colors mixed at some ratio/percentage in a subtractive color space. In a subtractive primary color space or process, as the percentage of the lowest percentage third color component increases, the overall color becomes more dirty and eventually becomes shades of grays and/or browns. This directly relates to additive color processes and spaces through color space conversion.

An area in an image is a set of adjacent pixels in the image that have substantially the same color, in other words, substantially the same color component magnitudes. A practitioner of ordinary skill will recognize that the benefit of the invention can be attained by determining the accentuation

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function once for all the pixels in an area because the adjacent pixels have substantially the same color component magnitudes. Therefore, the invention can be applied to an image on a pixel by pixel basis (where the accentuation function is calculated and applied to each pixel individually) or on an area by area basis (where the function is calculated for an area of the image and the same function applied to each pixel in the area). The overall accentuation of the total image in this system is not color linear over the image.

The system determines the relative magnitude of each color component. It selects and adjusts the magnitude of one or more of the colors as a function of the determined relative magnitudes of each color component. The type and amount of the adjustment is a function of the relative magnitude differences. One or more of the magnitudes is adjusted to change the relative magnitudes. Typically, the difference in the subtractive color space is between the lowest and middle magnitude color. Also, typically, the lowest primary color component is reduced. In CMY(K), no adjustment is made if only two colors are present in the area or pixel being investigated. Black (K) is not considered a color in the initial accentuation step.

Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a color processing system in which the present invention can be incorporated.

Figure 2 is a subtractive space color wheel.

5 Figure 3 is a single slice color wheel for RYB from color pipe of Figure 6 with scaling functions.

Figure 4 is a look up table in CMYK correlating the original to the accentuated color.

10 Figure 5 is a conversion table showing the relationship of the color system of Figure 4 to a second color system.

Figure 6 is a conceptual view of the color pipe.

15 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The core of this invention is developed from and for subtractive primary colors. However, the system functions in both additive and subtractive color spaces through mathematical color-space transforms.

20 The present invention can be used in two modes. In a first mode, an image that is encoded using any color space since the component colors can be converted to a primary color space and the accentuation function applied in the primary color space. The resulting image can be converted back to
25 the original color space. Alternatively in a second mode, the accentuation function can be determined in a primary color space and then the accentuation function is transformed to any other color space so
30 that an image need not be converted--the transformed function is applied to the image in the color space of the image.

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By this means, a practitioner of ordinary skill will recognize that either mode is theoretically equivalent, but the latter is preferred so that data loss by transforming the image in and out of a primary color space (due to numerical rounding and the like) is avoided. Although the invention can be equivalently used in any color space, the use of the color black in some color space schemes requires special attention

10 RYB is the ideal color space and will be used to explain the concept of the invention with, CMY(K) used to explain an implementation of the invention.

 The present system looks at the relative differences between the colors and makes the correction based on a function. In CMYK, K, the black, is not adjusted in the initial function. But black still must be part of the color percentage, so that the CMYK to RGB conversion is accurate. When all three colors CMY(K) are substantially equal in color, they are "dirty" in color. As the differences in percentage between the colors becomes larger, the higher percentage primary colors become more dominant. The lowest magnitude value color of the three colors creates, in the combination the other two colors, a pastel dirtiness, grayness, brown-ness or a perceived lack of contrast, vividness or perceived sharpness. The present invention creates a higher color contrast, sharper, clearer picture or color and reduces the effect of the lower of the three colors, pixel by pixel or area by area. Note that the accentuation

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adjustment may be to one or more of the three colors.

Although transformations exist between most color spaces, they are not always perfect, and some loss of color information can take place when converting to and from color spaces.

CMYK is used as the subtractive color space for this system because the colors are close to primary, and because it is a commonly used subtractive color space. However, because the magenta in the CMYK color space has a blue component, operations on magenta affect two colors (red and blue), not one (red). The preferred color space for this system would be a new primary color space consisting of the primaries CRY(K) or a color space RYB(K). Since these are not presently available in subtractive system, the invention will be explained also with respect to CMYK and RGB. The RGB and CMYK color spaces have known direct mathematical relationships to each other.

A pixel containing the collection of values for individual color components can be analyzed in percentage magnitudes for C, M, Y, and K. Normally, this is done in RGB. The value of the minimum-value color component in a subtractive color space based on one of the following equations:

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$$(a) \quad \%MIN_{New} = [100\% - (\%MID - \%MIN)] * \%MIN$$

where:

MIN is the color component in a pixel or area that has the minimum percentage value;

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MID is the color component in a pixel or area

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that has the middle percentage value,

MAX is the color component in a pixel or area
that has the maximum percentage value, and

MIN_{New} is the accentuated minimum percentage
5 value color component;
or

$$(b) \quad \%MIN_{New} = [100\% - (\%MID - \%MIN) * f(CC)] * \%MIN$$

where f(CC) is a modifying or scaling function.

The modifying or scaling function f(CC) may be
10 zero if the difference between MID and MIN is very
small. The modifying function f(CC) may also
increase, decrease or change the adjustment
signified by the difference as a function of any of
the color components present or the specific
15 percentage relationship of the color components.

Instead of decreasing the minimum color
component MIN, the maximum color component MAX may
be increased. Also, both MIN may be decreased and
MAX increased. The middle color component MID may
20 also be adjusted. All adjustments are a function of
the difference MID - MIN as reflected by the
following formulas:

- (d) $\%MAX_{new} = MAX * f_{max} (MID-MIN)$
25 (e) $\%MID_{new} = MID * f_{mid} (MID-MIN)$
(f) $\%MIN_{new} = MIN * f_{min} (MID-MIN)$

The function or equivalents modifies one or
more of the component color values based on the
difference between the two lowest percentage color
30 component values. This can be converted to any other

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color space using conversions.

In order to maintain brightness close to the pre-processed image, an additional adjustment to all color components then takes place, dependent upon the initial amount adjustment that occurs. All components can be modified once the function has been calculated in order to maintain the original brightness or modify brightness.

In general, scaling functions of any type, including non-linear functions, may apply based on any combination of the color component values. Some circumstances may require that more or less scaling occur, for example, as discussed with respect to equation (b). This applies also to equations (d)-(f).

Accentuation may be equivalently performed based on lookup tables. The new color component values are determined by matching the original color component values to those in the table and reading the new color component values out of the table for that color component set.

Other rules and functions can apply such that some tones and other muddy, dull or low intensity colors would not be changed. The goal for color accentuation can be changed through scaling functions to, for example, to maintain a particular colors' dullness and make some chosen colors brighter or more intense or to literally change some colors by increasing or decreasing one primary color more than another. As was discussed with respect to

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equations (b)-(f).

Figure 1 illustrates a color processing system 20 for reproducing a color image 10, as image 12, on a media 14. If this is a printing process, then
5 media 14 is the object on which the printing is performed. If it's a display like a television or CRT, then media 14 is a display. The color processing system 20 generally includes a lens 22 providing input signals of the image 12 to a color
10 separator 24. The color separator 24 provides a minimum of three color and in this example, four color signals to the signal processor 26. The signal processor 26 then provides appropriate drive signals to projectors or printers 28, depending upon
15 whether it is a printer or a light projector.

Four projectors/printers are shown but other projector or printers may be used depending upon the number of colors being processed. For example, it could be a three color additive system, a four color
20 separation system, or a six color system.

The color processing system 20 can be thought of as a combination of components to process the color signal. For example, The lens 22 would introduce a color image to a color encoding system
25 24 that color separates a pixel into color components for a given color space. The encoded image information is presented to a signal processor 26 that applies scaling functions that affect the color accentuation and also applies color space
30 transformations. Upon completion of the signal

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processing, the image information is transferred to the projector/printer 28 to recombine color components through either a light projection, ink printing system, or other recombinant method to form the processed image 12.

The color accentuation of the present method would be in the signal processor 26 and may be part of the original camera or scanner and/or may be in the signal processor 26 for the projector or printer. The signal processor 26 may include well-known signal correction software modified to incorporate the present invention.

The present method will be described with respect to a four-color separation system, for example, CMYK with the principles applicable to other color separations including the color formats LCH, HLS, YUV, HSV, HLS and CIE-LUV. Some of these systems deal with different forms of hue (H), saturation (S), luminance or lightness (L, Y), and chrominance [©] or the difference of a three-component color system (U, V). Saturation is the degree of color intensity. Hue is also known as the name of the color and luminance is the degree of light/dark of the color.

In Figure 2, note that any color on the outside of the wheel is vivid and/or pure. Any color on the outside of the wheel is either one primary color or combinations of two primary colors, as in a rainbow. If any amount of a third primary color is added to the outside of the wheel, the color starts becoming

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dirty, less vivid, and moves into the interior of the wheel. As it approaches the center, it becomes dirty gray or brown, depending on its component colors. Eventually, as the color component percentages become large and near equal, the color becomes dirty gray which is the center of the wheel.

The Figure 3 wheel is the 100% slice through a solid color cylinder ("color pipe"), the surface of which contains the three primary colors Red, Yellow, Blue, equally spaced along the circumference. The slice of the color cylinder ranges in intensity from 0% at one end of the cylinder to 100% at the other end. Figure 6 shows a conceptual view of the color pipe.

The percentage shown on the color pipe signifies the maximum value of any of the three primary colors. Thus, if Red is the maximum color at 80%, the color wheel would be the 80% wheel of the color pipe.

The representations of the pipe and the wheel are to illustrate the principles fundamental to this invention. To be on the outside of the color wheel, one color may be at 100% for a 100% slice of Figure 3, a second color may be at any percentage, but the third color must be at 0%. Any multi-component color which contains more than two of the primaries Red, Yellow, Blue must be inside the "color pipe", and not on the surface. The colors within the circle appear dirty, having tones of brown and gray

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A scaling function S_1 is shown which increases between the center and the outside of the wheel. This function increasingly reduces the contribution of the minimum third color as that third color gets closer to the outside of the wheel. A set of scaling function adjustments S_2 , S_3 and S_4 are also shown. They illustrate that the scaling function varies as the color moves from dirty, for example, toward pure. S_2 shows adjustment for an original color close to a pure color. S_3 and S_4 show additional smaller adjustments.

The arrows show adjusting the value of any color component using a scaling function that modifies the total color component values so that the total color moves towards the outside vivid portion of the circle. The scaling function is based on differences between color component values. The length of the arrow represents the relative adjustment for one example scaling function. The amount of accentuation relates directly to the arrow length for that pixel accentuation. The closer a color is to the outside of the wheel, the more it is accentuated towards a vivid pure color on the outside of the wheel.

S_1 , S_2 , S_3 and S_4 are shown as radii since the adjustment is of only one color component. If changes are made to more than one color component, the result may not be a radii as shown by S_5 , depending on the function. This example scaling function S_5 shows a curved adjustment favoring one of

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the primary colors. The scaling function can change in any dimension in the color pipe. A scaling function may also be used which moves circumferentially and changes the color or hue.

5 This would result by changing two of the three colors. The color pipe and wheel also have a fourth dimension of white/black (not shown). The fourth dimension adds amounts of white or black to lighten or darken/dull any color on the pipe/wheel by
10 degrees of colorless gray (black into white). The pipe/wheel dimensions are red, yellow, blue, and black.

In the example illustrated in Figure 4 for the CMYK color system, the original value is shown in
15 one column as a percentage of saturation for each of the component colors. Black or K has not been shown for sake of clarity since it is not used to determine the adjustment nor is it adjusted. During the next phase in Figure 4, for example, the
20 accentuated/adjusted numbers are shown in the third column and the last column shows the percentage of accentuation. In this example, the difference between the middle and lowest color magnitude is taken and this difference is the accentuation
25 percentage factor.

For example, with a simple % scaling function for color 0001 having C=90, M=10, Y=10, the difference between M and Y is zero and therefore there is zero percent adjustment to the lowest

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color. Alternatively, since both M and Y dirty C, both M and Y may be reduced the same amount.

For the color 0002 having C=90, M=20, Y=10, the difference between M and Y is 10 so the third color
5 Y is reduced by 10% from 10 to nine. For the color 0306, C=50, M=20, Y=80 become C=50, M=14, Y=80. The difference between C and M is 30 and therefore there is a 30% reduction in the lowest percentage color M. For the color 0065, the percentages are C=90, M=70,
10 Y=27. The difference between M, the middle color, and Y, the lowest color, is 43, so Y now becomes 14. Thus, the "dirtiness" of this color has reduced by approximately half using this function. This system method can be converted to any other color system by
15 known conversions as shown in Figure 5.

In the present system, no specific color is adjusted, but the lowest of three colors is the one that is adjusted downward in magnitude. This system works in such a way that grays, browns and pastels
20 do not change or change little. When the color is gray-brown, for example, 70% for cyan, magenta and yellow, there is no accentuation because there are not differences between the minimum color percentages.

25 Although the example is shown as reducing the percentage of the lowest color, the other color components may also be adjusted. For example, the highest may be increased by itself or in combination with lowering the lowest. Also, the middle color

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can be raised. All of these reduce the effect or contribution of the third or lowest color.

As previously mentioned, there are certain combinations which could or could not be changed.

5 For example, color 250, Y=60 and M=55 differ by only five percent. This color would not become substantially more intense or vivid by lowering 55 by the five percent using the methods. Thus, this color could remain in its present state by changing
10 the scaling function.

Also, depending upon the order of the percentage of the color or other color component information, the scaling function may be a modification of the numerical difference of the
15 middle and lowest percentage of color components, as discussed with respect to equations (b)-(f). The primary colors has different degrees of dirtiness. Blue contributes more dirtiness than red which contributes more than yellow for example. Thus if
20 blue is the lowest percentage color component it will be reduced more that if red or yellow was the lowest percentage color component.

Figure 5 shows the translation of the color accentuation of the CMYK color system of Figure 4 to
25 the RGB color system. This translation was performed using Adobe Photoshop, although any know translation can be used. A review of Figure 5 shows an increase in the relative magnitude between the highest and lowest magnitude color in both color
30 systems. Although a conversion of the corrected

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CMYK to RGB is illustrated, the present method could be used on the RGB system using different conversion functions or converting the accentuation function and performing the color modification in RGB. The
5 same is true for other color spaces.

The present system is considered a color accentuation system, not a color correction system, although it is expected that this process can become a new kind of color correction. Color correction
10 implies that the to be printed or displayed color is corrected to be identical to the original image.

The present method or system has used the amplitude of the color components as the parameter to be measured and adjusted. Other parameters of the
15 system may be used for the relative measures and adjustment. They could include any of color, hue, saturation, luminance, chrominance, focus or any other video control.

Although the present invention has been
20 described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only, and is not to be taken by way of limitation. The spirit and scope of the present invention are to be limited only by the
25 terms of the appended.

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WHAT IS CLAIMED:

1. A method of color accentuation in a color processing system comprising:

determining the relative magnitude of each primary color component of a color separation;

determining the difference of the magnitude of a middle primary color component to a lowest primary color component; and

selecting and adjusting the magnitude of one or more of the color components as a function of the determined difference of the middle primary color component to the lowest primary color component.

2. A method according to claim 1, wherein the adjustment is proportional to the relative magnitude of the difference.

3. A method according to claim 1, wherein the magnitude of the color component is adjusted only if the magnitude difference is above a predetermined value.

4. A method according to claim 1, wherein the color of the lowest primary color component is used for the selecting and adjusting.

5. A method according to claim 1, wherein the magnitude is adjusted to increase the relative magnitude between the highest and lowest magnitude color component.

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6. A method according to claim 1, wherein the color components are translated from a first color space into a primary color space before the determining steps and translated back to the first color space from the primary color space after the adjusting step.

7. A method according to claim 1, including transforming the determining steps and the selecting step from the primary color space to a first color space; and performing the adjusting step in the first color space.

8. A method according to claim 1, wherein the process is performed on a pixel basis.

9. A method according to claim 1, wherein the process is preferred on an area basis.

10. A method according to claim 1, the process is performed on a signal processor.

11. A color processing system for receiving input signal for an image to be displayed in color, the system including a signal processor and wherein the signal processor:

receives or derives color separation from the input signals;

determines the relative magnitude of each color of the color separation;

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determines the difference of the magnitude of a middle primary color component to a lowest primary color component; and

selects and adjusts the magnitude of one or more of the color components as a function of the determined difference of the middle primary color component to the lowest primary color component.

12. A system according to claim 11, wherein the adjustment is proportional to the relative magnitude difference.

13. A system according to claim 11, wherein the magnitude of the colors is adjusted only if the magnitude difference is above a predetermined value.

14. A system according to claim 11, wherein the color of the lowest primary color component is used for the selecting and adjusting.

15. A system according to claim 11, wherein the magnitude is adjusted to increase the relative magnitude between the highest and lowest magnitude color.

16. A system according to claim 11, wherein the processor translates the color components from a first color space into a primary color space before the determining and translated back to the first color space from the primary color space after the adjustment.

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17. A system according to claim 11, including transforming the determining steps and the selecting step from the primary color space to a first color space; and performing the adjusting step in the first color space.

18. A system according to claim 11, wherein the processor operates on a pixel basis.

19. A system according to claim 11, wherein the processor operates on an area basis.

20. A system according to claim 11, wherein the color processing system is one of a camera, video recorder, optical scanner and printer.

21. A system according to claim 11, wherein the color processing system is one of an image display, a video display and a printer.

22. A method of color accentuation of a color image made up of areas, encoded in a color space, the method comprising:

detecting in each area the magnitude of each color component of the color space; and

changing the magnitude of color components in each area in accordance with a pre-determined scaling function, based on the relative differences of the color components in a primary color

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subtractive color space, applied to the detected color components.