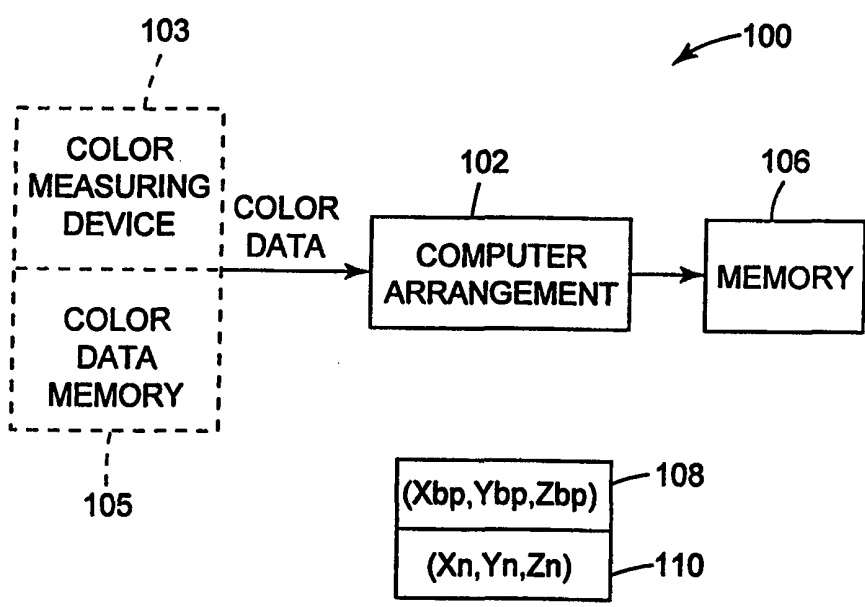




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification ⁶ : G01J 3/46, H04N 1/60</p>	<p>A1</p>	<p>(11) International Publication Number: WO 99/00648 (43) International Publication Date: 7 January 1999 (07.01.99)</p>
<p>(21) International Application Number: PCT/US98/09764 (22) International Filing Date: 13 May 1998 (13.05.98) (30) Priority Data: 08/884,411 27 June 1997 (27.06.97) US (71) Applicant: MINNESOTA MINING AND MANUFACTURING COMPANY [US/US]; 3M Center, P.O. Box 33427, Saint Paul, MN 55133-3427 (US). (72) Inventors: EDGE, Christopher, J.; P.O. Box 33427, Saint Paul, MN 55133-3427 (US). FISCHER, Timothy, A.; P.O. Box 33427, Saint Paul, MN 55133-3427 (US). (74) Agents: HORNICKEL, John, H.; Minnesota Mining and Manufacturing Company, Office of Intellectual Property Counsel, P.O. Box 33427, Saint Paul, MN 55133-3427 (US) et al.</p>	<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>With international search report.</i></p>	

(54) Title: CHARACTERIZATION OF COLOR IMAGING SYSTEMS



(57) Abstract

Characterizing a color imaging system involves generating color values representing colors of output samples of the color imaging system. The color values are converted into a device-independent color coordinate system using an adjustable white reference vector and a black reference vector. The white reference vector is calculated using the black reference vector. Color values can be transformed between color imaging systems using the device-independent color coordinate system.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

CHARACTERIZATION OF COLOR IMAGING SYSTEMS

Field of the Invention

The present invention relates to color imaging systems. More particularly, the present invention relates to characterizing color imaging systems to account for perceptual effects.

Background of the Invention

Color reproduction processes typically involve using color imaging systems to produce colors on various media. These color imaging systems may be used to duplicate a color image from one medium to another medium, *e.g.*, from one printed copy to another or from a display screen to a printed copy. Color reproduction processes are used in various application environments, for example, color proofing applications. In color reproduction processes, rendering colors similarly across different media is desirable. To reproduce colors accurately, many processes use color coordinate systems known as color spaces to characterize the color output of color imaging systems. One commonly-used color space is Commission Internationale de l' Eclairage (CIE) $L^*a^*b^*$ space.

Color spaces can also be used to characterize the color output of one color imaging system relative to other color imaging systems. Characterizing a color imaging system typically involves calculating a color response function for the color imaging system using the coordinates of the color space, *e.g.*, the L^* , a^* , and b^* coordinates of the CIE $L^*a^*b^*$ space.

Color characterization systems often attempt to account for psychophysical and other effects on human color perception. If inadequately addressed, these effects potentially introduce non-uniformities in color characterization across color imaging systems. These non-uniformities may result in differences in color appearance between different color imaging systems and decrease the accuracy of color characterization.

One psychophysical effect on human color perception, known as adaptation, involves the effect of surrounding colors on the subjective appearance of a color. For example, colors appear darker when viewed against relatively light

backgrounds. Conversely, dark backgrounds cause colors to appear lighter than they actually are.

Many color imaging systems are used in connection with displaying colors against a nominally white background or white reference, such as paper or other media. Different color imaging systems may involve producing colors on media having different white references. The human eye perceives the different white references as white and other colors produced on the media relative to the respective white references. As a result, a single objective color is subjectively perceived differently against different backgrounds.

Some color characterization systems attempt to compensate for differences in white references by using transformations to modify tristimulus values based on the white reference. While such systems are effective in characterizing relative color within a single color imaging system, given a particular imaging medium and a particular set of viewing conditions such as illumination and viewing angle, many of these systems produce less accurate results when transforming colors between different color imaging systems. One problem inadequately considered by many color characterization systems is the effect of variations in white reference for different color imaging systems due to differences in the imaging substrate or display white point. For example, some color characterization systems that use the CIE $L^*a^*b^*$ color space produce non-uniformities in matching color proofing systems having different imaging substrate white reference. In particular, some such color characterization systems have been observed to produce severe non-uniformities when mapping from a substantially white imaging base to a somewhat blue-shifted imaging base.

Other color characterization systems using different color spaces have been observed to produce uniform mapping in light shades of colors, but less uniform mapping in more intense colors. As a result, after a transformation function has been generated to match color values between two color imaging systems, a human operator typically engages in significant empirical adjustment to obtain an acceptable visual match. This empirical adjustment is potentially labor-intensive and time-consuming.

Another psychophysical perceptual effect is known as black point adaptation. This phenomenon involves the perception of a near-black color as black despite the presence of stray light that imparts non-zero tristimulus values to the near-black color. This effect is particularly noticeable when a color
5 characterization system attempts to characterize perceived colors on a computer monitor, where near-black colors appear black despite significant stray light that devices measure as having tristimulus values significantly higher than zero.

Other color imaging systems are also susceptible to perceptual effects attributable to black point adaptation. For example, using certain color
10 characterization systems to simulate newspaper colors on opaque paper results in reproduced colors that appear washed out. This result is attributable to the significant non-zero tristimulus values for the darkest color or black reference formed on newsprint. These non-zero tristimulus values are partially attributable to stray light scattered from the coarse fibers and partially attributable to
15 inadequate ink coverage of the newsprint. Many conventional color characterization systems fail to adequately compensate for black point adaptation.

Summary of the Invention

According to one embodiment, the present invention is directed to a method for characterizing a color imaging system. The method includes obtaining
20 first color values in a color coordinate system using output samples of the color imaging system. The first color values represent the colors of the output samples and are converted into second color values in a device-independent color coordinate system using first reference values, *e.g.*, a white reference vector, and second reference values, *e.g.*, a black reference vector. The first reference values
25 are adjusted using the first color values. Another embodiments are directed to an arrangement and a data storage medium for performing this method.

According to another embodiment of the present invention, a color characterization method includes obtaining first color values in a color coordinate system. The first color values represent colors of output samples of the color
30 imaging system and are converted into second color values in a device-independent color coordinate system. First and second reference values are used in the

conversion process. The first reference values are calculated using the second reference values, which are calculated as a function of a medium. The first reference values are adjusted using the first color values.

5 According to a system embodiment of the present invention, color characterization is effected using a computer arrangement. The computer arrangement is configured and arranged to receive first color values in a color coordinate system. The first color values represent colors of output samples. A memory is responsive to the computer arrangement and is configured and arranged to store second color values in a device-independent color coordinate system. The
10 computer arrangement is further configured and arranged to convert the first color values into the second color values using first and second reference values, the first reference values being adjusted using the second reference values.

Another aspect of the present invention is directed to a color transformation method for performing a color transformation between first and
15 second color imaging systems. The color transformation method includes obtaining first and color values respectively representing colors of output samples of the first and second color imaging systems. The first and second color values are respectively converted into third and fourth color values using a device-independent color coordinate system. First reference values are calculated from a
20 medium, and second reference values are calculated from the first reference values. The second reference values are adjusted using the first and second color values. Color transformation values are generated using the third and fourth color values. The method may be performed by a color transformation arrangement.

Brief Description of the Drawings

25 FIG. 1 is a block diagram illustrating a color characterization arrangement, according to one embodiment of the present invention;

FIG. 2 is a flow chart illustrating an example color characterization method, according to one embodiment of the present invention; and

30 FIG. 3 is a flow chart illustrating a color transformation method, according to another embodiment of the present invention.

Detailed Description of the Various Embodiments

The present invention is believed to be applicable to a variety of systems that characterize color imaging systems. The present invention has been found to be particularly advantageous for characterizing color imaging systems susceptible to certain perceptual effects and for transforming colors between color imaging systems. An appreciation of the invention is best gained through a discussion of these particular application examples.

According to one aspect of the present invention, a color characterization technique may be applied to a variety of color imaging systems to generate a characterization or profile of a color imaging system. The characterization may be used, for example, to analyze a single color imaging system or to transform the color response of one color imaging system to match the color response of another color imaging system. The color characterization technique uses a device-independent color space that includes reference vectors to compensate for perceptual effects attributable to, for example, the psychophysical response of a human viewer. These perceptual effects depend on, for example, lighting, background coloration, viewing angle, and/or other variables. By compensating for these effects, the technique accurately characterizes color imaging systems and improves the accuracy of mapping between color imaging systems.

FIG. 1 illustrates an example system 100 according to the present invention configured to characterize a color imaging system. The system 100 includes an appropriately-programmed computer arrangement 102. The computer arrangement 102 may be implemented using any of a variety of conventional resources, for example, a personal computer and CD-ROM based software. Other computer-based designs may be used as well. For example, the computer arrangement 102 may be implemented using a microprocessor that accesses a read-only memory (ROM) into which a software application program is loaded. The software application program may be incorporated, for example, in a color-management software package, such as that provided by the Imation's Rainbow™ color proofing system, commercially available from Imation Corp., of Oakdale,

Minnesota. Alternatively, the computer arrangement 102 may be incorporated as part of an intelligent printer. In such a configuration, the software application program is loaded, for example, into a printer memory.

5 The computer arrangement 102 obtains color data 104 that represents colors of output samples of a color imaging system to be characterized. The color imaging system may be, for example, a color printing system, a color display system, or a color projection system. It should be understood, however, that the color characterization technique may be applied to other types of color imaging systems according to the present invention. The color data 104 may be
10 obtained, for example, directly from a color imaging system via a color measuring device 103 such as a colorimeter or a spectrophotometer, or by accessing a color data file stored in a color data memory 105. The dashed lines around the color measuring device 103 and the color data memory 105 of FIG. 1 indicate that either or both can provide the color data 104. For example, a colorimeter may be
15 configured to measure color values for test patches formed on paper to characterize a color printing system.

The color measuring device 103 may comprise, for example, a color measurement system such as a Gretag™ SPM 50 color measurement device, commercially available from Gretag, Inc., of Regensdorf, Switzerland, or a
20 densitometer such as an X-Rite color densitometer, commercially available from X-Rite, of Grandville, Michigan. Alternatively, to characterize color display or projection systems, the color measuring device optionally comprises a video camera or digital camera. The color data 104 obtained by the color measuring device may be loaded into the color data memory as a color data file or directly
25 loaded into a memory associated with the computer arrangement 102. The computer arrangement 102 can access the color data file to obtain previous color data 104 measured by the color measuring device. The color data memory optionally stores several color data files for a variety of different color imaging systems. The system 100 can thus be used to characterize a color imaging system
30 selected from multiple color imaging systems having color data 104 stored in the color data memory.

The color data 104 represents, for example, CIE XYZ tristimulus values for each of a variety of color output samples generated by a color imaging system. Alternatively, the color data 104 may comprise other types of color values that can be converted to CIE XYZ tristimulus values. The color data 104 is
5 selected to sample the range or gamut of colors that can be realized by the color imaging system under study. Selecting the color data 104 to sample the gamut broadly provides an improvement to the accuracy of the color characterization across the gamut.

The color data 104 typically includes data that the computer
10 arrangement 102 uses in calculating a white reference vector 108 and a black reference vector 110. This data includes, for example, color values for an imaging base, such as paper, and color values for a maximum color output of the color imaging system. The CIE XYZ tristimulus values represent the relative amounts of primary color stimuli involved in matching colors within the CIE color system.
15 The relative X, Y, and Z values are influenced, for example, by the power distribution of the illuminant, *e.g.*, D_{50} , and the CIE standard observer function, *e.g.*, 2° or 10° . Alternatively, the color data 104 may be, for example, RGB or CMYK data.

FIG. 2 illustrates an example color characterization method 200 for
20 characterizing a color imaging system according to the present invention. In FIG. 2, at block 202, a system, such as the color characterization system 100 of FIG. 1, obtains CIE XYZ color values. This can be accomplished, for example, either directly from color data or through conversion from another type of color data. Next, as depicted at a block 204, the system calculates a set of values known as a
25 black reference vector. The black reference vector compensates for black point adaptation, which occurs, for example, when a nominally black color displayed on a computer monitor appears black to the human eye despite significant stray light that imparts significantly non-zero tristimulus values to the nominally black color. The black reference vector is configurable and may be calculated using any of a
30 variety of techniques appropriate for a particular imaging medium. For example, in certain application environments in which the black reference is near zero, a vector

of zeros may be used as the black reference vector. In certain color printing systems using a cyan-magenta-yellow-black (CMYK) color space, the black reference vector may be defined using measured tristimulus values corresponding to cyan, magenta and yellow values of zero and a maximum black value.

5 Alternatively, the black reference vector may be set using measured tristimulus values corresponding to maximum values of all four colorants or to cyan, magenta, yellow, and black values that yield maximum black ink coverage for a maximum black value. In certain other application environments using a red-green-blue (RGB) coordinate system, the black reference vector may be calculated from
10 measured tristimulus values corresponding to red, green, and blue values of zero.

To characterize other color imaging systems, the color characterization system may calculate the black reference vector by multiplying tristimulus values of a perfect white diffuser (X_n, Y_n, Z_n) by a preselected scaling factor β . For a perfect black point, *i.e.*, a black point having zero tristimulus
15 values, β is zero. For imperfect black points, β is non-zero. Calculating the black reference vector using a scaling factor ϵ_r has been found particularly useful in transforming color values between certain color imaging systems, such as a color printing system for color printing on newsprint and the Imation Rainbow™ color proofing system. Using measured tristimulus values to calculate the black
20 reference vector has been found particularly useful for matching colors between a color display system for displaying colors on a color monitor and the Imation Matchprint™ color proofing system, commercially available from Imation Corp., of Oakdale, Minnesota.

Block 206 of FIG. 2 depicts the color characterization system
25 calculating a white reference vector after calculating the black reference vector. It should be understood, however, that the system may alternatively calculate the white reference vector before calculating the black reference vector. The white reference vector is a vector defined by the tristimulus values $X_n, Y_n,$ and Z_n obtained for a white reference associated with the color imaging system. Any of a
30 variety of white references may be used. For example, in some color imaging systems, such as those employing the CIELAB color space, the white reference

vector comprises tristimulus values X_N , Y_N , and Z_N for a perfectly diffuse white reflector, *i.e.*, a medium exhibiting a maximum reflectance across the entire visible light spectrum. Using a perfectly diffuse white reflector to obtain the white reference vector yields relatively accurate results for most colors.

5 In certain other color imaging systems, the white reference vector is calculated from an imaging base vector defined by tristimulus values X_b , Y_b , and Z_b obtained for an imaging base associated with the particular color imaging system under study. In a color printing system, for example, the imaging base is the printing substrate on which colorants are deposited to form an image. In a color
10 display or color projection system, the imaging base is the white point produced by the display or projection system. This approach results in accurate reproduction of colors close to the media white.

As depicted at a block 208, after calculating the white reference vector, the color characterization system adjusts the white reference vector
15 according to the particular color data being converted to the modified color space of the present invention. Adjusting the white reference vector (X_n , Y_n , Z_n) produces an adjusted white reference vector (X_n' , Y_n' , Z_n'). The adjusted white reference vector (X_n' , Y_n' , Z_n') is used for converting the color data to modified color data in the modified color space.

20 The white reference vector (X_n , Y_n , Z_n) may be adjusted using a variety of techniques, including, for example, equations and/or estimation techniques. In a color coordinate system using L^* , a^* , and b^* coordinates, the white reference vector (X_n , Y_n , Z_n) may be adjusted to generate the adjusted white reference vector (X_n' , Y_n' , Z_n') according to the following equations:

25
$$X_n' = X_b(1 - \text{sat}(X, X_{bp}, X_n)) + X_n \cdot \text{sat}(X, X_{bp}, X_n)$$

$$Y_n' = Y_b(1 - \text{sat}(Y, Y_{bp}, Y_n)) + Y_n \cdot \text{sat}(Y, Y_{bp}, Y_n)$$

$$Z_n' = Z_b(1 - \text{sat}(Z, Z_{bp}, Z_n)) + Z_n \cdot \text{sat}(Z, Z_{bp}, Z_n),$$

where

30
$$\text{sat}(X, X_{bp}, X_n) = (X - X_n) / (X_{bp} - X_n)$$

$$\text{sat}(Y, Y_{bp}, Y_n) = (Y - Y_n) / (Y_{bp} - Y_n)$$

$$\text{sat}(Z, Z_{bp}, Z_n) = (Z - Z_n) / (Z_{bp} - Z_n)$$

X_{bp} , Y_{bp} , and Z_{bp} are the tristimulus values comprising the black reference vector (X_{bp} , Y_{bp} , Z_{bp}). Alternately, a vector (X_{max} , Y_{max} , Z_{max}) comprising the tristimulus values of the most saturated values in the particular imaging system may be substituted for the black reference vector (X_{bp} , Y_{bp} , Z_{bp}). To simplify calculations, the vector (X_{max} , Y_{max} , Z_{max}) can often be set to zero because the tristimulus values approach zero in the most saturated color, *e.g.*, maximum black. Calculating saturation for each tristimulus value has been found to be more accurate in many cases than calculating a single saturation value for all three tristimulus values. For example, for certain colors, the human eye perceives significant saturation in one tristimulus value but low saturation in other tristimulus values. While the white reference vector may be adjusted using the functions described above, more complex functions can be used in certain application environments to produce improved visual matches. For example, the white reference vector can be adjusted using higher-order polynomial functions. Alternatively, the white reference vector can be adjusted as a function of lightness and colorfulness levels.

Next, at a block 210, the tristimulus color values are converted to modified color values in a modified color space having, for example, L^* , a^* , and b^* coordinates. If the black reference vector (X_{bp} , Y_{bp} , Z_{bp}) is used in the block 208 to adjust the white reference vector, the modified color values can be calculated using, for example, the following equations:

$$\begin{aligned}
 L^* &= 116((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3} - 16 \\
 a^* &= 500[((X - X_{bp}) / (X_n' - X_{bp}))^{1/3} - \\
 &\quad ((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3}] \\
 b^* &= 200[((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3} - \\
 &\quad ((Z - Z_{bp}) / (Z_n' - Z_{bp}))^{1/3}],
 \end{aligned}$$

In application environments in which the vector (X_{max} , Y_{max} , Z_{max}) is used to adjust the white reference vector and is set to zero, the above equations reduce to the following forms:

$$\begin{aligned}
 L^* &= 116(Y / Y_n')^{1/3} - 16 \\
 a^* &= 500[(X / X_n')^{1/3} - (Y / Y_n')^{1/3}] \\
 b^* &= 200[(Y / Y_n')^{1/3} - (Z / Z_n')^{1/3}].
 \end{aligned}$$

It should be understood that other device-independent color spaces may be used for converting the tristimulus color values. Additional examples of color spaces that may be used include, but are not limited to, the HUNTLAB, ICPF LAB, and RLAB color spaces.

5 According to another aspect of the present invention, color transformation is effected between different color imaging systems. FIG. 3 illustrates an example method for performing this transformation. The method may be performed, for example, by the color characterization system 100 of FIG. 1. As depicted at a block 302, color data is obtained for the respective color imaging
10 systems between which the transformation is to be performed. At a block 304, a black reference vector is calculated for each color imaging system using equations similar to those used to calculate the black reference vector in connection with the block 204 of FIG. 2. Next, at a block 306, white reference vectors are calculated or estimated for each color imaging system. The white reference vectors can be
15 calculated in a manner similar to that used for calculating the white reference vector in connection with the block 206 of FIG. 2. As discussed in connection with FIG. 2, this may be accomplished using an imaging base vector obtained for each color imaging system.

 At a block 308, the white reference vectors for each color imaging
20 system are adjusted according to the color data for each color imaging system. This adjustment is performed using equations similar to those used in connection with the block 208 of FIG. 2 or by estimation. The adjusted white reference vectors are then used to generate color transformation values that map color values
25 between the color imaging systems. The color transformation values may be stored, for example, as entries in a table.

What is claimed is:

1. A color characterization method for characterizing a color imaging system, the method comprising:
generating first color values in a color coordinate system by using
5 output samples of the color imaging system, the first color values representing colors of the output samples of the color imaging system; and
converting the first color values into second color values in a device-independent color coordinate system using first and second reference values, the first reference values being adjusted using the first color values.
- 10 2. A color characterization method, according to claim 1, further comprising calculating the second reference values as a function of a medium.
3. A color characterization method, according to claim 2, further comprising defining the second reference values as a vector of zeros.
- 15 4. A color characterization method, according to claim 2, further comprising defining the second reference values using a maximum value in a black channel of the color imaging system and minimum values in at least one additional channel of the color imaging system.
- 20 5. A color characterization method, according to claim 2, further comprising defining the second reference values using maximum values in channels of the color imaging system.
6. A color characterization method, according to any of claims 1-5 further comprising calculating the first reference values using the second reference values.

7. A color characterization method according to claim 6 further comprising:

adjusting the first reference values using the first color values.

8. A color characterization method, according to claim 1, wherein the device-independent color coordinate system is an $L^*a^*b^*$ color coordinate system.

9. A color characterization method according to claim 1, further comprising:

generating third color values by using output samples of a second color imaging system, the third color values representing colors of the output samples of the second color imaging system;

converting the third color values into fourth color values using a device-independent color coordinate system;

calculating the first reference values from a medium and the second reference values from the first reference values;

adjusting the second reference values using the first and third color values;

generating color transformation values using the second and fourth color values; and

performing a color transformation between the first and second imaging systems using the color transforming values.

10. A color characterization system configured to perform the method of any of claims 1-9.

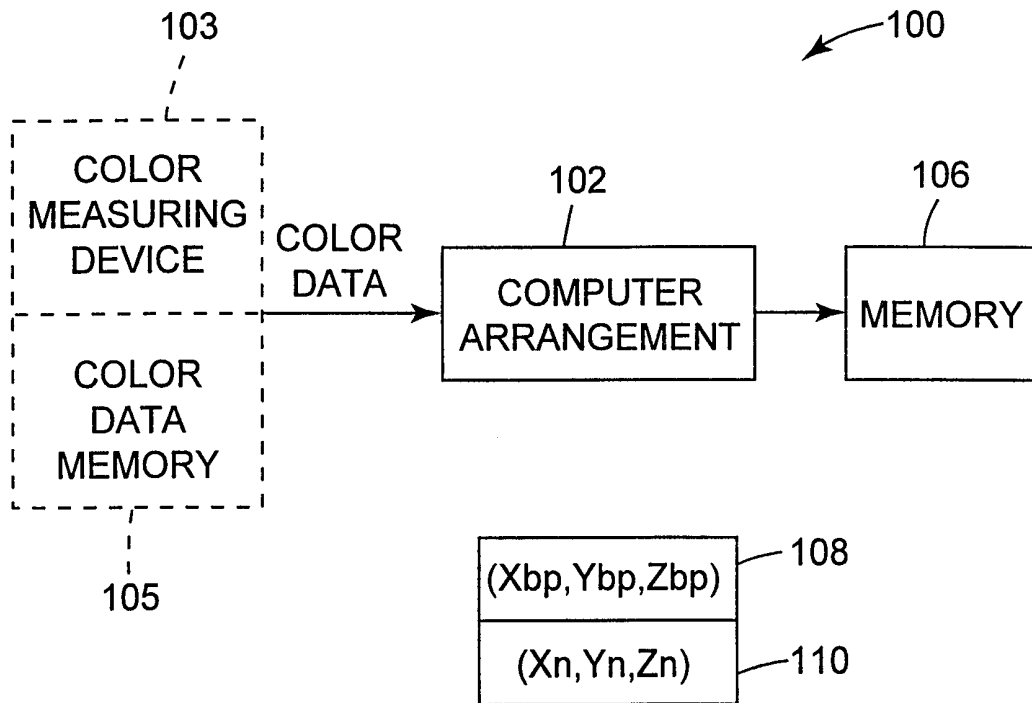


Fig. 1

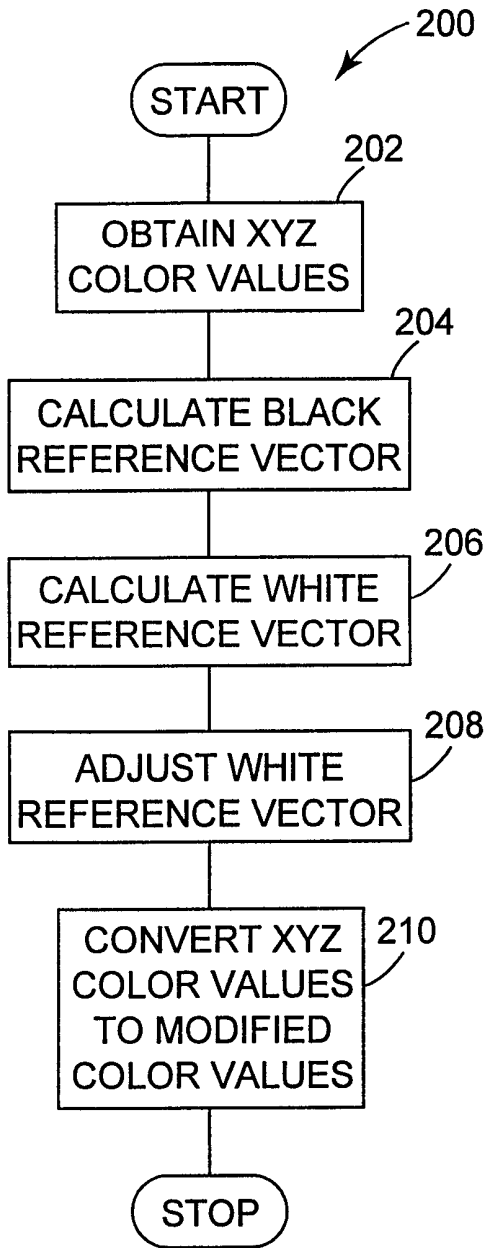


Fig. 2

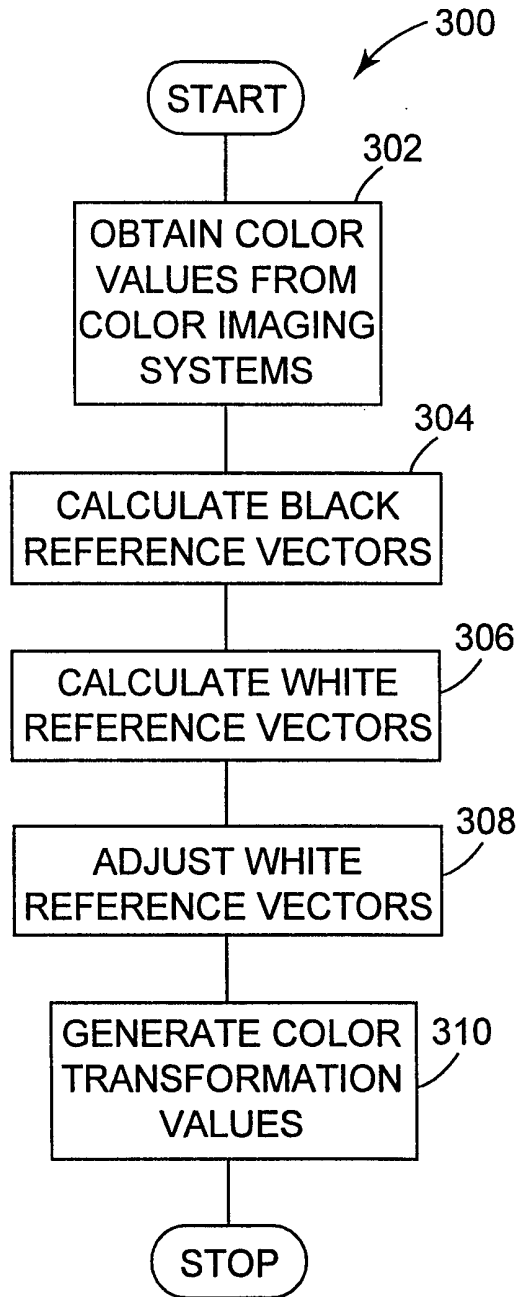


Fig. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/09764

A. CLASSIFICATION OF SUBJECT MATTER IPC 6 G01J3/46 H04N1/60				
According to International Patent Classification (IPC) or to both national classification and IPC				
B. FIELDS SEARCHED				
Minimum documentation searched (classification system followed by classification symbols) IPC 6 G01J				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched				
Electronic data base consulted during the international search (name of data base and, where practical, search terms used)				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
X	EP 0 273 398 A (KONICA) 6 July 1988 see abstract see page 5, line 47 - page 6, line 44 see page 8, line 21 - line 26 see page 9, line 26 - line 27 see page 22, line 41 - page 23, line 4 see page 23, line 11 - page 24, line 23 see figures 6,38-41 ---	1,2,8,10		
A	EP 0 484 102 A (IBM) 6 May 1992 see column 11, line 47 - column 13, line 19; figure 7 ---	1-5,10		
A	PATENT ABSTRACTS OF JAPAN vol. 97, no. 8, 29 August 1997 & JP 09 102885 A (RICOH), 15 April 1997 see abstract ---	1-5,10		
--- -/--				
<input checked="" type="checkbox"/> Further documents are listed in the continuation of box C.				
<input checked="" type="checkbox"/> Patent family members are listed in annex.				
° Special categories of cited documents :				
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none; vertical-align: top;"> "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; border: none; vertical-align: top;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family </td> </tr> </table>			"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family			
Date of the actual completion of the international search <div style="text-align: center; font-weight: bold;">10 September 1998</div>		Date of mailing of the international search report <div style="text-align: center; font-weight: bold;">17/09/1998</div>		
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer <div style="text-align: center; font-weight: bold;">Thomas, R.M.</div>		

INTERNATIONAL SEARCH REPORT

Int. .onal Application No
PCT/US 98/09764

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 97, no. 10, 31 October 1997 & JP 09 147098 A (NEC), 6 June 1997 see abstract ---	1-5, 10
A	EP 0 550 212 A (XEROX) 7 July 1993 ---	
A	EP 0 562 971 A (EASTMAN KODAK) 29 September 1993 -----	

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. Application No PCT/US 98/09764
--

Patent document cited in search report	A	Publication date	Patent family member(s)	Publication date
EP 0273398	A	06-07-1988	JP 63254863 A	21-10-1988
			JP 63254887 A	21-10-1988
			JP 2575134 B	22-01-1997
			JP 63254888 A	21-10-1988
			JP 7048869 B	24-05-1995
			JP 63254889 A	21-10-1988
			JP 2528463 B	28-08-1996
			JP 63254864 A	21-10-1988
			JP 63254865 A	21-10-1988
			JP 1013890 A	18-01-1989
			JP 7016257 B	22-02-1995
			JP 63162248 A	05-07-1988
			US 4959711 A	25-09-1990
			US 5065234 A	12-11-1991
EP 0484102	A	06-05-1992	US 5265200 A	23-11-1993
			JP 4274573 A	30-09-1992
EP 0550212	A	07-07-1993	US 5231504 A	27-07-1993
			DE 69223228 D	02-01-1998
			DE 69223228 T	18-06-1998
			JP 6022127 A	28-01-1994
EP 0562971	A	29-09-1993	US 5363318 A	08-11-1994
			JP 7288698 A	31-10-1995