(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 April 2010 (01.04.2010)

PCT

(10) International Publication Number
WO 2010/036326 A1

(51) International Patent Classification:
H04N 1/60 (2006.01)

(21) International Application Number:
PCT/US2009/005258

(22) International Filing Date:
22 September 2009 (22.09.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/100,804 29 September 2008 (29.09.2008) US
12/404,551 16 March 2009 (16.03.2009) US

(71) Applicant *(for all designated States except US)*: **EASTMAN KODAK COMPANY** [US/US]; 343 State Street, Rochester, New York 14650-2201 (US).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **EDGE, Christopher James** [US/US]; One Imation Way, Discovery 3D, Oakdale, Minnesota 55128 (US).

(74) Common Representative: **EASTMAN KODAK COMPANY**; 343 State Street, Rochester, New York 14650-2201 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,

[Continued on next page]

(54) Title: OPTIMIZING DISPLAY PROFILES TO SIMULATE CUSTOM ILLUMINATION

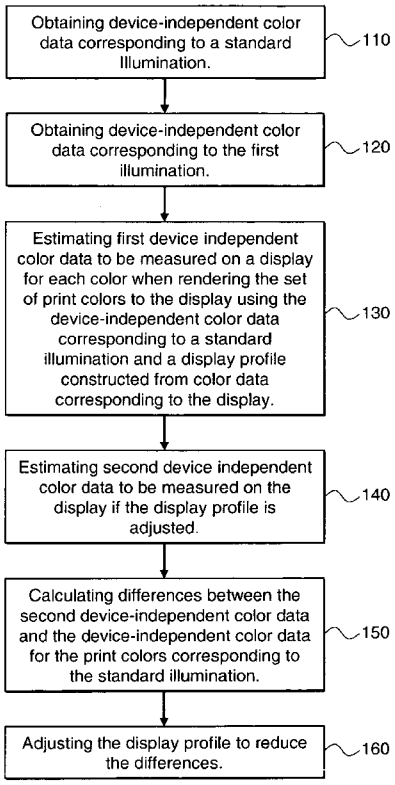


FIG. 1

(57) Abstract: A method for compensating for effects of illumination when comparing soft proofs to hard copy proofs viewed under non-standard illumination comprises obtaining (110), for a set of print colors, device-independent color data corresponding to the standard illumination and obtaining (120) the corresponding data for the non-standard illumination. The method further comprises estimating (130) first device independent color data to be measured on a display for each color when rendering the set of print colors to the display using the device-independent color data corresponding to the standard illumination and a display profile constructed from color data corresponding to the display, estimating (140) second device independent color data to be measured on the display if the display profile is adjusted, calculating (150) differences between the second device-independent color data and the device-independent color data for the print colors corresponding to the standard illumination and adjusting (160) the display profile to reduce differences.

WO 2010/036326 A1

MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

OPTIMIZING DISPLAY PROFILES TO SIMULATE CUSTOM ILLUMINATION

FIELD OF THE INVENTION

This invention relates to adjusting an existing accurate display profile in order to simulate the effects of imperfect standard lighting, such as fluorescent tubes that are designed to simulate D50 lighting.

BACKGROUND OF THE INVENTION

Fluorescent tubes that are designed to mimic the behavior of daylight (such as the D50 standard for daylight simulation) follow the requirements of international specifications for lighting, for example ISO 3664. These standards were optimized for the requirements of hard copy proofing. This means that different print media such as an ink jet proof and a press sheet must match numerically and visually under a daylight simulator, if calculations using the D50 standard illumination predict that the colors will match.

The standards are less rigorous with regard to the absolute simulation of D50 for a D50 simulator. For example, a solid yellow color printed with an ink jet printer and printing press might shift by 5 ΔE in the direction of green for a particular D50 simulator. That lighting may still be considered an acceptable approximation to D50 as long as the difference between the two colors is small.

This qualification of tubes based on relative versus absolute simulation of D50 is problematic when one attempts to match a display to a printed image viewed in a D50 simulator. In this case, the display may be calibrated and profiled in order to simulate colors viewed with theoretical D50. The ΔE match to D50 can be made very accurate in an absolute sense. If the D50 simulator in fact is significantly different spectrally from D50, resulting in significant shifts in absolute color rendering, there will be significant differences between the printed image in the D50 simulator and the image on the display.

For those who care about such challenges, it is possible to address this issue by measuring the spectra of the illumination, recalculating the values of XYZ and CIELAB, and creating a new ICC profile for characterizing the printed color media. The challenge of this approach is that all profiles would have to be

so created for that viewing environment, as well as databases of spot colors which typically contain lists of CIELAB values for each named color, such as lists of Pantone™ color libraries. Although this approach may well be convenient in the future, it is not convenient with current color management infrastructure which is optimized for CIELAB with theoretical D50 illumination.

SUMMARY OF THE INVENTION

The present invention is a method for compensating for effects of illumination when comparing soft proofs to hard copy proofs viewed under a non-standard illumination that differs from a standard illumination. As shown in Figure 1, the method comprises obtaining (110), for a set of print colors, device-independent color data corresponding to the standard illumination and obtaining (120), for the set of print colors, device-independent color data that corresponds to the non-standard illumination. The method further comprises estimating (130) first device independent color data to be measured on a display for each color when rendering the set of print colors to the display using the device-independent color data corresponding to the standard illumination and a display profile constructed from color data corresponding to the display, estimating (140) second device independent color data to be measured on the display if the display profile is adjusted, calculating (150) differences between the second device-independent color data and the device-independent color data for the print colors corresponding to the standard illumination and adjusting (160) the display profile to reduce the differences.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a flow chart showing a method for compensating for effects of illumination when comparing soft proofs to hard copy proofs viewed under a first illumination.

Figure 2 shows a processor for determining an adjusted RGB profile to simulate the effects of non-standard illumination.

Figure 3 is a flow chart showing a detailed method for compensating for effects of illumination when comparing soft proofs to hard copy proofs viewed under a first illumination.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is a method for compensating for effects of illumination when comparing soft proofs to hard copy proofs viewed under a non-standard illumination that differs from a standard illumination. As shown in Figure 1, the method comprises obtaining (110), for a set of print colors, device-independent color data corresponding to the standard illumination and obtaining (120), for the set of print colors, device-independent color data that corresponds to the non-standard illumination. The method further comprises estimating (130) first device independent color data to be measured on a display for each color when rendering the set of print colors to the display using the device-independent color data corresponding to the standard illumination and a display profile constructed from color data corresponding to the display, estimating (140) second device independent color data to be measured on the display if the display profile is adjusted, calculating (150) differences between the second device-independent color data and the device-independent color data for the print colors corresponding to the standard illumination and adjusting (160) the display profile to reduce the differences.

The device-independent color data corresponding to the standard illumination can be obtained by determining the reflectance spectra for each print color in the set of print colors and calculating the device independent color data using the standard illumination and the first illumination. The device independent color data for the second illumination can be calculated from direct emissive spectral measurement. The device independent color data can be determined from profiles corresponding to either the standard illumination or the first illumination.

In one embodiment, the present invention proposes to address the above problem via optimized adjustment of the RGB ICC profile used to render color images to the display. The method is executed using the processor system shown in Figure 2, where the processor 240 uses, for example, XYZ_{D50} data 210, $XYZ_{D50Simulation}$ data 220, and a RGB display profile 230 to calculate an adjusted RGB profile to simulate the effects of the first illumination and output an illuminant adjusted RGB display profile 250.

The method, as shown in detail in Figure 3, is as follows:

- Measure (310) CIELAB (or other colorimetric data) or spectral reflectance data for a set of printed colors using a standard reflective measurement device set to D50 or some other chosen reference illuminant;
- measure (320) the same colors emissively under the illumination of the D50 simulator or calculate the anticipated emissive measurement by multiplying the spectra of the D50 simulator by the spectral reflectance if so measured in the step above;
- for each color, scale (325) the emissive XYZ data and calculate CIELAB by comparing the reflective and emissive data of the whitest color and multiplying each $XYZ_{emissive}$ by $XYZ_{reflective}/XYZ_{emissive}$ for the whitest color sample;
- identify (330) a display profile that accurately converts RGB to XYZ and XYZ to RGB for that display;
- adjust (340) the display profile;
- convert (350) each value of XYZ_{D50} to $RGB_{display}$ using the adjusted display profile;
- convert (360) $RGB_{display}$ to XYZ_{Adj} with the unadjusted profile;
- calculate (370) differences between XYZ_{Adj} and $XYZ_{D50\ Simulation}$;
- determine (380) whether the differences between XYZ_{Adj} and $XYZ_{D50\ Simulation}$ are smaller than a predetermined difference;
- if the differences are, smaller than the predetermined difference, then output and save the adjusted RGB display profile, else go back to (340) above.
- continue the above process until $XYZ'_{emissive}$ and $XYZ_{reflective}$ are within acceptable tolerances; and
- output (390) adjusted RGB profile to simulate effects of illuminant.

Steps (350, 360, and 370) above determine the impact of modifying the RGB profile by converting the colors to the RGB values of the display as though it were performed using color management, then using the accurate unadjusted profile to estimate the measured impact of the adjustment. This should preferably be accomplished by converting $XYZ'_{emissive}$ and $XYZ_{reflective}$ to $CIELAB'_{emissive}$ and $CIELAB_{reflective}$ in order to reduce the error to below a predetermined value in a perceptually uniform color space. An automated approach to the difference reduction process is to define a cost function such as the sum of the squares of the ΔE differences between $CIELAB'_{emissive}$ and $CIELAB_{reflective}$ for the sample set of colors, and proceed to reduce the cost function to below a predetermined value by adjusting the parameters that define the RGB display profile. Well known methods such as Powell's method can be used to perform the automatic iterative error reduction of the cost function.

In one embodiment of the present invention, steps 310 or 320 can be performed by using a profile for the print colors constructed using values of L*a*b* calculated using standard D50 illumination or the simulated D50 illumination and by converting each CMYK color value to $XYZ_{reflective}$ and $XYZ_{emissive}$, thereby simulating the results of steps 310 and 320.

Regarding adjustments to the RGB profile, the effects of most D50 simulators can be addressed for chromatic colors by adjusting the values of chromaticities x, y for each RGB channel. Further improvement can be obtained by performing selective adjustments to the 6 RGBCMY vertices of the RGB gamut as described in commonly-assigned U.S. Patent Application Publication No. 2006/0181723 (Edge). In recent tests, accuracy of approximately 1 – 1.5 ΔE precision was achieved by adjusting chromaticities only, and nearly 0 error achieved by further adjusting the RGBCMY vertices of the RGB profile.

Since spectral measurement devices are often limited in resolution, the actual magnitude of ΔE differences between the appearance of colors under D50 illumination versus under illumination from a D50 simulator may be correct in direction of color but understated in magnitude. A multiplication coefficient,

for example, can be used to increase all differences in ΔL^*, Δa^*, Δb^*, etc. in order to capture the true magnitude of visual difference prior to performing the adjustment of the display profile. In an actual test, it was found that multiplying all differences by a factor of 2 exactly captured the true impact of using approximated or simulated D50 illumination versus using actual D50 illumination.

PARTS LIST

110 obtaining device-independent color data corresponding to standard illumination

120 obtaining device-independent color data corresponding to the non-standard illumination

130 estimating first device independent color data to be measured on a display

140 estimating second device independent color data to be measured on the display if the display profile is adjusted

150 calculating differences between the second device-independent color data and the device-independent color data

160 adjusting the display profile to reduce the differences

210 XYZ_{D50} data

220 $XYZ_{D50Simulation}$ data

230 RGB display profile

240 processor

250 illuminant adjusted RGB display profile

310 measure CIELAB data

320 measure the same colors emissively

330 identify a display profile

340 adjust the display profile

350 convert each value of XYZ_{D50} to $RGB_{display}$

360 convert $RGB_{display}$ to XYZ_{Adj} with the unadjusted profile

370 calculate differences between XYZ_{Adj} and $XYZ_{D50\ Simulation}$

380 determine whether the differences between XYZ_{Adj} and $XYZ_{D50\ Simulation}$ are smaller than a predetermined difference

390 output adjusted RGB profile to simulate effects of illuminant

CLAIMS:

1. A method for compensating for effects of illumination when comparing soft proofs to hard copy proofs viewed under a first illumination comprising:

obtaining, for a set of print colors, device-independent color data corresponding to a standard illumination;

obtaining, for the set of print colors, device-independent color data that corresponds to the first illumination;

estimating first device independent color data to be measured on a display for each color when rendering the set of print colors to the display using the device-independent color data corresponding to a standard illumination and a display profile constructed from color data corresponding to the display;

estimating second device independent color data to be measured on the display if the display profile is adjusted;

calculating differences between the second device-independent color data and the device-independent color data for the print colors corresponding to the standard illumination; and

adjusting the display profile to reduce the differences.

2. The method of claim 1, wherein the obtaining comprises determining the reflectance spectra for each print color in the set of print colors and calculating the device independent color data using the standard illumination and the first illumination.

3. The method of claim 1, wherein the device independent color data for the second illumination is calculated from direct emissive spectral measurement.

4. The method of claim 1, wherein the obtaining comprises determining the device independent color data from profiles corresponding to either the standard illumination or the first illumination.

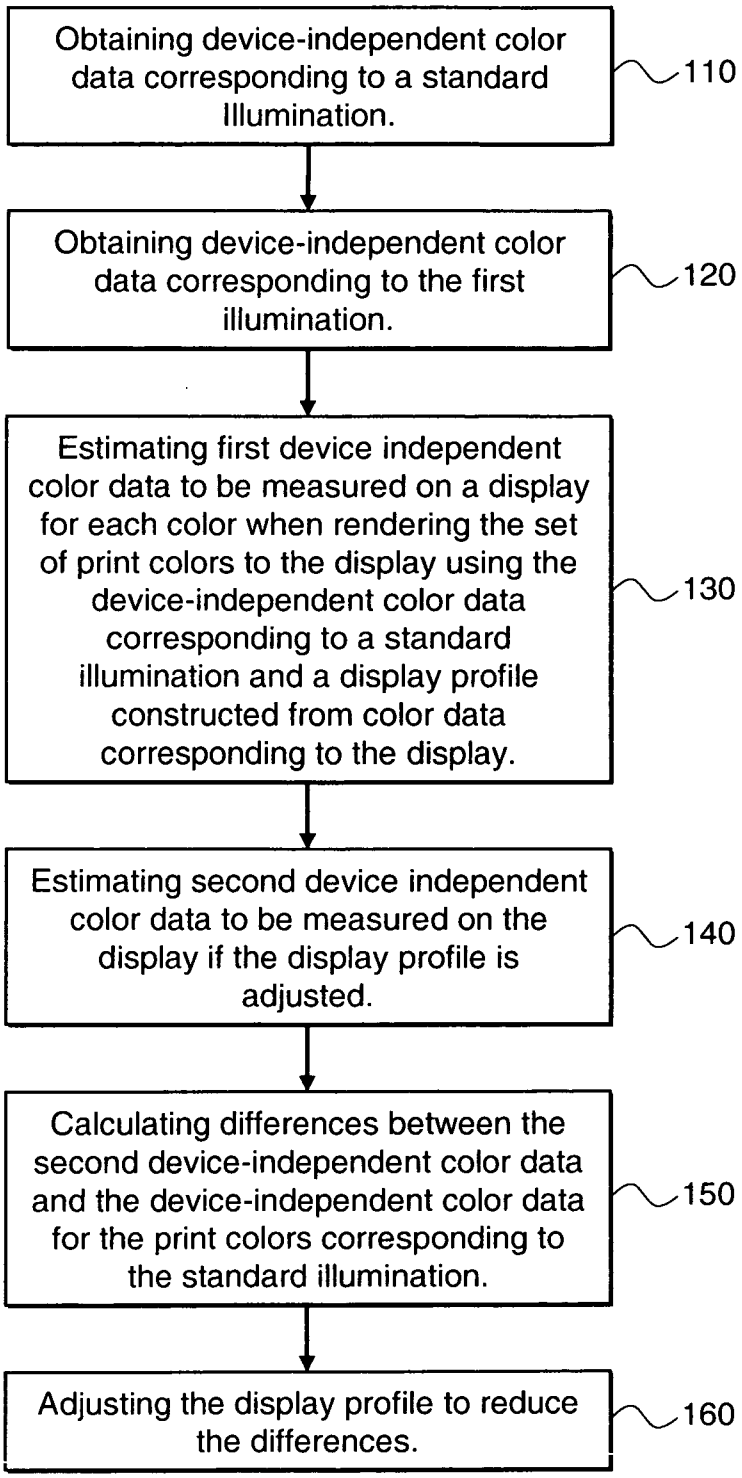

Obtaining device-independent color data corresponding to a standard Illumination.
110
Obtaining device-independent color data corresponding to the first illumination.
120
Estimating first device independent color data to be measured on a display for each color when rendering the set of print colors to the display using the device-independent color data corresponding to a standard illumination and a display profile constructed from color data corresponding to the display.
130
Estimating second device independent color data to be measured on the display if the display profile is adjusted.
140
Calculating differences between the second device-independent color data and the device-independent color data for the print colors corresponding to the standard illumination.
150
Adjusting the display profile to reduce the differences.
160

FIG. 1

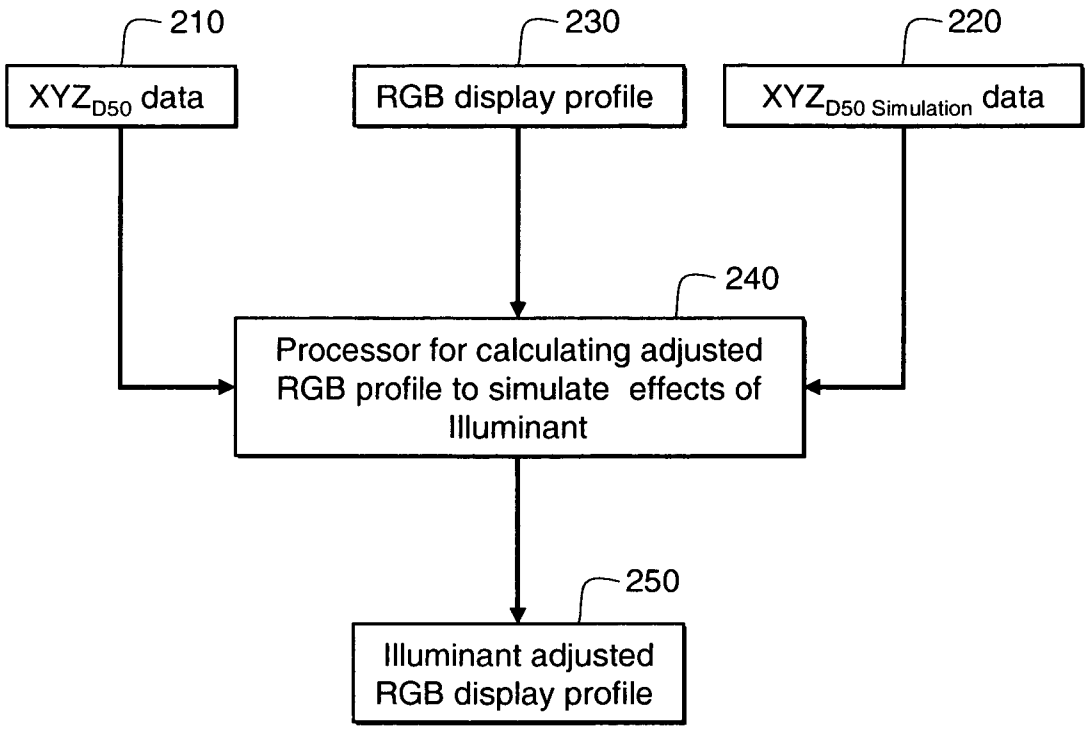

210
230
220
XYZD50 data
RGB display profile
XYZD50 Simulation data
240
Processor for calculating adjusted RGB profile to simulate effects of Illuminant
250
Illuminant adjusted RGB display profile

FIG. 2

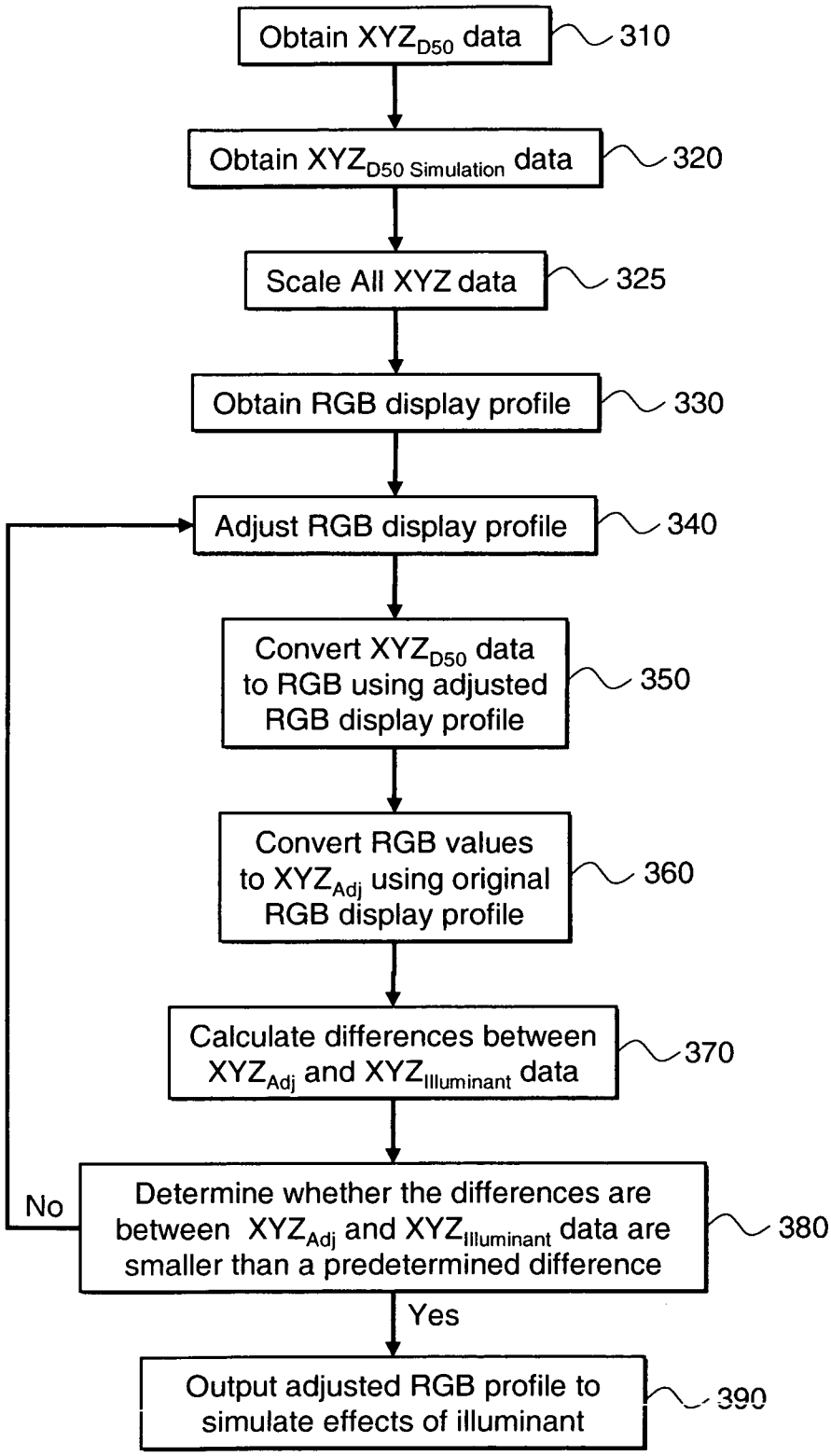

Obtain XYZ_{D50} data
310
Obtain $XYZ_{D50\ Simulation}$ data
320
Scale All XYZ data
325
Obtain RGB display profile
330
Adjust RGB display profile
340
Convert XYZ_{D50} data to RGB using adjusted RGB display profile
350
Convert RGB values to XYZ_{Adj} using original RGB display profile
360
Calculate differences between XYZ_{Adj} and $XYZ_{Illuminant}$ data
370
No
Determine whether the differences are between XYZ_{Adj} and $XYZ_{Illuminant}$ data are smaller than a predetermined difference
380
Yes
Output adjusted RGB profile to simulate effects of illuminant
390

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2009/005258

A. CLASSIFICATION OF SUBJECT MATTER
INV. 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)
H04N

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)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/068550 A1 (BRAUN KAREN M [US]) 31 March 2005 (2005-03-31) abstract paragraphs [0005] - [0007], [0014] - [0019]; figures 1,2	1-4
A	WO 2004/068845 A (KODAK POLYCHROME GRAPHICS LLC [US]) 12 August 2004 (2004-08-12) abstract paragraphs [0006], [0026] - [0031]	1-4
A	WO 02/076086 A (KODAK POLYCHROME GRAPHICS CO [US]) 26 September 2002 (2002-09-26) abstract page 11, line 10 - page 13, line 15 figure 5	1-4

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"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	Date of mailing of the international search report
26 November 2009	17/12/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Beugin, Anne

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2009/005258

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2006/181723 A1 (EDGE CHRISTOPHER J [US]) 17 August 2006 (2006-08-17) the whole document	1-4

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2009/005258

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005068550 A1	31-03-2005	NONE	
WO 2004068845 A	12-08-2004	CN 1745570 A	08-03-2006
		EP 1588550 A1	26-10-2005
		JP 2006520557 T	07-09-2006
WO 02076086 A	26-09-2002	AT 341153 T	15-10-2006
		BR 0208095 A	02-03-2004
		CN 1498494 A	19-05-2004
		DE 60214984 T2	06-06-2007
		EP 1368962 A1	10-12-2003
		JP 2005506723 T	03-03-2005
		US 2007153316 A1	05-07-2007
		US 2002167528 A1	14-11-2002
US 2006181723 A1	17-08-2006	NONE	