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(54) **Title:** GENERATING COLOR-SPACE TRANSFORMS FOR DIFFERENT PRINT DENSITIES

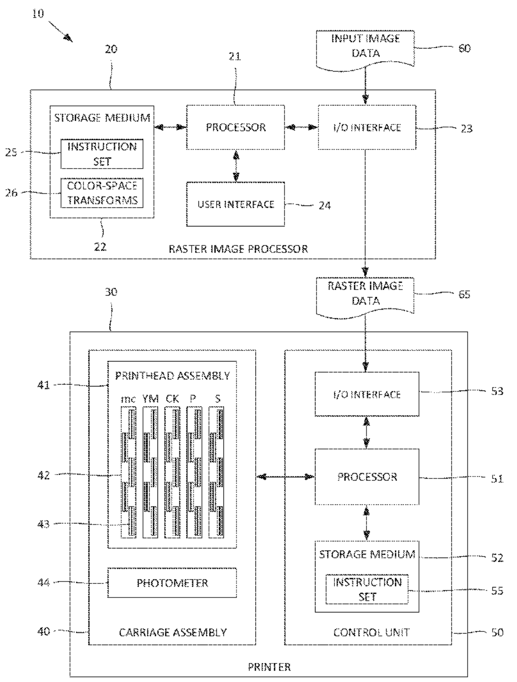

Fig. 1

(57) **Abstract:** A method is described in which a plurality of first color-space transforms are provided, each corresponding to a different print density and converting image data from a first color space to a second color space. A target color chart is printed onto a print medium, and the color patches of the printed target color chart are measured to generate colorimetric data. The colorimetric data is used to generate a second color-space transform for converting image data from the second color space to a third color space. A plurality of third color-space transforms are then generated using the first color-space transforms and the second color-space transform. Each of the third color-space transforms corresponds to a different print density and converts image data from the third color space to the first color space.

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GENERATING COLOR-SPACE TRANSFORMS FOR DIFFERENT PRINT DENSITIES

BACKGROUND

[0001] A printer may provide the option of printing image data at different print densities. Differences in the colorimetry of the printed image may arise when printing at the different print densities. Accordingly, the printer may be characterized for each print density. This may involve printing a target color chart at each print density, measuring the printed color chart using a photometer, and using the measured data to generate a color-space transform that is unique to each print density and which is subsequently used by the printer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Figure 1 is a block diagram of an example printing system;

[0003] Figure 2 illustrates an example process of a raster image processor of the printing system;

[0004] Figure 3 illustrates an example process of a printer of the printing system;

[0005] Figure 4 illustrates an example method of generating color-space transforms;

[0006] Figure 5 illustrates an example method of generating a target color chart; and

[0007] Figure 6 is a diagram of a further example of a printing system.

DETAILED DESCRIPTION

[0008] Figure 1 shows an example printing system 10 that comprises a raster image processor 20 and a printer 30.

[0009] The raster image processor (RIP) comprises a processor 21, a storage medium 22, an input/output interface 23, and a user interface 24. The processor 21 is responsible for controlling the operation of the RIP 20 and executes an instruction set 25 stored in the storage medium 22. The storage medium 22 additionally stores a plurality of color-space transforms 26. Each of these color-space transforms 26 corresponds to a different print density of the printer 30 and, as described below, is used by a color management module of the RIP 20.

[0010] The printer 30 comprises a carriage assembly 40 and a control unit 50. The carriage assembly 40 comprises a printhead assembly 41 and a photometer 45.

[0011] The printhead assembly 41 comprises a plurality of printheads 42. Each printhead 42 comprises a plurality of dies 43, with each die comprising a plurality of nozzles through which drops of printing fluid are ejected onto a print medium. Eight different printing fluids are supplied to the printheads 42; these are: cyan (C), magenta (M), yellow (Y), black (B), light cyan (c), light magenta (m), optimizer (P) and overcoat (S). The printer 30 therefore has eight color channels, which will hereafter be abbreviated to CMYKcmPS. The printer 30 may comprise fewer or additional color channels. By way of example, the printer 30 may comprise just four color channels (e.g. CMYK), or the printer 30 may comprise additional color channels for white (W), orange (O) and/or green (G).

[0012] The printer 30 has eight color channels. However, two of the color channels, namely the optimizer and overcoat channels, are not colorants. Nevertheless, these printing fluids may influence the colorimetry of the printed image. Where reference is made to a color channel, it should be understood that the channel may correspond to a colorant or a non-colorant. Similarly, where reference is made to a color space, it should be understood that the color space may comprise color channels that correspond to colorants and/or non-colorants.

[0013] The photometer 45 measures the reflectance and/or transmittance of images printed onto the print medium. The photometer 45 may comprise, for example, a spectrophotometer or filter photometer (also referred to as a colorimeter).

[0014] The control unit 50 comprises a processor 51, a storage medium 52, an input/output interface 53. The processor 51 is responsible for controlling the operation of the printer 30 and executes an instruction set 55 stored in the storage medium 52.

[0015] During use of the printing system 10, the RIP 20 receives input image data 60 from an input device via the input/output interface 23. A user may set various printer settings using the user interface 24 of the RIP 20. Among the available printer settings, the user may select the print density to be used by the printer 30. For example, where the printer 30 is a wide-format printer, a user may select a particular print mode, which may define the print density to be used along with other printing parameters, such as number of print passes. The available print densities or print modes may depend on the type of print medium onto which the image data is to be printed. Once the various printer settings have been set and the user elects to print the input image data, the RIP 20 converts the input image data 60 into raster image data 65. The raster image data 65 is then sent to the printer 30 along with the selected printer settings.

[0016] Figure 2 shows an example of how the RIP 20 may convert the input image data 60 into the raster image data 65. In this particular example, the processor 21 of the RIP 20 implements a color management module 70 and a raster engine module 71.

[0017] The input image data 60 received by the RIP 20 may be in different formats or color spaces. In one example, the input image data 60 may include an embedded input profile 61. The input profile is a color-space transform that conforms to a prescribed format defined by the International Color Consortium (ICC).

[0018] The color management module 70 uses the input profile 61 to convert 72 the input image data 60 from an input-device color space, such as RGB or CYMK, to a device-independent color space, such as CIELAB or CIEXYZ. The color management module 70 selects a color-space transform 26 from the storage medium 22 according to the selected print density. The color management module 70 then uses the selected color-space transform 26 to convert 73 the input image data 60 from the device-independent color space to an output-device color space, i.e. the color space of the output device, which in this instance is the printer 30. In the particular example illustrated in Figure 2, the input-device color space is RGB, the device-independent color space is CIELAB, and the output-device color space is CYMK.

[0019] The raster engine module 71 converts 74 the input image data (now in CYMK color space) into the raster image data 65, and the raster image data 65 is sent to the printer 30, along with the selected printer settings.

[0020] Figure 3 shows an example of how the printer 30 may print the raster image data 65 received from the RIP 20. In this particular example, the processor 51 of the printer 30 implements a color mapping module 80, and a half-toning module 81.

[0021] The color mapping module 80 converts 82 the raster image data 65 from the output-device color space (i.e. CMYK) to a native color space of the printer 30, which in this instance is CMYKcmPS. The halftoning module 81 reduces the amount of information for each color value of the image data, whilst preserving overall color characteristics. For example, the halftoning module 81 may convert 83 the color values output by the color mapping module 80 into 2-bit values. Each of the color values output by the halftoning module 81 specifies, directly or indirectly, a discrete number of drops of printing fluid for the respective color channel.

[0022] Figure 4 shows an example method for generating the color-space transforms 26 that are used by the color management module 70 of the RIP 20. Color-space transforms 26 may be generated for a number of reasons, e.g. when a new type of print medium is used or when color differences are noted between prints. Such color differences may arise due to, for example, aging of the printheads, the installation of a new printhead, subtle changes between different batches or rolls of the same print medium.

[0023] The method 100 comprises providing 110 a plurality of first color-space transforms. Each of the transforms corresponds to a different print density of the printer 30, and converts image data from a first color space to a second color space. The first color space and the second color space are both device color spaces of the printer 30. The first color space is the same as that used for the input of the color mapping module 80; in the discussion above, this was referred to as the output-device color space and is CMYK. The second color space is the same as that used as the input of the halftoning module 81, which in this example is CMYKcmPS.

[0024] Each of the first color-space transforms converts image data from the first color space to the second color space. In one example, each of the first color-space transforms comprises color lookup tables (LUTs) and linear LUTs. The color LUTs convert color values from the first color space to the second color space using linear interpolation. Although linear interpolation is used, conversion from the first color space to the second color space may be non-linear. The linear LUTs therefore linearize the converted color values so as to reduce interpolation errors.

[0025] The first color-space transforms may be in a format prescribed by a standard settings organization. For example, each of the first color-space transforms may be a device link profile, as defined by the ICC. Alternatively, the first color-space transforms may be in a non-standard or proprietary format.

[0026] The method further comprises printing 120, with the printer, a target color chart onto a print medium. The target color chart comprises color values in the second color space, which in this example is CMYKcmPS. The image data for the target color chart is therefore delivered directly to the halftoning module 81. When printed, the target color chart comprises a plurality of color patches.

[0027] The target color chart may be generated by converting a reference color chart having color values in the first color space (e.g. CMYK) into a plurality of color charts having color values in the second color space (e.g. CMYKcmPS) using the first color-space transforms. Each of the plurality of color charts then corresponds to a different print density. The plurality of color charts may be combined to create a single, large target color chart. Alternatively, the plurality of color charts may be merged (e.g. using cluster analysis) to create a single, smaller target color chart. An example method of generating a target color chart is described further below.

[0028] After printing the target color chart, the method comprises measuring 130 the color patches of the printer chart to obtain colorimetric data.

The color patches may be measured using a photometer, such as a spectrophotometer or filter photometer. The photometer may form part of the printer, as in the example printer 30 of Figure 1. Alternatively, the photometer may be a standalone device or may form part of another system.

[0029] The method then comprises generating 140 a second color-space transform using the colorimetric data. The second color-space transform converts image data from the second color space to a third color space. The third color space is a device-independent color space, such as CIELAB or CIEXYZ. The colorimetric data are used to generate color values in the third color space. The color values obtained from the target color chart (second color space) and the color values obtained from the colorimetric data (third color space) are then used as training data in the generation of the second color-space transform. The second color-space transform may be generated using regression analysis or other type of interpolation method, perhaps using machine learning.

[0030] As with the first color-space transforms, the second color-space transform may comprise color LUTs for converting color values from the second color space to the third color space.

[0031] The method then comprises generating 150 a plurality of third color-space transforms using the first color-space transforms and the second color-space transform. Each of the third color-space transforms corresponds to a different print density of the printer and converts image data from the third color space (e.g. CIELAB) to the first color space (e.g. CYMK).

[0032] Each third color-space transform is generated using a respective first color-space transform and the second color-space transform. Each third color-space transform may be generated by first combing the respective first color-space transform (e.g. CYMK > CYMKcmPS) and the second color-space transform (e.g. CYMKcmPS > CIELAB) to generate a color-space transform that converts image data from first color space to the third color space (e.g. CYMK > CIELAB). This transform may then be inverted to generate the third color-space transform (e.g. CIELAB > CYMK).

[0033] Each of the third color-space transforms may comprise color LUTs for converting color values from the third color space to the first color space. Moreover, the third color-space transforms may be in a format prescribed by a standard settings organization. For example, each of the third color-space transforms may be an ICC output profile. Alternatively, the third color-space transforms may be in a non-standard or proprietary format.

[0034] The third color-space transforms may then be stored to the storage medium 22 of the RIP 20 for subsequent use by the color management module 70.

[0035] Each print density of the printer 30 may differ in terms of colorimetry. By providing a color-space transform for each print density, good color accuracy may be achieved irrespective of the selected print density. With the method described above, color-space transforms may be generated for a plurality of print densities by printing just a single color chart onto the print medium. As a result, the time and effort on the part of the user to characterize the printer for each print density, and the expended materials (e.g. printing fluids and media), may be reduced. In particular, the color-space transforms may be generated without having to print, measure and characterize a color chart for each and every print density.

[0036] Figure 5 shows an example method 200 of generating a target color chart for use within the method 100 of Figure 4.

[0037] The method 200 comprises providing 210 a reference color chart. The reference color chart may be a standard color chart set by a standard setting organization, such as the IT8.7/4 color chart set by the American National Standards Institute, or the ECI2002 color chart set by the European Color Initiative. Alternatively, the reference color chart may be a non-standard or proprietary color chart. The reference color chart comprises color values in the first color space (e.g. CMYK).

[0038] The method 200 further comprises converting 220 the reference color chart from the first color space (e.g. CMYK) to the second color space (e.g. CMYKcmPS) using each of the first color-space transforms. This then generates a plurality of color charts, each of which corresponds to a respective first color-space transform.

[0039] The method 200 then comprises merging 230 the plurality of color charts to create a single target color chart. In one example, the color charts are merged using clustering analysis, such as K-means clustering analysis. The number of centroids used in the clustering analysis may correspond to the number of color patches of the reference color chart. So, for example, if the reference color chart (e.g. ECI2002) comprises 1485 color patches, the clustering analysis may employ 1485 centroids such that the resulting target color chart also comprises 1485 color patches. Alternatively, the clustering analysis may employ a different number of centroids such that the target color chart has fewer or more color patches than that of the reference color chart.

[0040] By generating the target color chart in this way, the color patches of the target color chart provide a relatively good representation of the various print densities of the printer. Where clustering analysis is used, the lowest and highest print densities may be poorly represented if the clustering analysis is completely unconstrained. Accordingly, the clustering analysis may be constrained such that there are centroids located at the of the extremes of the dataset. This may be achieved by limiting the number of centroids positioned at the extremes of the dataset, or by limiting the number of data points within the centroids at the extremes of the dataset. Alternatively, some of the data points at the extremes of the dataset may be excluded from the clustering analysis. So, for example, if the target color chart has 1485 color patches, the method may select 40 data points for which the sum of the channel values is lowest, and 40 data points for which the sum of the channel values is highest. Clustering analysis is then performed on the remaining data points using 1405 centroids.

[0041] The example methods described above may be performed wholly or partly by the printer 30 of Figure 1. For example, in addition to the modules illustrated in Figure 3, the processor 51 may implement a color characterization module for performing the method of Figure 4 and/or Figure 5. The storage medium 52 of the printer 30 may store the first color-space transforms (e.g. in the forms of ICC device link profiles) and the target color chart for use by the color characterization module. The storage medium 52 may additionally store the reference color chart, which the color characterization module may use to generate the target color chart. Once generated, the third color-space transforms may be transferred from the printer 30 to the RIP 20 (e.g. as part of a synchronization routine) for subsequent use by the color management module 70.

[0042] The example methods may in part be performed by a device located remotely from the printer.

[0043] Figure 6 shows an example printer system 90 that comprises a plurality of printers 30 connected remotely to a color characterization device 95. In order to characterize a printer 30 and generate the color-space transforms, the printer 30 prints the target color chart onto the print medium, measures the printed target color chart, and sends the resulting colorimetric data to the color characterization device 95 via the input/output interface 33. The characterization device 95 generates the third color-space transforms using the received colorimetric data, and sends the generated transforms to the printer 30. The printer 30 then transfers the color-space transforms 36 to the RIP 20 (e.g. as part of a synchronization routine).

[0044] In generating the third color-space transforms, the color characterization device 95 generates the second color-transform using the colorimetric data and the color values of the target color chart. The color characterization device 95 may store the target color chart. Indeed, the color characterization device 95 may generate and then send the target color chart to the printer 30 for printing. Alternatively, the printer 30 may send the target color chart to the color characterization device 95 along with the colorimetric data. The color characterization device 95 then generates the third color-space transforms using the generated second color-space transform and the first color-space transforms, which may be stored on the color characterization device 95. By characterizing the printer 30 in this way, the computation to generate the color-space transforms, and in particular the regression analysis or interpolation to generate the second color-space transform, may be performed on a remote device rather than the printer 30.

[0045] The preceding description has been presented to illustrate and describe examples of the principles described. This description is not intended to be exhaustive or to limit these principles to any precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is to be understood that any feature described in relation to any one example may be used alone, or in combination with other features described, and may also be used in combination with any features of any other of the examples, or any combination of any other of the examples.

CLAIMS

What is claimed is:

1. A method comprising:

providing a plurality of first color-space transforms, each corresponding to a different print density and converting image data from a first color space to a second color space ;

printing a target color chart onto a print medium;

measuring color patches of the printed target color chart to generate colorimetric data;

generating a second color-space transform using the colorimetric data, the second color-space transform converting image data from the second color space to a third color space; and

generating a plurality of third color-space transforms using the first color-space transforms and the second color-space transform, each of the third color-space transforms corresponding to a different print density and converting image data from the third color space to the first color space.

2. A method as claimed in claim 1, wherein the method comprises generating the target color chart using the first color-space transforms.

3. A method as claimed in claim 1, wherein the method comprises converting a reference color chart using each of the plurality of first color-space transforms to generate a plurality of color charts, and merging the plurality of color charts to generate the target color chat.

4. A method as claimed in claim 3, wherein merging comprises using clustering analysis.

5. A method as claimed in claim 1, wherein the target color chart comprises color values in the second color space.

6. A method as claimed in claim 1, wherein the first color space and the second color space are device-dependent color spaces of the printer, and the third color space is a device-independent color space.

7. A printer comprising:

a processor;

a photometer; and

a storage medium storing:

a target color chart;

a plurality of first color-space transforms, each corresponding to a different print density of the printer and converting image data from a first color space to a second color space; and

instructions for execution by the processor;

wherein the instructions, when executed by the processor, cause the printer to:

print the target color chart onto a print medium;

measure color patches of the printed target color chart with the photometer to generate colorimetric data;

generate a second color-space transform using the colorimetric data, the second color-space transform converting image data from the second color space to a third color space; and

generate a plurality of third color-space transforms using the first color-space transforms and the second color transform, wherein each of the third color-space transforms corresponds to a different print density of the printer and converts image data from the third color space to the first color space.

8. A printer as claimed in claim 7, wherein the target color chart is generated using the first color-space transforms.

9. A printer as claimed in claim 8, wherein the target color chart is generated by converting a reference color chart using each of the plurality of

first color-space transforms to generate a plurality of color charts, and merging the plurality of color charts.

10. A printer as claimed in claim 7, wherein the target color chart comprises color values in the second color space.

11. A printer comprising:

a processor;

an interface;

a photometer; and

a storage medium storing instructions for execution by the processor;

wherein the instructions, when executed by the processor, cause the printer to:

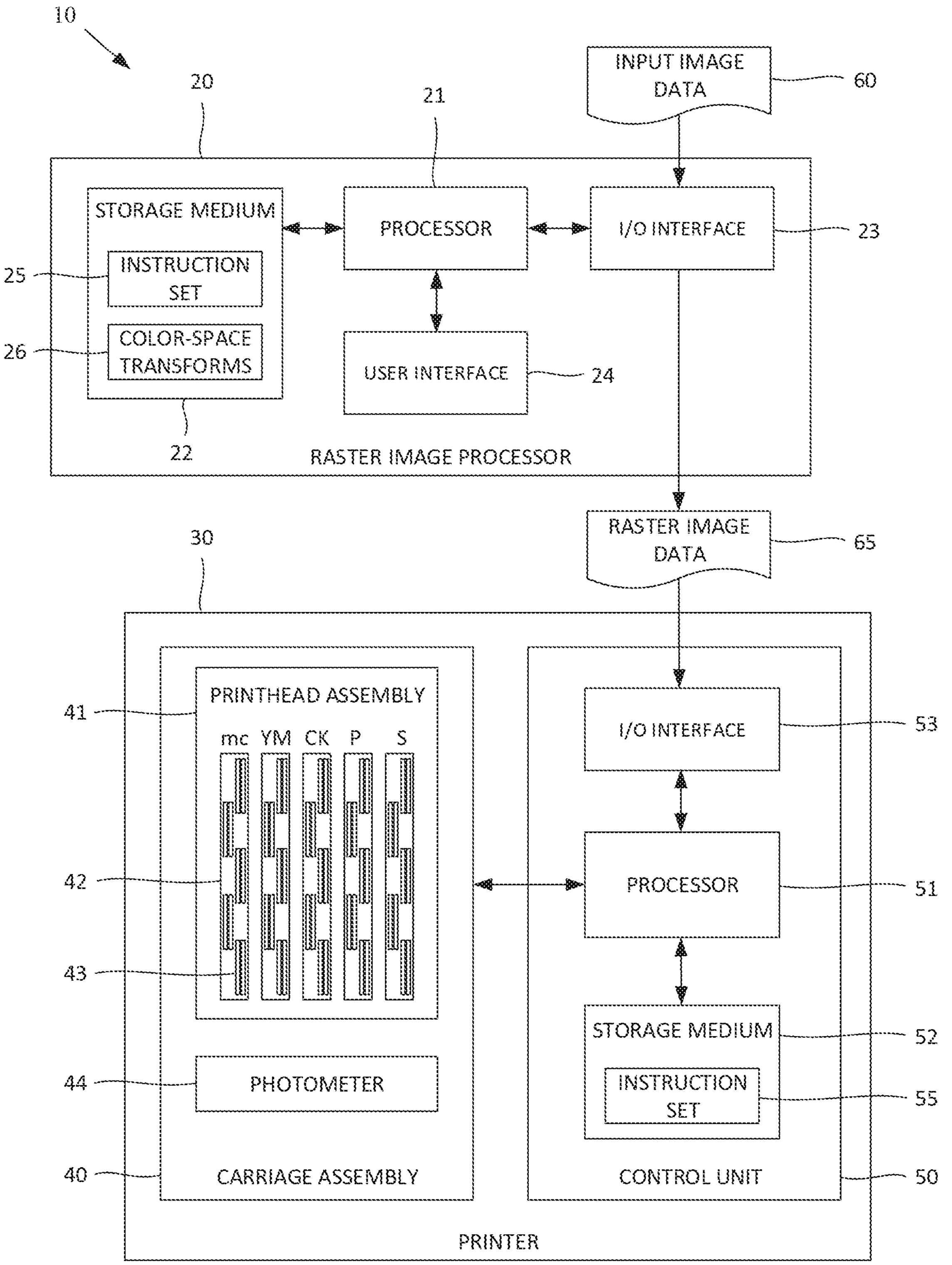
print a target color chart onto a print medium;

measure color patches of the printed target color chart with the photometer to generate colorimetric data;

send the colorimetric data to a remote computer via the interface; and

receive a plurality of color-space transforms from the remote computer via the interface, wherein each of the color-space transforms corresponds to a different print density of the printer and converts image data from a device-independent color space to a device-dependent color space.

12. A printer as claimed in claim 11, wherein the target color chart is generated by converting a reference color chart using a plurality of further color-space transforms to generate a plurality of color charts, and merging the plurality of color charts, wherein each of the further color-space transforms corresponds to a different print density of the printer.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INSTRUCTION SET
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COLOR-SPACE TRANSFORMS
USER INTERFACE
24
22
RASTER IMAGE PROCESSOR
RASTER IMAGE DATA
65
30
41
PRINTHEAD ASSEMBLY
mc YM CK P S
I/O INTERFACE
53
42
PROCESSOR
51
43
STORAGE MEDIUM
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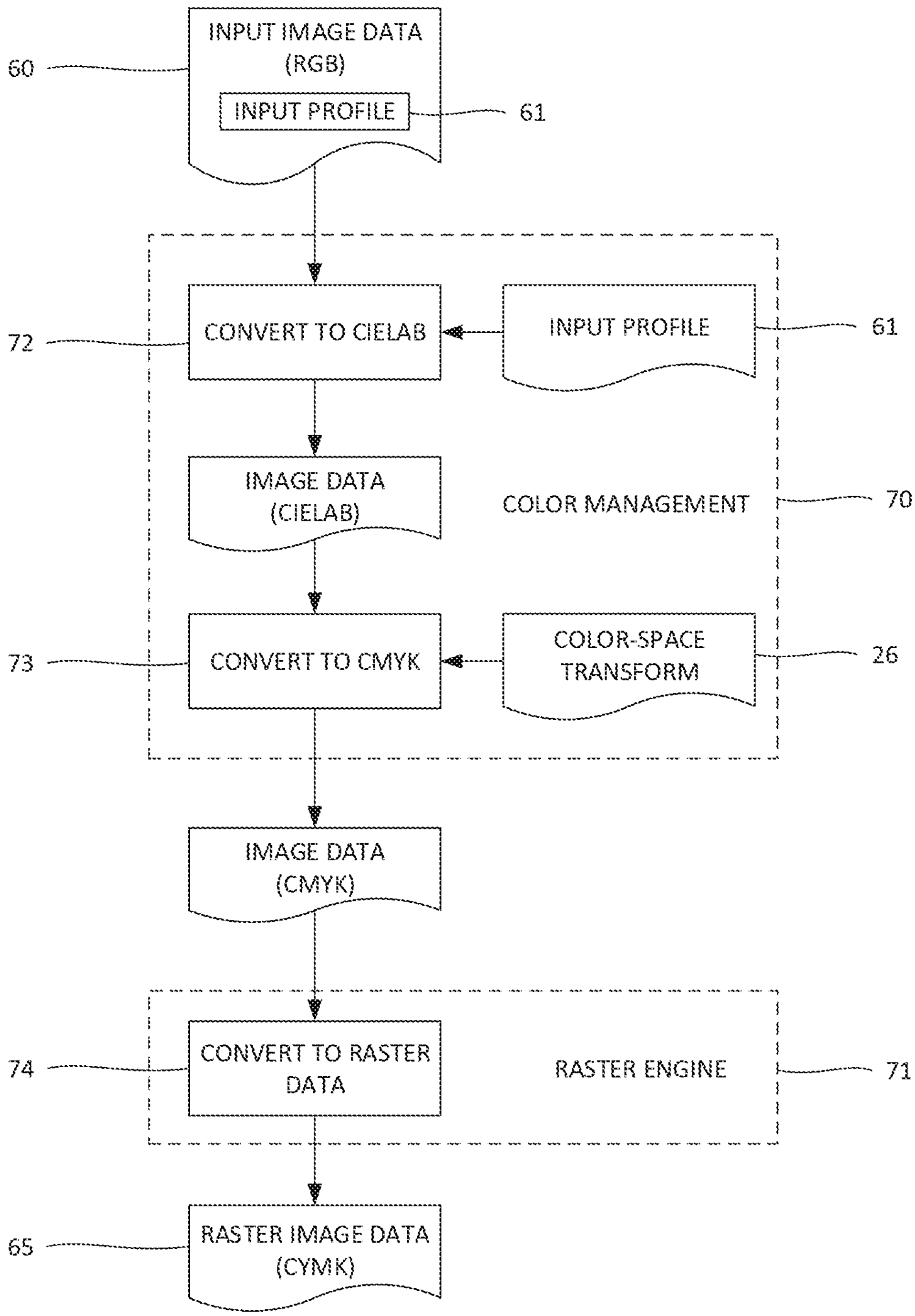
44
PHOTOMETER
INSTRUCTION SET
55
40
CARRIAGE ASSEMBLY
CONTROL UNIT
50
PRINTER

Fig. 1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61
CONVERT TO CIELAB
72
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61
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(CIELAB)
COLOR MANAGEMENT
70
CONVERT TO CMYK
73
COLOR-SPACE
TRANSFORM
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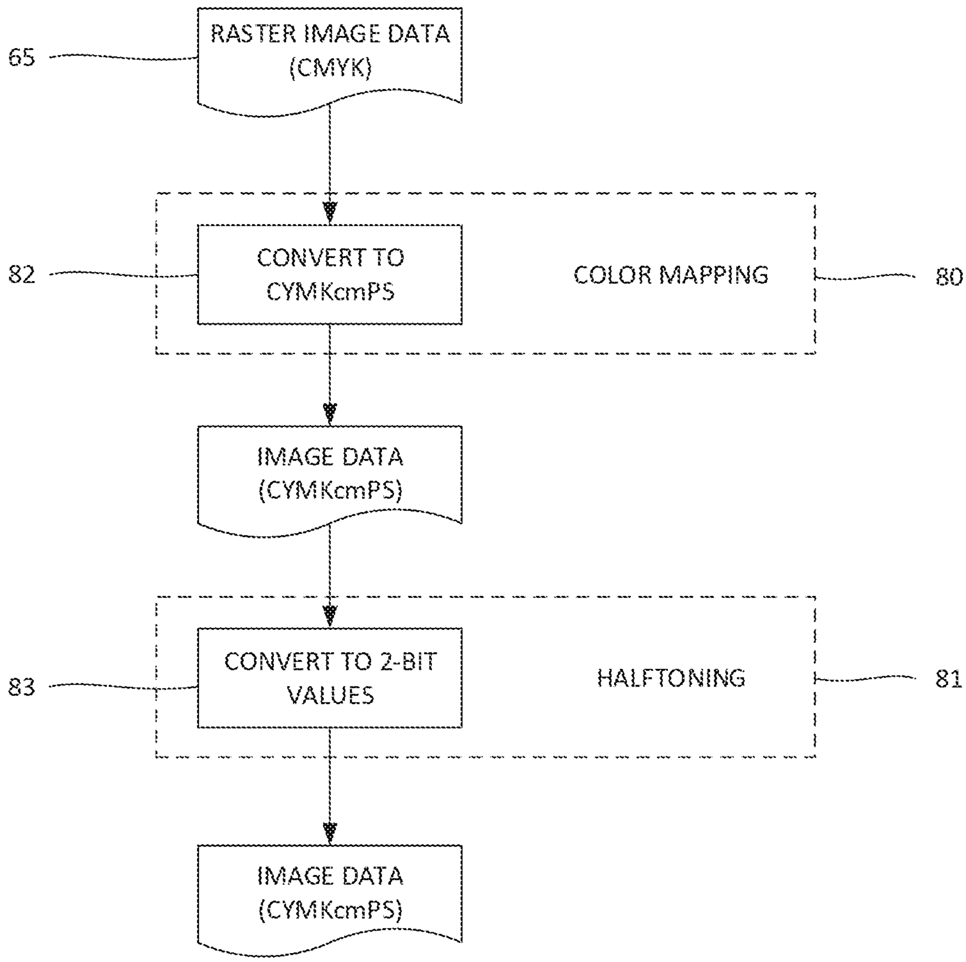
(CMYK)
CONVERT TO RASTER
DATA
74
RASTER ENGINE
71
RASTER IMAGE DATA
(CYMK)
65

Fig. 2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CONVERT TO CYMKcmPS
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COLOR MAPPING
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IMAGE DATA (CYMKcmPS)
CONVERT TO 2-BIT VALUES
83
HALFTONING
81
IMAGE DATA (CYMKcmPS)

Fig. 3

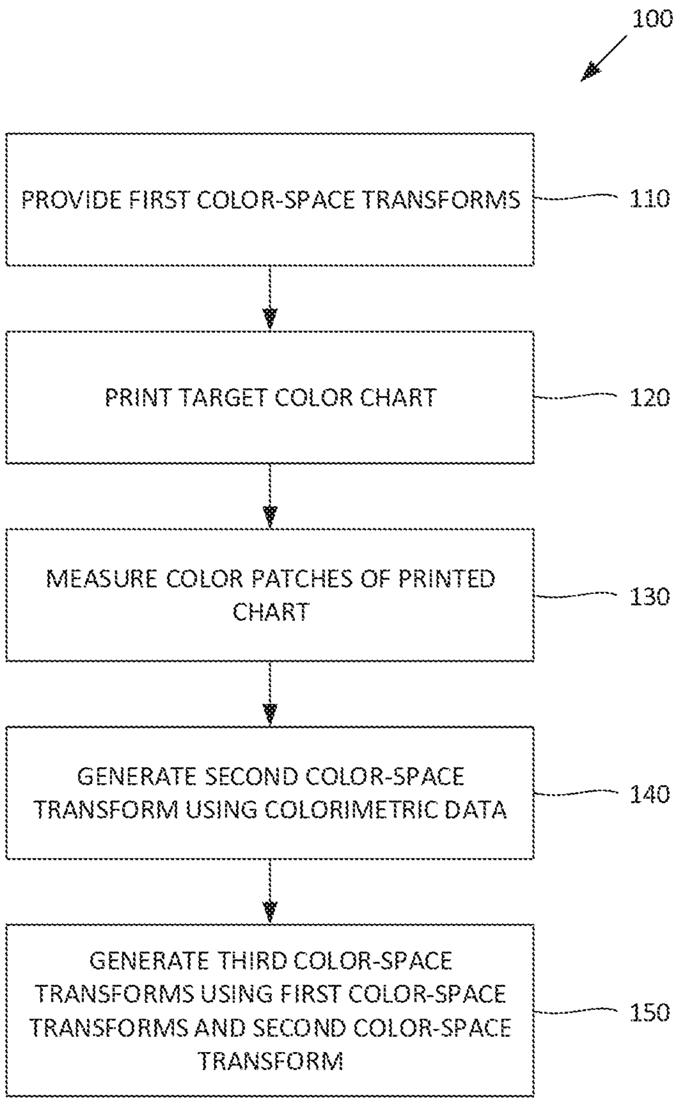
100
PROVIDE FIRST COLOR-SPACE TRANSFORMS
110
PRINT TARGET COLOR CHART
120
MEASURE COLOR PATCHES OF PRINTED CHART
130
GENERATE SECOND COLOR-SPACE TRANSFORM USING COLORIMETRIC DATA
140
GENERATE THIRD COLOR-SPACE TRANSFORMS USING FIRST COLOR-SPACE TRANSFORMS AND SECOND COLOR-SPACE TRANSFORM
150

Fig. 4

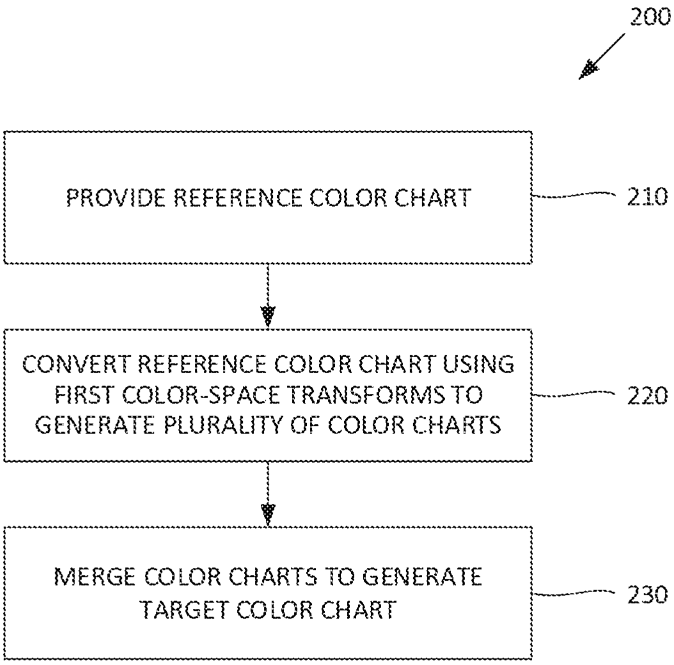
200
PROVIDE REFERENCE COLOR CHART
210
CONVERT REFERENCE COLOR CHART USING FIRST COLOR-SPACE TRANSFORMS TO GENERATE PLURALITY OF COLOR CHARTS
220
MERGE COLOR CHARTS TO GENERATE TARGET COLOR CHART
230

Fig. 5

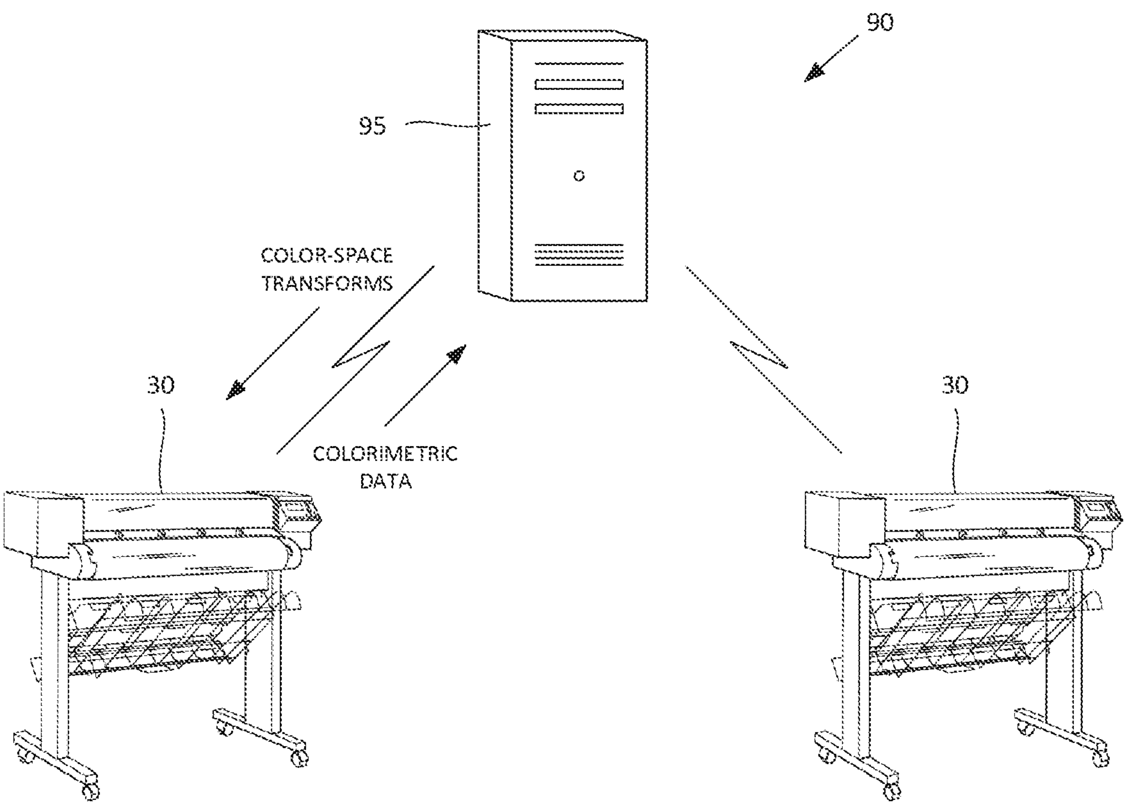

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2020/043379

A. CLASSIFICATION OF SUBJECT MATTER

G06F 3/12 *(2006.01)*
H04N 1/60 *(2006.01)*

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)

G06F 3/00, 3/12, H04N 1/00, 1/60, G09G 5/10

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 practicable, search terms used)

PatSearch (RUPTO Internal), USPTO, PAJ, Espacenet, Information Retrieval System of FIPS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2476556 A1 (IN.TE.SA. S.P.A) 18.07.2017, paragraphs [0018], [0008]-[0012], [0035], [0038], [0048], [0052], [0053], [0056], [0063]-[0065]	1-3, 5-12
Y		4
Y	US 2010/0289835 A1 (HOLUB RICHARD A.) 18.11.2010, paragraphs [0257], [0410]	4
A	US 2016/0075880 A1 (CABOT CORPORATION) 17.03.2016	1-12
A	JP 2011097548 A (FUJIFILM CORP) 12.05.2011	1-12
A	US 2008/0253649 A1 (XEROX CORPORATION) 16.10.2008	1-12

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Date of the actual completion of the international search

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