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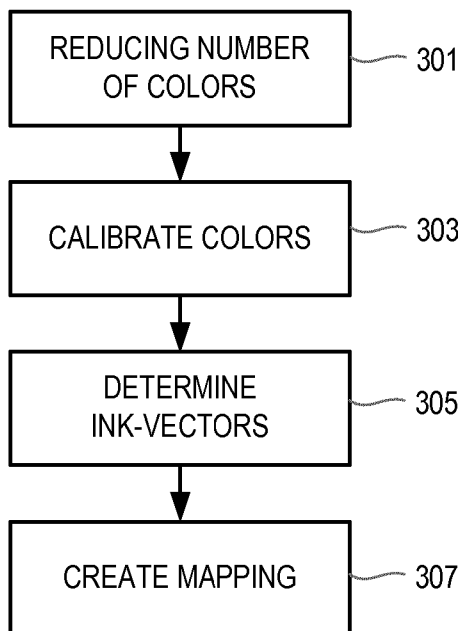
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[Continued on next page]

(54) Title: COLOR IMAGE PROCESSING



(57) Abstract: A color input image comprising a plurality of pixels, each pixels encoded in RGB color space, is processed to convert the RGB pixels to another color space domain for printing the color input image. The number of colors within a cell of the input image is reduced (301). Each cell comprises an NxM array of pixels and the number of colors is reduced to a maximum of b source colors, wherein b is a positive integer equal to or greater than 2. Each of the resulting colors of each cell is calibrated (303) to generate a printable color. The cells are then processed to convert the pixels of each cell into another color space, for example, to determining (305) ink-vectors, in the another color space, for each calibrated color.

Fig. 3

WO 2014/177172 A1

TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, 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))*

## COLOR IMAGE PROCESSING

### BACKGROUND

- 5 All printers implement some data transformation that converts pixels in sRGB (or in any other color space) to drops on paper, and ultimately to printed objects of a given colorimetry. This transformation is done following a set of requirements intended to provide the desired image quality, printing speed or any other attribute.
- 10 This transformation is achieved by a plurality of pipeline stages which transform a continuous tone image (usually RGB, 24 bits per pixel) to a halftone image (usually CMYK).

### BRIEF DESCRIPTION OF DRAWINGS

- 15 For a more complete understanding, reference is now made to the following description taken in conjunction with the accompanying drawings in which:
- 20 Figure 1 is a simplified schematic diagram of a color printing system according to an example;
- Figure 2 is a simplified schematic diagram of an apparatus for processing a color image data according to one example;
- 25 Figure 3 is a flowchart of method of processing a color image data;
- Figure 4 is an illustration of an example of pixel cell of a color image in an uncompressed format;
- 30 Figure 5 is an illustration of the cell of Figure 3 reduced to 2 colors; and
- Figure 6 is a block diagram of an example of a computing environment according to the printing system of Figure 1.

- 35 DETAILED DESCRIPTION

Figure 1 illustrates an example of a printing system and image processing 100. Printing system 100 can be implemented, at least in part, by one or more suitable computing devices, such as computing device 102. Other computing devices that may be used include, but are not limited to, a personal computer, a laptop computer, a desktop  
5 computer, a digital camera, a personal digital assistance device, a cellular phone, a video player, and other types of image sources.

In one implementation, an image 104 is uploaded to the computing device 102 using input device 106. In other implementations, the image may be retrieved from a  
10 previously generated image set contained on a storage media, or retrieved from a remote storage location, such as an online application, using the Internet. Image 104 may be a still digital image created by a digital camera, a scanner, or the like. In other implementations the image may be a moving image such as a digital video. Image 104 may be sent to an output device such as printing device 108 by the computing device  
15 102. Other printing devices that may be used include, but are not limited to, a dot-matrix printer, an inkjet printer, a laser printer, line printer, a solid ink printer, and a digital printer. In other implementations, the image may be displayed to a user on an output device 108 including, but not limited to, a TV set of various technologies (Cathode Ray Tube, Liquid Crystal Display, plasma), a computer display, a mobile  
20 phone display, a video projector, a multicolor Light Emitting Diode display, and the like.

In one implementation, the printing system 100 comprises image processing apparatus 110. The image processing apparatus 110 may be integral with the computing device 102 or the printing device 108. The image processing apparatus may utilise Halftone  
25 Area Neugebauer Separation (HANS) techniques to process the input image 104 into a printable format.

The apparatus 110 for processing a color input image, as shown in Figure 2, comprises a color reducer 201 having an input connected to an input terminal 203 of the  
30 apparatus 110. The output of the color reducer 201 is connected to a calibrator 205. The calibrator is connected to a converter 207 and the converter is connected to the input of a mapper 209. The output of the mapper 209 is connected to an output terminal 211.

Operation of the apparatus 110 will now be described with reference to Figure 3. The color reducer 201 receives a color input image 104 on the input terminal 203 of the apparatus 110. The color input image comprises a plurality of pixels, each pixel is encoded in RGB color space. The color reducer 201 is configured to reduce 301 the number of colors within a cell of the input image 104 to a maximum of at least 2 source colors. The number of colors in a cell may be reduced to any number of colors as required, for example, 4, 5, 6, 7 and 8 colors. In this example, it is assumed that the number of colors within a cell is reduced to a maximum of 2 colors. First, the input image 104 is divided into a plurality of substantially equal cells of NxM array of pixels, where N may equal M, for example, a 4x4 pixel array.. If there 2 colors or less, the colors of the cell are maintained and encoded as they are. Each of the 2 colors of each cell is calibrated 303 by the calibrator 205. Next the calibrated colors are processed for converting the pixels of each cell into another color space domain for printing the input image, for example, linearization, color space conversion, and halftoning, such tone dependent halftoning. In the example, shown in Figure 3, ink-vectors, defined in the another color space, are determined 305 for each of the 2 source colors by the converter 207. Finally a mapping is created, 307, of each pixel of the NxM array according to the determined ink-vector by the mapper 209. The output of the mapper 209 on the output terminal 211 provides the color image for printing by the printer device 108. In an example, it outputs a halftone image for printing.

In more detail each of the stages of calibration 203, conversion 205 and mapping 207 of the RGB colors is carried out on an image data having a compressed format in which an NxM pixel cell is reduced into 2 RGB colors and a mask. This is illustrated, in an example, in Figures 3 and 4 with respect to a 4x4 pixel cell. Each pixel 301\_1 to 301\_16 is defined by respective Red 303\_1 to 303\_16, Green 305\_1 to 305\_16 of the cell and Blue 307\_1 to 307\_16 bytes. Therefore, for a continuous tone RGB image, each of these pixels need 3 bytes in order to be represented in RGB and therefore the bandwidth required to process contone pixels is very high.

In the example of Figure 4, the number of different colors within the cell is determined. If the number of colors exceeds 2 colors, the number of colors is reduced, for example, using a technique known as color cell compression. The 4x4 pixel cell of Figure 3 is then encoded by a mask 405, 407 of 1 bit for each of the 4x4 pixels indicating if that pixel is mapped to a first color 401 coded by the red, green and blue bytes 409, 411, 413, or to a second color coded by the red, green and blue bytes 415, 417, 419. In this

way the cell of 16 pixels of this example is encoded using only 8 bytes 405, 409, 411, 413, 407, 415, 417, 419 of Figure 4 instead of 3 bytes for each of the 16 pixels.

The color calibration RGB to RGB is carried out by first dividing the RGB color space into, for example, 16 cubes for each dimension. The upper bits of the RGB pixels are used to select the cube for that pixel. Then the final output color is calculated performing tetrahedral interpolations within that cube. This step is performed only for each of the 2 colors in the NxM cell, requiring only 8 bytes of the example of Figure 4 to be processed.

10

Next each reduced RGB color is represented as a collection of Neugebauers Primaries (NPs) and the probabilities associated to it. For example a purple color may be represented with 20% probability of White + 30% probability of Cyan + 20% probability of magenta + 20% probability of CyanMagenta. The ink-vectors (e.g. NPacs) are determined for each of the 2 colors of the NxM cell. This is achieved by dividing the RGB space into a plurality of cubes (for example 16 cubes for each dimension). A cube for each color is selected based on the upper bits of the color. At least 4 vertices of the selected cube is selected. Tetrahedral interpolation of the selected vertices is performed. From this a set of NPacs is selected. A halftone matrix is applied to select an Npac rom the set of NPacs for each of the 2 colors. This is very expensive computationally. This step is performed only for each of the 2 colors in the NxM cell, greatly reducing the computational effort.

20

The final mapping stage may comprise HANS halftoning. In one implementation, the NPacs utilize a set of equations referred to as the Neugebauer equations. Neugebauer equations are tools for characterizing color printing systems based upon halftoning techniques. The Neugebauer equations, are associated with colors referred to as the Neugebauer Primaries, which in a binary (bi-level) printing device, are the  $2^n$  combination of n inks, wherein the application of each of the n inks is at either 0% or 100% within an n-dimensional ink space. Generally, the number of Neugebauer Primaries (NPs) is  $k^n$ , where k is the number of levels at which an ink can be used and n is the number of inks. For example, for a printer comprising six different inks either 0, 1, or 2 drops of each ink may be specified at each halftone pixel, resulting in 36 or 729 Neugebauer Primaries (NPs).

30

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The printing device 108 will direct the image 104 to be printed upon a substrate 116 as dictated by the image processing apparatus 110. The substrate 116 may include, without limitation, any variety of paper (lightweight, heavyweight, coated, uncoated, paperboard, cardboard, etc.), films, foils, textiles, fabrics, or plastics.

5

It should be noted that while printing system 100 is described in the context of image processing in a computing environment, it is to be appreciated and understood that it can be employed in other contexts and environments involving other types of data processing without departing from the spirit and scope of the claimed subject matter.

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Figure 5 is a schematic block diagram of an exemplary general operating system 500. The system 500 may be configured as any suitable system capable of implementing interactive user interface 110 and associated color processes. In one exemplary configuration, the system comprises at least one processor 502 and a memory 504.

15

The processing unit 502 may be implemented as appropriate in hardware, software, firmware, or combinations thereof. Software or firmware implementations of the processing unit 502 may include computer- or machine-executable instructions written in any suitable programming language to perform the various functions described.

20

Memory 504 may store programs of instructions that are loadable and executable on the processor 502, as well as data generated during the execution of these programs. Depending on the configuration and type of computing device, memory 504 may be volatile (such as RAM) and/or non-volatile (such as ROM, flash memory, etc.). The system may also include additional removable storage 506 and/or non-removable

25

storage 508 including, but not limited to, magnetic storage, optical disks, and/or tape storage. The disk drives and their associated computer-readable medium may provide non-volatile storage of computer readable instructions, data structures, program modules, and other data for the communication devices.

30

Memory 504, removable storage 506, and non-removable storage 508 are all examples of the computer storage medium. Additional types of computer storage medium that may be present include, but are not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CDROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by the computing device 102.

35

Turning to the contents of the memory 504 in more detail, may include an operating system 510 for the image processing apparatus. For example, the system 500 illustrates architecture of these components residing on one system or one server.

5 Alternatively, these components may reside in multiple other locations, servers, or systems. For instance, all of the components may exist on a client side. Furthermore, two or more of the illustrated components may combine to form a single component at a single location.

10 In one implementation, the memory 504 includes the printing interface 110a data management module 512, and an automatic module 514. The data management module 512 stores and manages storage of information, such as images, ROI, equations, and the like, and may communicate with one or more local and/or remote databases or services. The automatic module 514 allows the process to operate  
15 without human intervention.

The system 500 may also contain communications connection(s) 516 that allow processor 502 to communicate with servers, the user terminals, and/or other devices on a network. Communications connection(s) 516 is an example of communication  
20 medium. Communication medium typically embodies computer readable instructions, data structures, and program modules. By way of example, and not limitation, communication medium includes wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media. The term computer readable medium as used herein includes both storage  
25 medium and communication medium.

The system 500 may also include input device(s) 518 such as a keyboard, mouse, pen, voice input device, touch input device, etc., and output device(s) 520, such as a display, speakers, printer, etc. The system 500 may include a database hosted on the  
30 processor 502. All these devices are well known in the art and need not be discussed at length here.

The calibration and conversion stages 203, 205 are performed using the compressed RGB Format i.e. the processes are performed for the 2 colors of the cell. As a result,  
35 pixels can be processed 8 times faster for processing 2 RGB pixels instead of 16 for a 4x4 cell.

Given that that 80% of the work is performed 8 times faster, using Amdahl's law the total speed up is as follows:

$$\text{totalspeedup} = \frac{1}{(1-p) + \frac{p}{s}} = \frac{1}{(1-0.8) + 0.8/8} = 3.33$$

5

wherein  $p$  is the percentage of work done with the compressed format (reduced colors) RGB optimization, 80% in the example above,  $s$  is the speedup of the optimized part, 8 times in the example above.

10 This reduces the system bandwidth, provides very efficient, high throughput in the stages of image processing, running almost 4 times faster. The cost of components of the image processor is reduced as smaller FPGA, cheapest GPU/CPU can be utilised.

15 While the method, apparatus and related aspects have been described with reference to certain examples, various modifications, changes, omissions, and substitutions can be made without departing from the spirit of the present disclosure. It is intended, therefore, that the method, apparatus and related aspects be limited only by the scope of the following claims and their equivalents. The features of any dependent claim may be combined with the features of any of the independent claims or other dependent  
20 claims.

CLAIMS

1. A method of processing a color input image comprising a plurality of pixels, each pixel encoded in RGB color space, to convert the RGB pixels to another color space domain for printing the color input image, the method comprising the steps of:
- 5 (a) reducing the number of colors within a cell of an input image, each cell comprising an NxM array of pixels, to b source colors, if it is determined that the number of colors is greater than b, wherein b is a positive integer equal to or greater than 2;
- 10 (b) calibrating each of the colors resulting from step (a) of each cell to generate a printable color; and
- (c) processing the calibrated colors for converting the pixels of each cell into another color space domain for printing the input image.
- 15
2. A method according to claim 1, wherein the step of calibrating comprises:
- dividing the RGB color space into a plurality of cubes for each dimension;
- for each source color of each cell reduced by step (a), selecting the cube containing that color;
- 20 calculating the location of each source color of each cell reduced by step (a) within the selected cube, the calculated location locating the printable color.
3. A method according to claim 2, wherein the step of calculating the location of each reduced color within the selected cube comprises
- 25 performing tetrahedral interpolations within the selected cube for each source color of each cell reduced by step (a).
4. A method according to claim 2, wherein the step of processing comprises:
- determining an ink-vector, in the another color space, of each calibrated
- 30 color.
5. A method according to claim 4, wherein the step of determining the ink-vector of each calibrated color comprises: for each selected cube,
- selecting at least 4 vertices of the cube and their corresponding ink-
- 35 vectors;

interpolate the at least 4 ink-vectors to generate a set of ink-vectors;  
and  
applying a halftone matrix to the set of ink-vectors to select a single  
ink-vector from the set of ink-vectors.

5

6. A method according to claim 1, wherein the method further comprises the step of:  
(d) creating a mapping for each pixel of the cell according to the determined  
ink-vector.

10 7. A method according to claim 1, wherein the step of processing comprises at least  
one of:

linearization, color space conversion, and halftoning.

8. A method of printing, the method comprising the steps of:

15 (a) reducing the number of colors within a cell of an input image, each cell  
comprising an NxM array of pixels, to 2 colors, if it is determined that the number  
of colors is greater than 2;

(b) calibrating each of the colors of each cell reduced by step (a);

(c) determining the NPs to represent each of the colors of each cell

20 reduced by step (a);

(d) creating a mapping of each pixel of the cell according to the determined  
ink-vector; and

(e) printing the input image based on the mappings.

25 9. Apparatus for processing a color image data comprising a plurality of pixels  
encoded in RGB color space to convert the RGB pixels to another color space domain,  
the apparatus comprising:

a color reducer configured to reduce the number of colors within a cell of an  
input image, each cell comprising an NxM array of pixels to 2 colors, if it is  
30 determined that the number of colors is greater than 2;

a calibrator configured to calibrate each of the colors of each cell reduced  
by step (a); and

a converter configured to process the calibrated colors for converting the  
pixels of each cell into another color space domain for printing the input image.

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10. Apparatus according to claim 9, wherein the converter is configured to:  
determine an ink-vector, in the another color space, of each calibrated color.
11. Apparatus according to claim 10, wherein the apparatus further comprises  
5 a mapper configured to map each pixel of the cell according to the  
determined ink-vectors.
12. A printing system for printing a color input image, the color input image  
comprising a plurality of pixels encoded in RGB color space, in another color space  
10 domain, the system comprising  
an image processing apparatus, the image processing apparatus comprising:  
a color reducer configured to reduce the number of colors within a cell of an  
input image, each cell comprising an NxM array of pixels to 2 colors, if it is  
determined that the number of colors is greater than 2;  
15 a calibrator configured to calibrate each of the colors of each cell reduced  
by the color reducer;  
a converter configured to determine an ink-vector, in the another color  
space, for each calibrated color;  
a mapper configured to create a mapping of each pixel of the cell according  
20 to the determined ink-vectors; and  
a printing device configured to print the color input image based on the mapping.
13. One or more computer-readable storage media comprising instructions stored  
thereon, the when executed, direct a processor to perform a method comprising:  
25 (a) reducing the number of colors within a cell of an input image, each cell  
comprising an NxM array of pixels, to b source colors, if it is determined that the  
number of colors is greater than b, wherein b is a positive integer equal to or  
greater than 2;  
(b) calibrating each of the colors resulting form step (a) of each cell to  
30 generate a printable color; and  
(c) processing the calibrated colors for converting the pixels of each cell into another  
color space domain for printing the input image

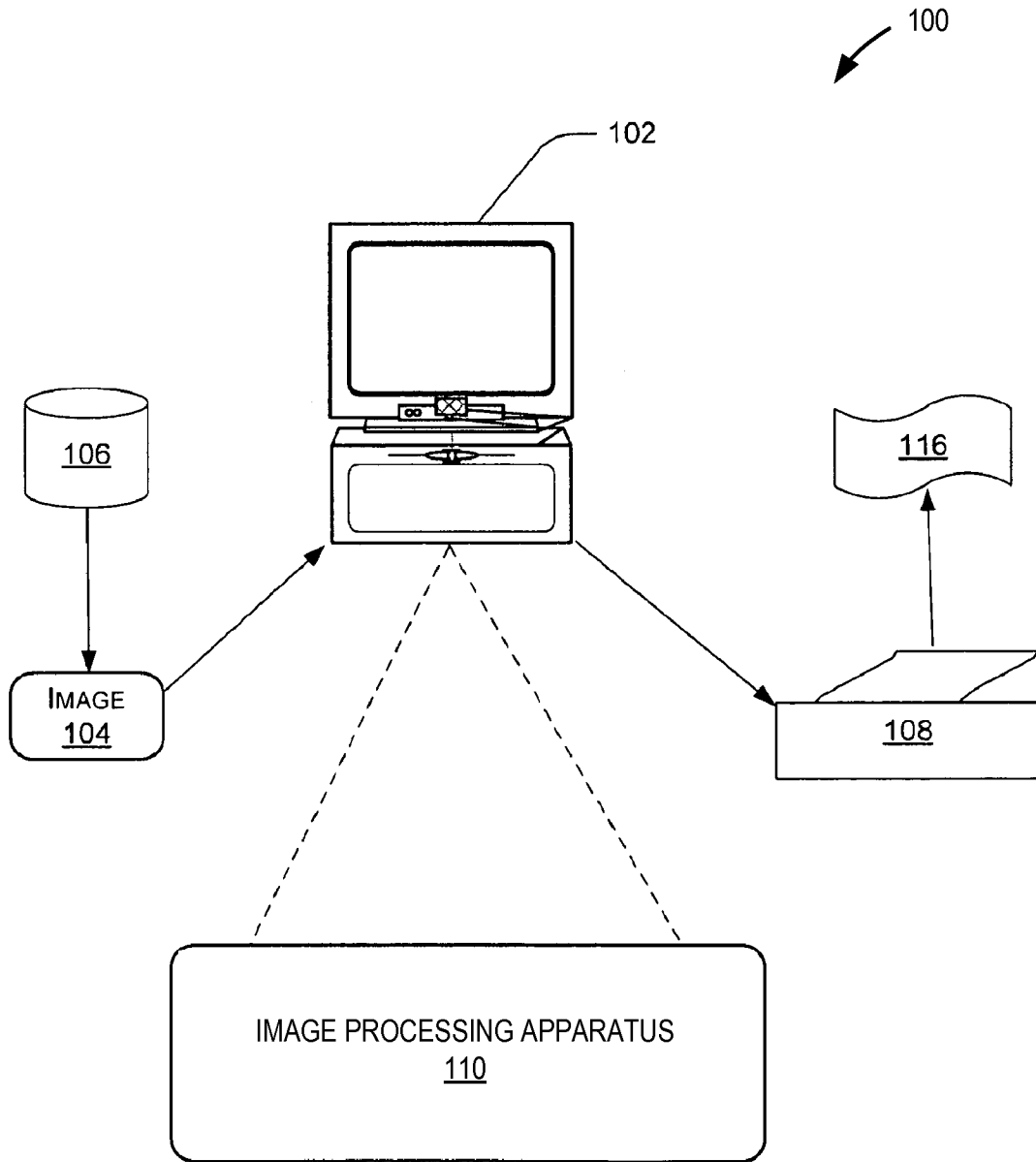


Fig. 1

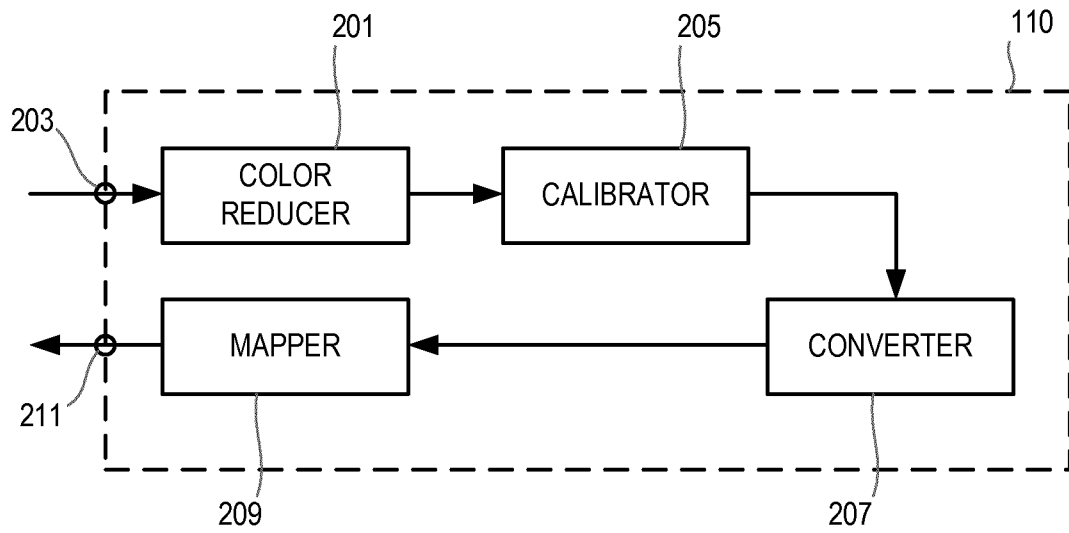


Fig. 2

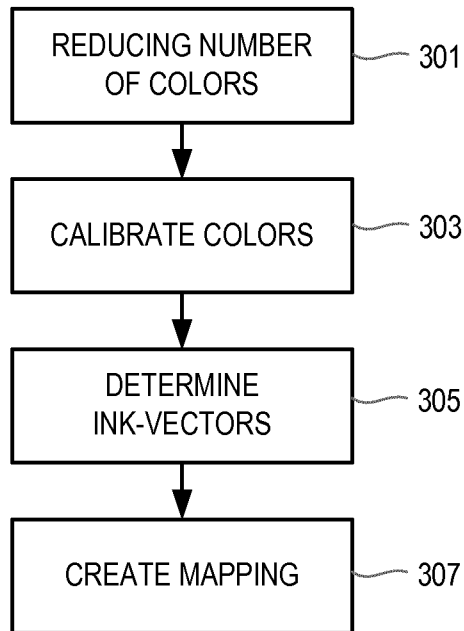


Fig. 3

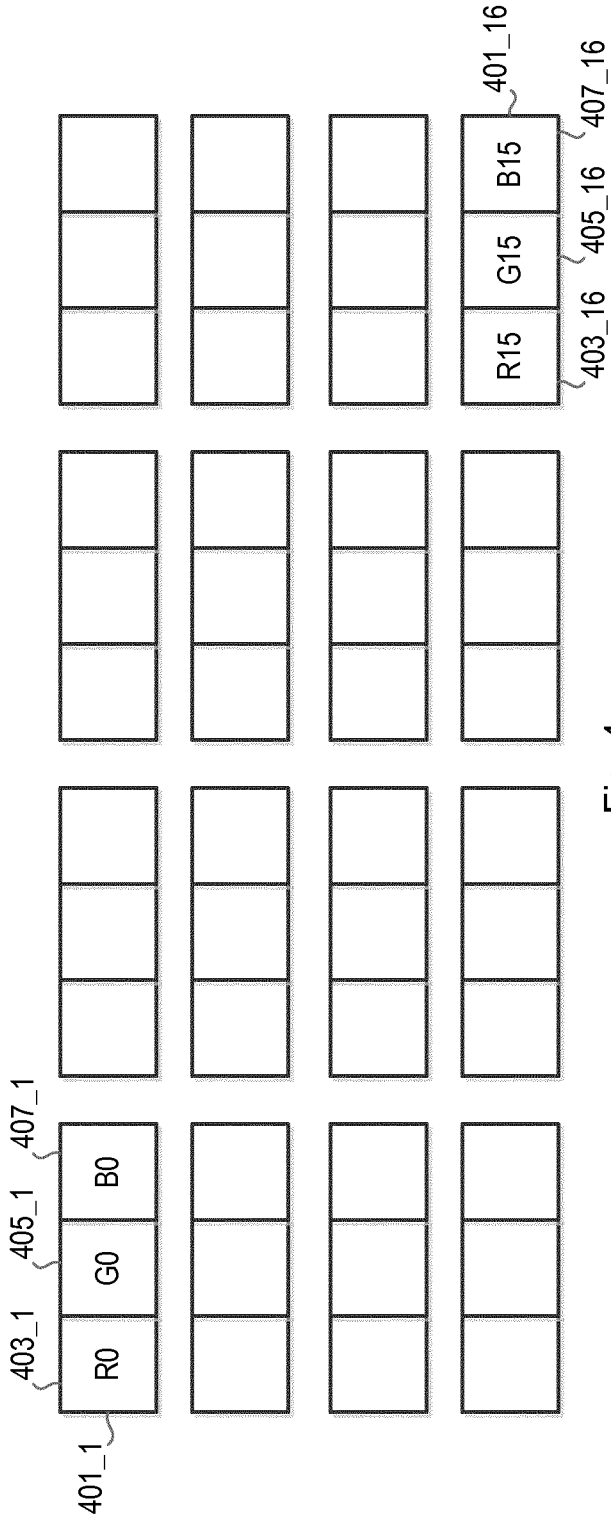


Fig. 4

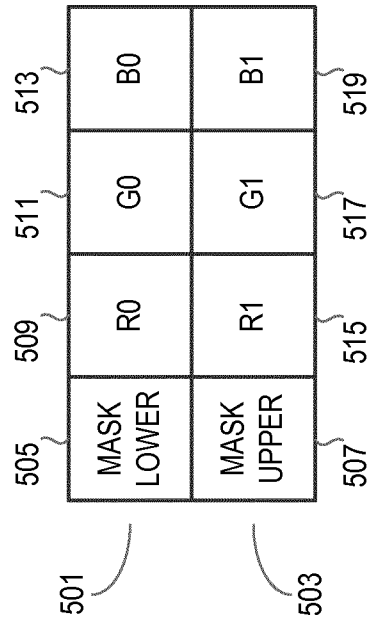


Fig. 5

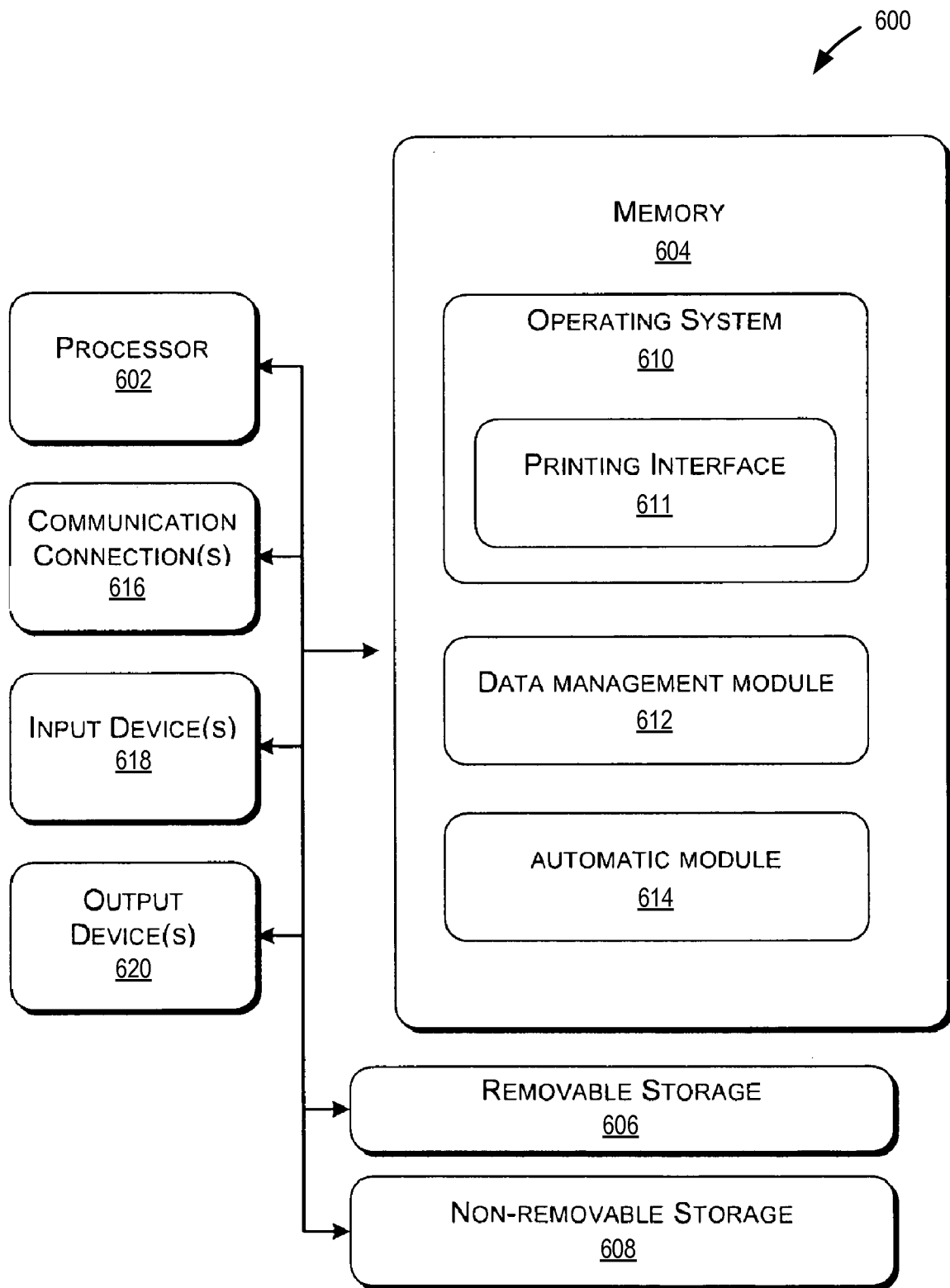


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2013/058862

A. CLASSIFICATION OF SUBJECT MATTER  
INV. H04N1/60 H04N1/64  
ADD.  
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 practicable, 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.
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X	US 2012/236337 A1 (SHIMOSATO HIROAKI [JP]) 20 September 2012 (2012-09-20) paragraphs [0057] - [0081] ----- -/--	1-13

Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents :

<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"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)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"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</p> <p>"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</p> <p>"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</p> <p>"&amp;" document member of the same patent family</p>
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Date of the actual completion of the international search <b>8 January 2014</b>	Date of mailing of the international search report <b>15/01/2014</b>
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer <b>Hardell, Alexander</b>
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## INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2013/058862

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2013/058862

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