(12) PATENT
(19) AUSTRALIAN PATENT OFFICE

(11) Application No. AU 200050188 B2
(10) Patent No. 761896

(54) Title
Image reconstruction architecture

(51)[6] International Patent Classification(s)
H04N 001/46

(21) Application No: 200050188

(22) Application Date: 2000.05.15

(87) WIPO No: WO00/70863

(30) Priority Data

(31) Number	(32) Date	(33) Country
09/314573	1999.05.18	US

(43) Publication Date : 2000.12.05
(43) Publication Journal Date : 2001.02.08
(44) Accepted Journal Date : 2003.06.12

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(56) Related Art
US 5212770
US 5467412
US 5384648

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H04N 1/46 — A2

(11) International Publication Number: **WO 00/70863**

(43) International Publication Date: 23 November 2000 (23.11.00)

(21) International Application Number: PCT/US00/13390

(22) International Filing Date: 15 May 2000 (15.05.00)

(30) Priority Data:
09/314,573 18 May 1999 (18.05.99) US

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(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, 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, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, 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, GW, ML, MR, NE, SN, TD, TG).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: IMAGE RECONSTRUCTION ARCHITECTURE

(57) Abstract

An improved method and apparatus for reconstructing digitzed images processes one or more color formats, e.g. contone or 1-bit, and readily operates with both single and multiple scan systems. The preferred embodiment of the invention provides an image reconstruction path that receives a digitized image, e.g. from a scanner or from memory. The output of the image reconstruction path is a processed RGB or CMYK image that may be printed or stored in memory. The image reconstruction path itself is configured to operate in either of a multiple or single scan environment if the source of the digitized image is a scanner. Within the image reconstruction path there is a plurality of functional units that can be controlled by user or internal controls, or that can be optionally bypassed. These functional units include a preliminary color adjustment function, an automatic deskew function, a background and dust removal function, a descreen function, a text detection and enhancement function, a color conversion function, a scaling function, and a color manipulation function.

Image Reconstruction Architecture

BACKGROUND OF THE INVENTION

TECHNICAL FIELD

The invention relates to the processing of digitized images. More particularly, the invention relates to an image reconstruction architecture in which digitized images that are obtained from an image source, such as a scanner, are processed for output to an output device, such as a printer.

DESCRIPTION OF THE PRIOR ART

In image processing, image signals typically undergo various adjustments or corrections. For example, when printing a digitized image these adjustments and corrections can include:

- Color adjustment;
- Deskewing;
- Background and dust removal;
- Descreening;
- Text detection;
- Text Enhancement;
- Color conversion;
- Scaling; and
- Color manipulation.

In most image processing systems, digitized image signal correctors perform the adjustments or corrections based on the processing parameters provided by the operators.

The task of selecting the appropriate processing parameters for these digitized image signal correctors to achieve certain desired output results is normally left to the operator and is one of the more difficult tasks in image processing. As the complexity of the image processing model grows with advances in image processing technology, this task has become even more difficult.

In most if not all adjustments or corrections, the operator typically does not want to know about the particular processing parameters being used, he simply wants to achieve the desired output results. Thus, it is desirable to be able to determine the optimal processing parameters for digitized image signal correctors automatically on an image processing system to correct digitized signals to achieve specified output results for an image.

Examples of automatic or semi-automatic image processing systems include E. Spiegel, M. Broudo, R. Lavie, Y. Bresler, Y. Pluda, E. Baron, *Apparatus and Techniques For Processing of Data Such As Color Images*, U.S. Patent No. 5,615,282 (25 March 1997) and P. Capitant, D. Collier, *Correcting Digitized Signals To Achieve Specified Output Results For An Image*, U.S. Patent No. 5,467,412 (14 November 1995).

However, such systems provide only limited image reconstruction capability. For example, such systems do not incorporate descreening or text detection facilities, such that an image reconstruction subsystem must be appended thereto. Further, such systems do not provide multiple data paths, *e.g.* for single and multiple scans, nor do such systems support both contone and 1-bit printing.

It would be advantageous to provide an improved method and apparatus for reconstructing digitized images.

SUMMARY OF THE INVENTION

According to the present invention, there is provided a method for reconstructing a digitized image provided by a scanner or an image memory, the method including:

providing said digitized image to an image reconstruction path, said image reconstruction path being selectively configurable to process images produced by single scan and multiple scan copy systems, and being selectively configurable to process images for reproduction on 1-bit and contone printing devices, said image reconstruction path capable of producing RGB and CMYK output images; and

providing said output image to any of a printer or an image memory.

Embodiments of the invention provides an improved method and apparatus for reconstructing digitized images. Embodiments of the invention processes one or more color formats, contone or 1-bit, and readily operates with image sources that can include both single and multiple scan systems. For purpose of the discussion herein, multiple scan refers to systems that scan an image once per print separation, i.e. for a CMYK printing system the image is scanned four times, and printing separations for C, M, Y, and K are generated one by one and single scan refers to copy systems that scan an image once for all print separations, e.g. for a CYMK printing system the image is scanned once.

The preferred embodiment of the invention provides an image reconstruction path that receives a digitized image, e.g. from a scanner or from memory. The output of the image reconstruction path is a processed RGD or CMYK image that may be printed or stored in memory. The image reconstruction path itself is configures to operate in either of a multiple scan or single scan environment when the source of the digitized image is a scanner. Within the image reconstruction path there are a plurality of functional units that can be controlled by user or internal controls, or that can be optionally bypassed. These functional units can include any of a preliminary color adjustment function, an automatic deskew function, a background and dust removal function, a descreen function, a text detection and enhancement function, a color conversion function, a scaling function, and a color manipulation function. It will be appreciated by those skilled in the art that other functions may be provided.

The present invention in another aspect provides apparatus for reconstructing a digitized image provided by a scanner or an image memory, the apparatus including:

means for providing said digitized image to an image reconstruction path, said image reconstruction path being selectively configurable to process images produced by single scan and multiple scan copy systems, and being selectively configurable to process images for reproduction on 1-bit and contone printing devices,

said image reconstruction path capable of producing RGB and CMYK output images; and

means for providing said output image to any of a printer or an image memory.

An important feature of an embodiment of this architecture is that it is open-ended on both the input and output ends. This means that with the appropriate customization it is ready to accommodate different scanners at the input source and different printers at the output target.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention might be more fully understood, embodiments of the invention will be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 is a block schematic diagram of a digitized image processing system, including an image reconstruction path according to an embodiment of the invention;

Figs. 2a and 2b provide a processing flow diagram for an image reconstruction path that processes a multipass scanned image according to one embodiment of the invention; and

Figs. 3a and 3b provide a processing flow diagram for an image reconstruction path within a single scan system according to an embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

An embodiment of the invention provides an improved method and apparatus for reconstructing digitized images. One important feature of the invention includes the ability to process one or more color formats, e.g. contone or 1-bit, and to operate upon any image source. For purpose of the discussion herein, multiple scan refers to systems that scan an image once per print separation, i.e. for a CMYK printing system the image is scanned four times,

and printing separations for C, M, Y, and K are generated one by one; and single scan refers to copy systems that scan an image once for all print separations, *e.g.* for a CYMK printing system the image is scanned once.

The preferred embodiment of the invention provides an image reconstruction path that receives a digitized image, *e.g.* from a scanner or from memory. The output of the image reconstruction path is a processed RGB or CMYK image that may be printed or stored in memory. The image reconstruction path itself is configured to operate in either of a multiple scan or single scan environment when the source of the digitized image is a scanner. Within the image reconstruction path there is a plurality of functional units that can be controlled by user or internal controls, or that can be optionally bypassed. These functional units include a preliminary color adjustment function, an automatic deskew function, a background and dust removal function, a descreen function, a text detection and enhancement function, a color conversion function, a scaling function, and a color manipulation function. It will be appreciated by those skilled in the art that other functions may be provided.

Fig. 1 is a block schematic diagram of a digitized image processing system, including an image reconstruction path according to the invention. The image reconstruction path 10 accepts digitized image data from any of several sources, *e.g.* an image that is stored in a memory system 14 in any known format, video 12, for example MPEG or MPEG2 data (which may be cropped 13 or otherwise processed, if desired), JPEG or other image data 16 (such as GIF, TIFF, or PICT data), and RGB data 18, for example from a scanner. In the case of video data, the system provides a mechanism, as is known in the art, for decompressing and deblocking the data, upsampling, and converting YUV to RGB 19.

Thus, the image reconstruction path in the presently preferred embodiment of the invention provides a front end capability for processing any type of digitized image data, although the internal operation of the image reconstruction path is based upon the ultimate receipt of digitized image data in an RGB format. It will be appreciated by those skilled in the art that the image reconstruction path may be configured to operate on digitized image data in any format, and that the presently preferred embodiment of the invention is provided solely for purposes of illustration and example and is not intended to limit the scope of the invention in any way.

The image reconstruction path 10 shown in Fig. 1 is for a single scan system. An appropriate image reconstruction path for a multipass architecture is discussed below in

connection with Figs. 2a and 2b. In the image reconstruction path, each functional unit can be controlled by either of a user or by internal controls.

Additionally, inclusion of each of the functional units in the image reconstruction path is optional.

The system has as its default an automatic behavior which can be suppressed by the operator, either by turning some automatic functions ON or OFF, or by controlling the parameter settings for those functions.

Accordingly, the invention provides a user with the flexibility to include only those functional units of interest to the user. In one embodiment of the invention, the user may select the desired functional units from a selection menu, such that the image reconstruction path is readily reconfigured for each job processed.

Functional units within the image reconstruction path may include any of:

Image rotation, duplexing, and tiling of images.

- Preliminary color adjustment: This functional unit converts the word size of the input image data as desired, and thereby stretches the input data to a desirable dynamic range. For example, the preliminary color adjustment functional unit receives images data from the scanner at 8-12 bits per component and returns 8-bit adjusted RGB values through the use of one-dimensional curves.

  This is done by using a look-up-table (LUT) sized by the number of possible input combinations, *e.g.* 4096 entries for 12 bit input.

- Automatic deskew: This functional unit performs small angle corrections for originals that are misplaced on the scanner's glass during the scanning process. Such techniques are well known in the art.

  Background and dust removal: This functional unit removes noise, dust, and uniform background, as requested by the user. Such techniques are well known in the art.

- Halftone detection: This functional unit detects areas of the image that were originally printed using a halftoning process, *i.e.* screen or error diffusion. The inventor has invented a halftone detection process (see R. Karidi, Image Classification, U.S. Patent Application Serial No. 09/111,047, filed July 7, 1998) which may be used to perform the function of this functional unit. The descreening algorithm disclosed therein preserves soft edges. Therefore, the preferred approach to halftone detection in the exemplary embodiment of the invention marks all possible screen areas for descreening unless sharp edge information is lost thereby, *e.g.* boundaries of graphics and characters.

  In the presently preferred embodiment of the invention, the halftone detection procedure is applied to the intensity component Y of the image. For each pixel, a decision is made whether the pixel is dark or light relative to its neighborhood (which is a 5x5 neighborhood in the presently preferred embodiment of the invention). Each pixel is then considered with a surrounding window (which is currently 9x9 in the presently preferred embodiment of the invention) and the size of the boundary set between the dark and light classes is measured. A pixel is marked as a halftone candidate only if the boundary size is less than a probabilistic estimate.

- Descreen: This functional unit reconstructs a contone image from halftone data obtained during the halftone detection procedure described above. The inventor has invented a descreening process (see R. Karidi, Method and Apparatus for Image Descreening, U.S. Patent Application Serial No. 09/108,270, filed July 1, 1998) which may be used to perform the function of this functional unit. In this procedure, an adaptive, edge-preserving low pass filter is applied to areas that are marked as halftone. For each pixel that is marked as halftone, a descreening kernel is applied to produce a smoothed neighborhood of the pixel. Within this smooth context, locations of those pixels whose values are within a certain threshold of the current pixel are marked. These locations are used to build a 0-1 mask that is applied to the low pass filter kernel. The masked kernel is then convolved with the original, *i.e.* non-smoothed, neighborhood of the current pixel.

  To avoid over-smoothing, the original pixel value is restored if the variation within the original window is smaller than one threshold, or the number of marked pixels is smaller than another threshold.

- Text detection: This functional unit decides which parts of the image contain text. In the presently preferred embodiment of the invention, text comprises black text on a white background, although other text detection schemes may be used. The inventor has invented a text detection process (see R. Karidi, Intelligent Detection Of Text On A Page, U.S. Patent Application Serial No. 09/xxx,xxx, filed April 15, 1999) which may be used to perform the function of this functional unit.

- Text enhancement: This functional unit makes the text clear and sharp. The presently preferred embodiment of the invention only enhances black text on a white background. The inventor has invented a text enhancement process (see R. Karidi, Text Enhancement System, U.S. Patent Application Serial No. 09/111,633 , filed July 7, 1998) which may be used to perform the function of this functional unit. In this embodiment of the invention, the ink component is processed. To get the ink level, *e.g.* 0-255, where 0=white, from the intensity level, a one dimensional look up table (LUT) is applied.

  After rescaling to the printing resolution, the total amount T of ink is a surrounding window (*e.g.* a 5x5 window) is measured. the number of pixels C that are darker than the current pixel are counted. In simplified form, a determination is made as follows: if (T>255 x dot factor x C), then put ink in the current pixel; otherwise leave the pixel white.

  Text enhancement is preferably customized in 1-Bit systems, but need not in contone systems.

- Color conversion: This functional unit converts from scanner color space to the printer/host color space. In the presently preferred embodiment of the invention, the procedure interpolates a color table from the input color space (*i.e.* RGB) to the output color space (*e.g.* RGB or CMYK). The interpolation is either linear (*i.e.* tetrahedral) or multi-linear. The color table is a composition of the scanner calibration table (*e.g.* from scanner RGB to a standardized or proprietary RGB used by the image reconstruction path) and the printing engine's Color Rendering Dictionary (CRD). The inputs to this functional unit include text detection tags to ensure that black text is printed with black ink only. For pixels that were marked as text, a three dimensional table is not typically used. Rather, a separate, Y to K, one dimensional table is used.

- Scale: This functional unit selects the image up/down to map print resolution and the user input. The presently preferred embodiment of the invention used a bi-cubic interpolation. Interpolation for scaling is a well known technique.

- Color manipulation: This function unit supports brightness, color saturation, and contrast adjustments. These functions are implemented through LUT's and linear operations (*e.g.* matrix multiplication).

After the image data have been processed via the image reconstruction path, the reconstructed image data are provided to an output module 20 that formats the image data as RGB/CMYK data, as appropriate for the output device. For example, the output device may be a computer memory 22, in which case the data may be maintained in an RGB format and/or compressed via a compression module 21. If the image data are to be provided to a printed by a printer 23, then the data are formatted as CMY or CMKY data for use by the printer.

Figs. 2a and 2b provide a processing flow diagram for an image reconstruction path that correspond to a multi-scan system according to the invention. Thus, the processing flow shown on Figs. 2a and 2b is traversed four times for a CMYK printer, once for each of the four separations.

During a scan of an image, an input signal 30 is provided to the image reconstruction path. Preliminary color adjustment is performed 31, resulting in an R',G',B' and a Y' signal output 32. The image reconstruction path performs a preliminary tagging operation 33 to produce preliminary color tags 34.

The color conversion procedure 35 is next applied, resulting in a current color signal (CC) and an intensity signal (Y) 36. No use of R', G', B' or Y' information is made form this point on 37 in the image reconstruction path because processing now proceeds for a current color channel in the multi-scan cycle.

The current color and intensity information, along with the preliminary tags, is provided to the dust and background removal function 38, resulting in a clean current color signal, a clean intensity signal, and classification tags 39. Classification tags contain information related to color, *e.g.* an indication of how neutral a pixel is, whether a pixel is within an edge, or whether a pixel is in a high contrast region. The classification tags also record pixel locations for which background removal was applied.

The clean intensity signal is binarized for halftone detection 40, resulting in a binarized intensity signal 41. The binarized intensity signal is then applied to the halftone detection function 42 to produce halftone tags 43.

The clean current color information is smoothed for descreening 44, resulting in smoothed current color information 45. The clean current color information, smoothed current color information, and halftone tags are applied to the descreening functional unit 46, resulting in descreened Current Color and intensity information and halftone tags 47.

The descreened intensity information and the classification tags are then applied to the text detection functional unit 48, resulting in text tags 49. The text tags and scaled intensity information are provided to the text enhancement functional unit 50, resulting in enhanced text and intensity information 51.

The scaled current color, intensity value of the enhanced text, and text tags are applied to a merge text function 52, resulting in reconstructed current color and intensity information. The reconstructed current color and intensity information is applied to the scale functional unit 54, resulting in scaled current color and intensity information 55. The scaled current color and intensity information is applied to a halftone threshold array or error diffusion functional unit 57. Typically, a 1-bit system requires an error diffusion based halftone module, while a contone system requires a threshold array based halftone system. Thereafter, an output is provided 56 to the selected destination, *e.g.* printer or memory.

Figs. 3a and 3b provide a processing flow diagram for an image reconstruction path within a single scan system according to the invention.

During a scan of an image by the scanner, an input RGB signal/ 50 is provided to the image reconstruction path. Preliminary color adjustment is performed/51, resulting in an R',G',B' and a Y' signal output/ 52.

The R',G',B' and Y' information is provided to the dust and background removal function/ 53, resulting in clean R,G,B and Y signals and class tags/54. The clean intensity signal is binarized for halftone detection/ 55, resulting in a binarized intensity signal/ 56. The binarized intensity signal is then applied to the halftone detection function/ 57 to produce halftone tags/ 58.

The clean RGB information is smoothed for descreening/ 59, resulting in smoothed RGB information/ 60. The clean RGB information, smoothed RGB information, and halftone tags are applied to the descreening functional unit/61, resulting in descreened R,G,B and intensity information, halftone tags, and neutral tags/ 62. Neutral tags are similar to classification tags and indicate whether a pixel is neutral or colored.

The descreened intensity information, class tags, halftone tags, and neutral tags are then applied to the text detection functional unit/ 63, resulting in text tags/ 64. The text tags and scaled intensity information are provided to the text enhancement functional unit/ 65, resulting in enhanced text and intensity information/ 66.

The RGB, intensity value of the enhanced text, and text tags are applied to a color conversion function/ 67, resulting in either of RGB or CMYK information/ 68. The reconstructed RGB or CMYK information is applied to the scale functional unit 69, resulting in scaled RGB and intensity information/ 70. There is no need to write this information to memory/ 71.

The RGB/CMYK information is applied to a halftone threshold array or error diffusion functional unit/ 72. Typically, a 1-bit system requires an error diffusion based halftone module, while a contone system requires a threshold array based halftone system. Thereafter, an output RGB/CMYK and text K layer signal is provided 73 to the selected destination, *e.g.* printer or memory.

Although the invention is described herein with reference to the preferred embodiment, one skilled in the art will readily appreciate that other applications may be substituted for those set forth herein without departing from the spirit and scope of the present invention. Accordingly, the invention should only be limited by the Claims included below.

The claims defining the invention are as follows:

1. A method for reconstructing a digitized image provided by a scanner or an image memory, the method including:

providing said digitized image to an image reconstruction path, said image reconstruction path being selectively configurable to process images produced by single scan and multiple scan copy systems, and being selectively configurable to process images for reproduction on 1-bit and contone printing devices, said image reconstruction path capable of producing RGB and CMYK output images; and

providing said output image to any of a printer or an image memory.

2. The method of Claim 1, further including providing a plurality of functional units in said image reconstruction path that can be controlled by user or internal controls, or that can be optionally bypassed.

3. The method of Claim 2, wherein said functional units include any of an image rotation function, a duplexing function, an image tiling function, preliminary color adjustment function, an automatic deskew function, a background and dust removal function, a descreen function, a text detection and enhancement function, a color conversion function, a scaling function, and a color manipulation function.

4. The method of Claim 2, wherein the functional units include a preliminary color adjustment module for converting a word size of input image data to stretch said input data to a desirable dynamic range.

5. The method of Claim 2, wherein the functional units include an automatic deskew module for performing small angle corrections for originals that are misplaced on a scanner's glass during a scanning process.

6. The method of Claim 2, wherein the functional units include a background and dust removal module for removing noise, dust, and uniform background from an image.

7. The method of Claim 2, wherein the functional units include a halftone detection module for detecting areas of an image that were originally printed using a halftoning process.

8. The method of Claim 2, wherein the functional units include a descreen module for reconstructing a contone image from halftone data obtained during a halftone detection procedure.

9. The method of Claim 2, wherein the functional units include a text detection module for deciding which parts of an image contain text.

10. The method of Claim 2, wherein the functional units include a text enhancement module for making a text portion of an image clear and sharp.

11. The method of Claim 2, wherein the functional units include a color conversion module for converting from scanner color space to a printer/host color space.

12. The method of Claim 2, wherein the functional units include a scale module for selecting an image up/down to map print resolution and user input.

13. The method of Claim 2, wherein the functional units include a color manipulation module for adjusting brightness, color saturation, and contrast.

14. The method of Claim 2, wherein the functional units include an image rotation module.

15. The method of Claim 2, wherein the functional units include a duplexing module.

16. The method of Claim 2, wherein the functional units include an image tiling module.

17. Apparatus for reconstructing a digitized image provided by a scanner or an image memory, the apparatus including:

means for providing said digitized image to an image reconstruction path, said image reconstruction path being selectively configurable to process images produced by single scan and multiple scan copy systems, and being selectively configurable to process images for reproduction on 1-bit and contone printing devices,

said image reconstruction path capable of producing RGB and CMYK output images; and

means for providing said output image to any of a printer or an image memory.

18. The apparatus of Claim 17, further including a plurality of functional units in said image reconstruction path that can be controlled by user or internal controls, or that can be optionally bypassed.

19. The apparatus of Claim 18, wherein said functional units include any of an image rotation functional, a duplexing functional, an image tiling functional preliminary color adjustment functional, an automatic deskew functional, a background and dust removal functional, a descreen functional, a text detection and enhancement functional, a color conversion functional, a scaling functional, and a color manipulation functional.

20. A method for reconstructing a digitised image provided by a scanner or an image memory, the method substantially as hereinbefore described and illustrated with reference to the accompanying drawings.

21. An apparatus for reconstructing a digitised image provided by a scanner or an image memory, the apparatus substantially as hereinbefore described and illustrated with reference to the accompanying drawings.

Dated this 2nd day of April 2003

PATENT ATTORNEY SERVICES

Attorneys for

ELECTRONICS FOR IMAGING INC

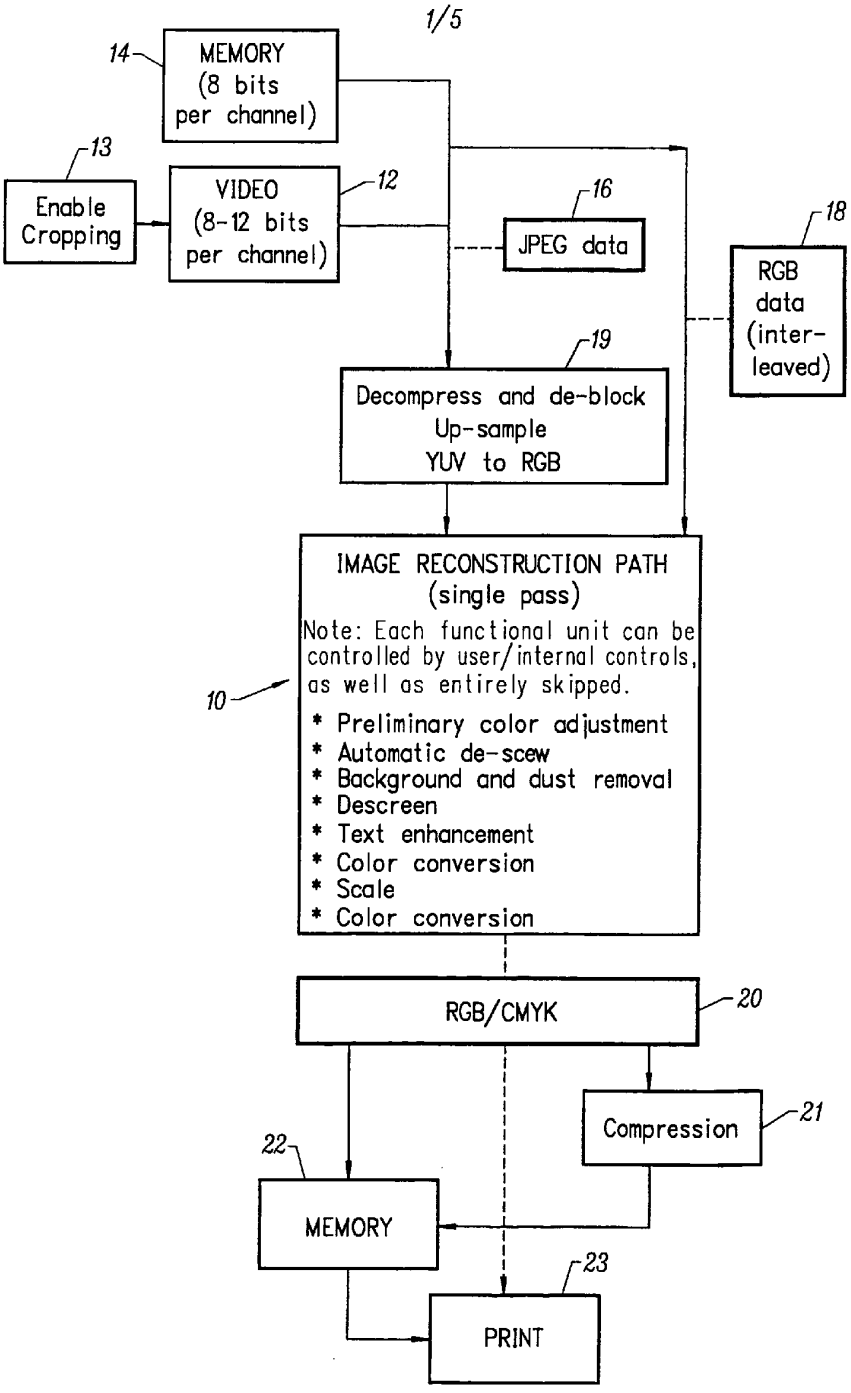
14
MEMORY
(8 bits
per channel)
13
Enable
Cropping
VIDEO
(8-12 bits
per channel)
12
16
JPEG data
18
RGB
data
(inter-
leaved)
19
Decompress and de-block
Up-sample
YUV to RGB
IMAGE RECONSTRUCTION PATH
(single pass)
Note: Each functional unit can be
controlled by user/internal controls,
as well as entirely skipped.
10
* Preliminary color adjustment
* Automatic de-scew
* Background and dust removal
* Descreen
* Text enhancement
* Color conversion
* Scale
* Color conversion
RGB/CMYK
20
Compression
21
22
MEMORY
23
PRINT

FIG. 1

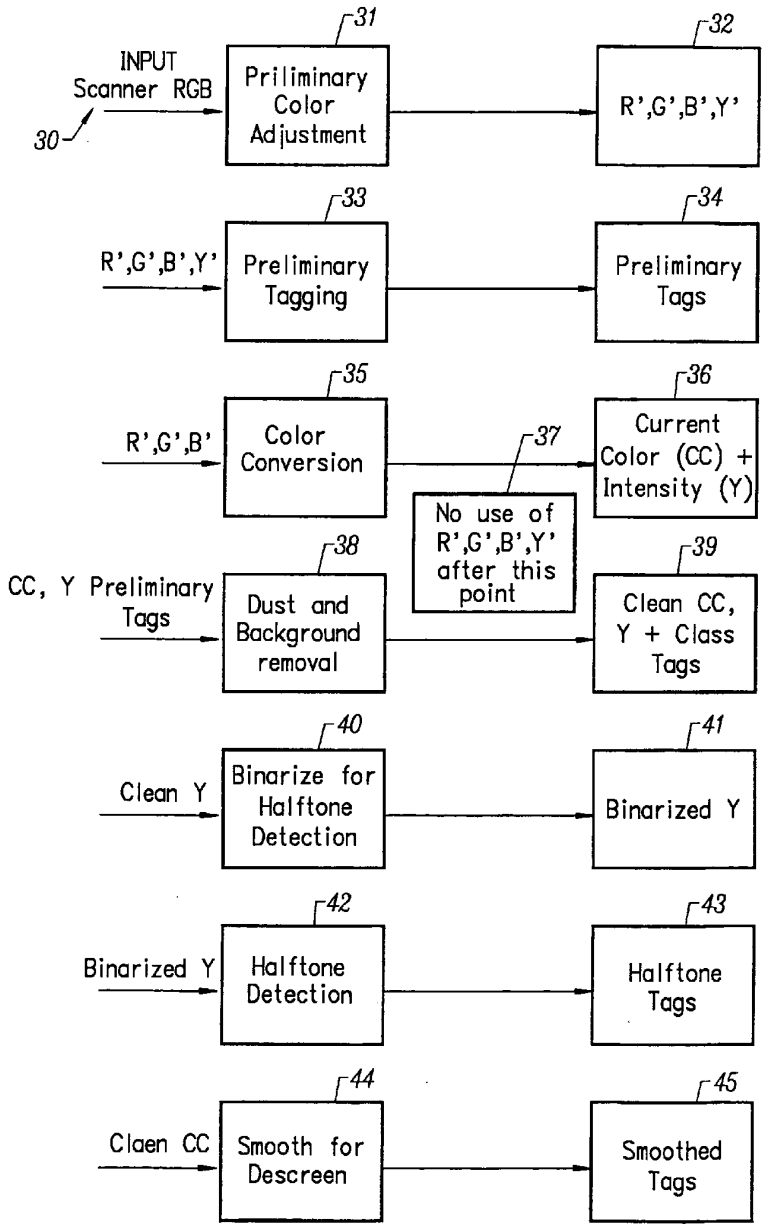
31
32
INPUT
Scanner RGB
30
Priliminary Color Adjustment
R',G',B',Y'
33
34
R',G',B',Y'
Preliminary Tagging
Preliminary Tags
35
36
R',G',B'
Color Conversion
37
Current Color (CC) + Intensity (Y)
No use of R',G',B',Y' after this point
38
39
CC, Y Preliminary Tags
Dust and Background removal
Clean CC, Y + Class Tags
40
41
Clean Y
Binarize for Halftone Detection
Binarized Y
42
43
Binarized Y
Halftone Detection
Halftone Tags
44
45
Claen CC
Smooth for Descreen
Smoothed Tags

FIG. 2A

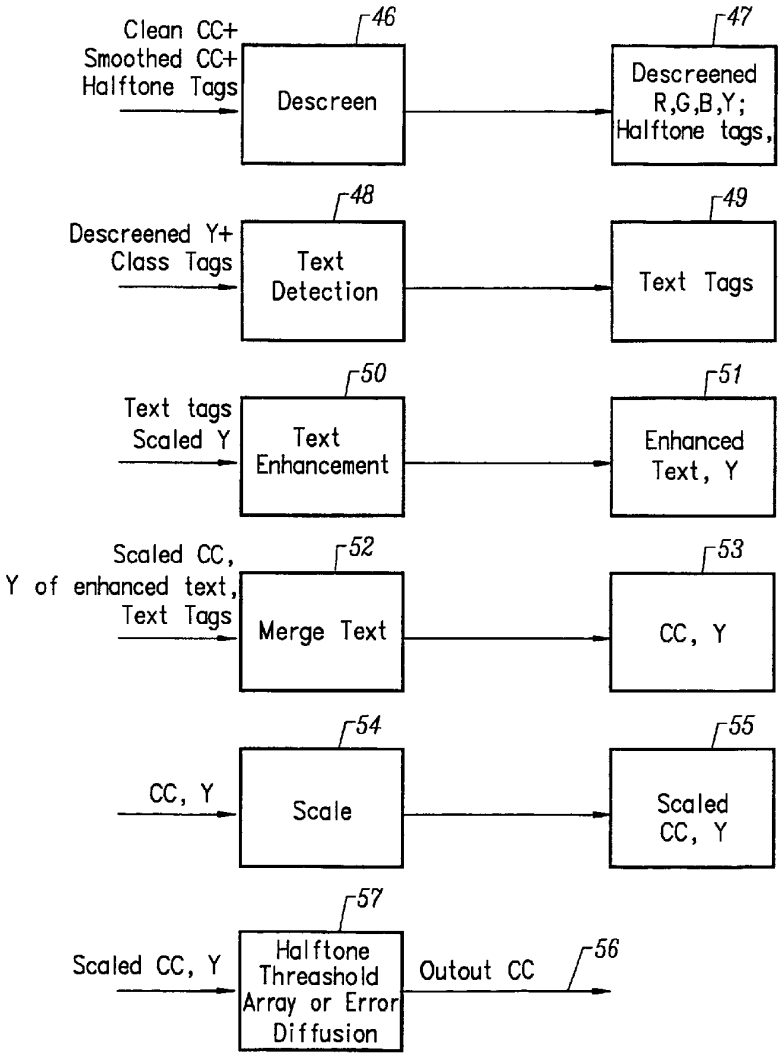
Clean CC+
Smoothed CC+
Halftone Tags
46
Descreen
47
Descreened
R,G,B,Y;
Halftone tags,
Descreened Y+
Class Tags
48
Text
Detection
49
Text Tags
Text tags
Scaled Y
50
Text
Enhancement
51
Enhanced
Text, Y
Scaled CC,
Y of enhanced text,
Text Tags
52
Merge Text
53
CC, Y
CC, Y
54
Scale
55
Scaled
CC, Y
Scaled CC, Y
57
Halftone
Threashold
Array or Error
Diffusion
Outout CC
56

FIG. 2B

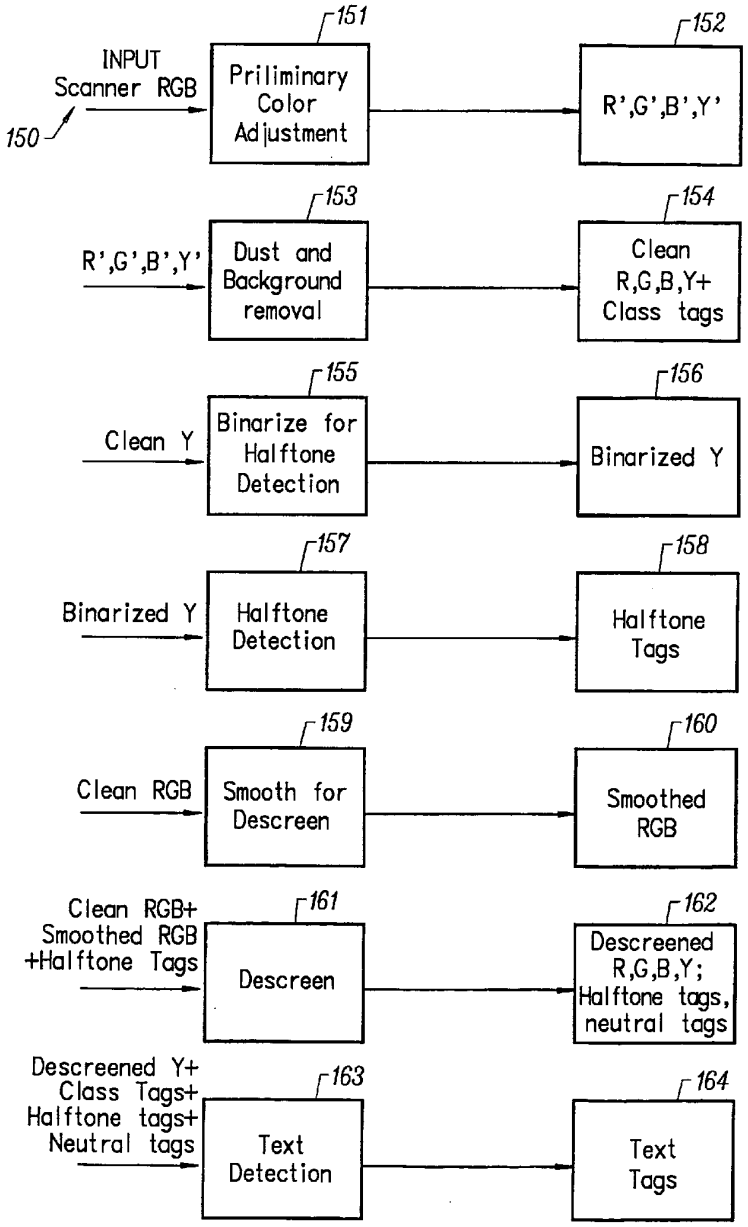
151
152
INPUT
Scanner RGB
150
Priliminary Color Adjustment
R',G',B',Y'
153
154
R',G',B',Y'
Dust and Background removal
Clean R,G,B,Y+ Class tags
155
156
Clean Y
Binarize for Halftone Detection
Binarized Y
157
158
Binarized Y
Halftone Detection
Halftone Tags
159
160
Clean RGB
Smooth for Descreen
Smoothed RGB
161
162
Clean RGB+ Smoothed RGB +Halftone Tags
Descreen
Descreened R,G,B,Y; Halftone tags, neutral tags
163
164
Descreened Y+ Class Tags+ Halftone tags+ Neutral tags
Text Detection
Text Tags

FIG. 3A

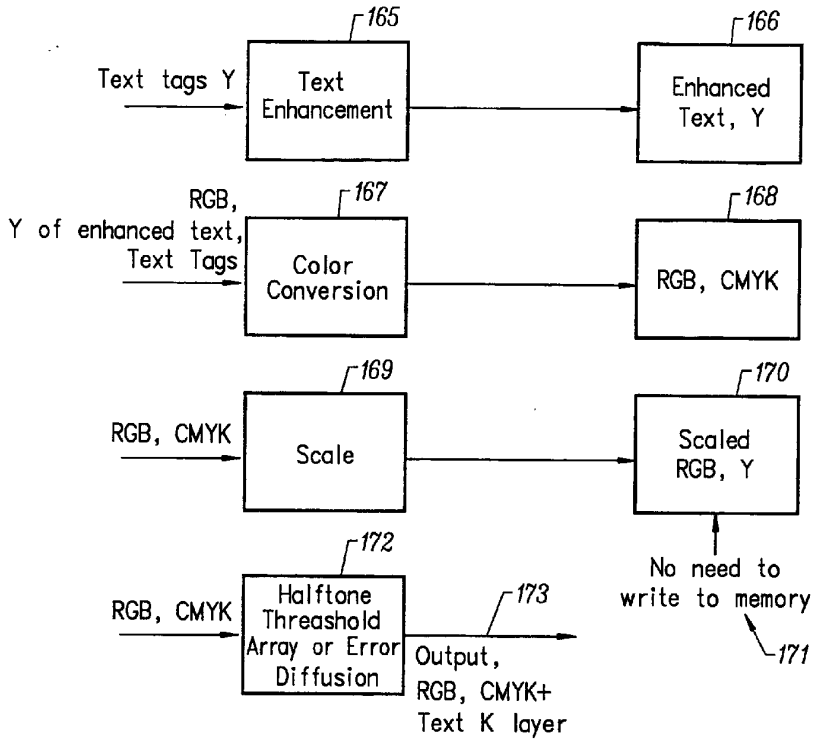
165
Text tags Y
Text Enhancement
166
Enhanced Text, Y
RGB, Y of enhanced text, Text Tags
167
Color Conversion
168
RGB, CMYK
169
RGB, CMYK
Scale
170
Scaled RGB, Y
No need to write to memory
171
172
RGB, CMYK
Halftone Threashold Array or Error Diffusion
173
Output, RGB, CMYK+ Text K layer

FIG. 3B