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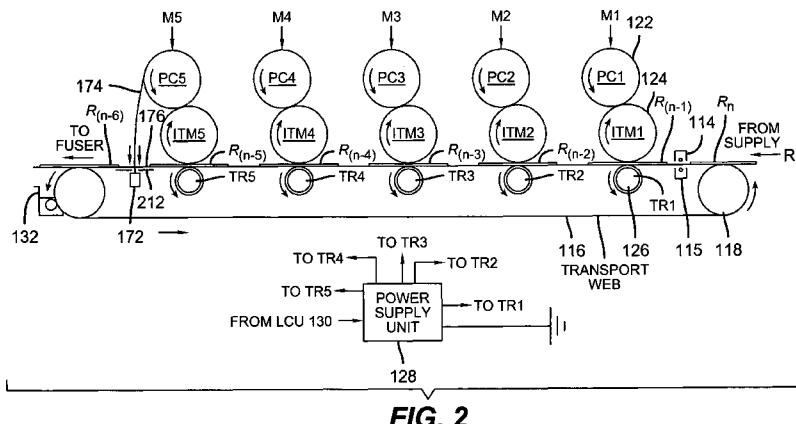
FIG. 2

(57) Abstract: One or more printers or printing systems are connected to a scanning device. Each printer includes one or more color modules that are used during a printing operation. A printer prints a target for each color module or color channel. The printed targets are then scanned by the scanning device. The printed targets may be rotated to any angle and then scanned by the scanning device. The scanned raster data is processed by a controller to detect non-uniformities in at least one density image and to generate one or more correction profiles for the printer. When an image is to be printed, one or more controllers receive the image data and use the one or more correction profiles to correct or compensate for the non-uniformities during the exposure process. A color module may include a LED printhead.

ADAPTIVE EXPOSURE PRINTING AND PRINTING SYSTEM

TECHNICAL FIELD

The present invention relates generally to the filed of digitally

5   controlled printing devices, and in particular to devices and methods that improve

the image quality of prints produced by these printing devices.

BACKGROUND

Digital printing has begun to play an ever-increasing role in the

10   commercial printing industry, and the demand for the capability of digital printing

technologies, such as electrophotography, drop-on-demand inkjet, and continuous

inkjet, to deliver high quality prints is also increasing. Various image artifacts in

the spatial domain, the temporal domain, or the spatial and temporal domains

adversely affect image quality. For instance, granularity is defined as the

15   aperiodic non-uniform reflection density/color distribution in the microscopic

spatial domain, and color consistency is affected by the stability of a printing press

over a period of time. One artifact that plagues most of the digital printing

systems is the one dimensional macro non-uniformity, which is usually denoted as

streaking or banding, depending on its aperiodic or periodic characteristics.

20   Streaking and banding can occur either parallel, perpendicular, or any other angle

to the printing process direction.

A digital press is composed of many subsystems, and each

subsystem can contribute to the streak/band artifact. For example, the

electrophotography imaging process consists of six major steps: charge, expose,

25   develop, transfer, fuse, and clean. The usual approach to eliminating the formation

of a streak or band artifact on a digital press is to optimize each subsystem and

hope the final assembled system will satisfy the product requirement. While the

subsystem optimization is necessary to improve the overall system performance in

image quality, it might result in a very stringent requirements or tolerances for

30   each subsystem because of the effect of accumulating error in the final system.

Furthermore, the subsystem optimization process does not address the problems

arising from the interaction among subsystems.

SUMMARY

Briefly summarized, according to one aspect of the invention, one or more printers or printing systems are connected to a scanning device. Each printer includes one or more color modules that are used during a printing operation. A printer prints a target for each color module or color channel. The printed targets are then scanned by the scanning device. The printed targets may be rotated to any angle and then scanned by the scanning device. The scanned raster data is processed by a controller to detect non-uniformities in at least one density image and to generate one or more correction profiles for the printer. When an image is to be printed, one or more controllers receive the image data and use the one or more correction profiles to correct or compensate for the non-uniformities during the exposure process.

If a printing system is implemented as an electrostatographic reproduction system, the system includes a printer having at least one color module, the at least one color module including an exposure device, and the printer including a process direction. A controller is configured to print a target with the at least one color module of the printer, the target including a plurality of alignment features and at least one uniform density image extending in a direction transverse to the process direction of the printer. A scanning device scans the printed target at a resolution and a gray scale commensurate with the exposure device of the at least one color module to obtain raster data representing the at least one density image and the alignment features of the target. A controller is configured to process the raster data to detect the alignment features and realign the raster data to correspond with pixel locations of the exposure device. The same controller or a different controller is configured to process the realigned raster data to detect non-uniformities in the at least one density image of the target occurring in a direction transverse to the process direction of the printer. The same controller or a different controller is configured to determine a correction profile that correlates the location and magnitude of the non-uniformities to individual pixel locations and exposure levels of the exposure device of the at least one color module. The same controller or a different controller is configured

to use the correction profile to compensate for the non-uniformities detected in the target by modifying the individual exposure levels of the exposure device when the at least one color module of the printer is used to print.

In one embodiment in accordance with the invention, a method of
5   printing includes printing a target for each color module of the printer. The printed target or targets are scanned by a scanning device to produce scanned raster data. The scanned raster data is processed to detect non-uniformities in the target and determine a correction profile. When an image is to be printed, the correction profile is used to compensate for the non-uniformities detected in the
10   target by printing the image with one or more color modules of the printer using the correction profile.

In another embodiment in accordance with the invention, a method of printing includes printing a target for the at least one color module of the printer, the target including a plurality of alignment features and at least one
15   uniform density image extending in a direction transverse to the process direction of the printer. The printed target is then scanned at a resolution and a gray scale commensurate with the exposure device of the at least one color module to obtain raster data representing the at least one density image and the alignment features of the target. The raster data is processed to detect the alignment features and
20   realign the raster data to correspond with pixel locations of the exposure device. The realigned raster data is processed to detect non-uniformities in the at least one density image of the target occurring in a direction transverse to the process direction of the printer. A correction profile is then determined that correlates the location and magnitude of the non-uniformities to individual pixel locations and
25   exposure levels of the exposure device of the at least one color module

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the invention will become more apparent by reference to the following detailed description of the
30   invention taken in conjunction with the accompanying drawings. The elements of the drawings are not necessarily to scale relative to each other.

FIG. 1 is a schematic side elevational view, in cross section, of an

exemplary electrographic printer suitable for use in an embodiment in accordance with the invention;

FIG. 2 is a schematic side elevation view, in cross section, of the reprographic image-producing portion of the electrographic printer shown in **FIG. 1**, on an enlarged scale;

FIG. 3 is a schematic side elevational view, in cross section, of one printing module of the electrographic printer shown in **FIG. 1**, on an enlarged scale;

FIG. 4 is a simplified block diagram of a first system in an embodiment in accordance with the invention;

FIG. 5 is a simplified block diagram of a second system in an embodiment in accordance with the invention;

FIG. 6 is a simplified illustration of a printed target that includes a non-uniformity in accordance with the prior art;

FIG. 7 is a flowchart of a method for generating a correction profile for a printing system in an embodiment in accordance with the invention;

FIG. 8 is a flowchart of a method for block 704 shown in **FIG. 7** in an embodiment in accordance with the invention;

FIG. 9 is a graphical illustration of a target having enlarged alignment marks in an embodiment in accordance with the invention; and

FIG. 10 is a flowchart of a method for printing an image in an embodiment in accordance with the invention.

DETAILED DESCRIPTION

Throughout the specification and claims the following terms take the meanings explicitly associated herein, unless the context clearly dictates otherwise. The meaning of "a," "an," and "the" includes plural reference, the meaning of "in" includes "in" and "on." The term "connected" means either a direct electrical connection between the items connected or an indirect connection through one or more passive or active intermediary devices. The term "circuit" means either a single component or a multiplicity of components, either active or

passive, that are connected together to provide a desired function. The term "signal" means at least one current, voltage, or data signal.

Additionally, directional terms such as "on", "over", "top", "bottom", are used with reference to the orientation of the Figure(s) being

5   described. Because components of embodiments of the present invention can be positioned in a number of different orientations, the directional terminology is used for purposes of illustration only and is in no way limiting.

Referring to the drawings, like numbers indicate like parts throughout the views.

10   FIGS. 1 and 2 are side elevational views schematically showing portions of a typical electrographic printer suitable for use in an embodiment in accordance with the invention. As depicted in FIGS. 1 and 2, apparatus 100 is configured as an electrographic printer that produces multi-channel layered prints. One embodiment of the invention involves printing using an electrophotographic

15   engine having five sets of single color image producing or printing stations or modules arranged in tandem and an optional finishing assembly. The invention contemplates that more or less than five stations may be combined to deposit toner on a single receiver member, or may include other typical electrographic writers, printer apparatus, or other finishing devices.

20   Electrographic printer 100 has a number of tandemly arranged electrostatographic image forming printing modules M1, M2, M3, M4, and M5 and a finishing assembly 102. Additional modules may be provided. Each of the printing modules generates a single-color toner image for transfer to a receiver member successively moved through the modules. The finishing assembly has a

25   fuser roller 104 and an opposing pressure roller 106 that form a fusing nip 108 there between. The finishing assembly 118 can also include a laminate application device 110. A receiver member R, during a single pass through the five modules, can have transferred, in registration, up to five single-color toner images to form a pentachrome image. As used herein, the term pentachrome implies that in an

30   image formed on a receiver member combinations of subsets of the five colors are combined to form other colors on the receiver member at various locations on the receiver member, and that all five colors participate to form process colors in at

least some of the subsets wherein each of the five colors may be combined with one or more of the other colors at a particular location on the receiver member to form a color different than the specific color toners combined at that location.

In one embodiment in accordance with the invention, printing
5   module M1 forms black (K) toner color separation images, M2 forms yellow (Y) toner color separation images, M3 forms magenta (M) toner color separation images, and M4 forms cyan (C) toner color separation images. Printing module M5 may form a red, blue, green or any other fifth color separation image. It is well known that the four primary colors cyan, magenta, yellow, and black may be
10   combined in various combinations of subsets thereof to form a representative spectrum of colors and having a respective gamut or range dependent upon the materials used and process used for forming the colors. However, in the electrographic printer 100, a fifth color can be added to improve the color gamut. In addition to adding to the color gamut, the fifth color may also be used as a
15   specialty color toner image, such as for making proprietary logos, a clear toner or a separate layer, such as a laminate L or film, for image protective purposes and/or a foil or filter for decorative or imaging purposes.

Receiver members (R_n - $R_{(n-6)}$), where n is the number of modules as shown in **FIG. 2**, are delivered from a paper supply unit (not shown) and
20   transported through the printing modules M1-M5 in a direction indicated in **FIG. 2** as R. The receiver members are adhered (e.g., preferably electrostatically via coupled corona tack-down chargers 114, 115) to an endless transport web 116 entrained and driven about rollers 118, an intermediate transfer member roller, and a transfer backup roller. Thus in printing module M1, a black color toner
25   separation image can be created on the photoconductive imaging roller PC1 (122), transferred to intermediate transfer member roller ITM1 (124), and transferred again to a receiver member moving through a transfer station, which includes ITM1 forming a pressure nip with a transfer backup roller TR1 (126). Similarly, printing modules M2, M3, M4, and M5 include, respectively: PC2, ITM2, TR2;
30   PC3, ITM3, TR3; PC4, ITM4, TR4; and PC5, ITM5, TR5. A receiver member, R_n, arriving from the supply, is shown passing over roller 118 for subsequent entry into the transfer station of the first printing module, M1, in which the

preceding receiver member $R_{(n-1)}$ is shown. Similarly, receiver members $R_{(n-2)}$, $R_{(n-3)}$, $R_{(n-4)}$, and $R_{(n-5)}$ are shown moving respectively through the transfer stations of printing modules M2, M3, M4, and M5. An unfused image formed on receiver member $R_{(n-6)}$ is moving, as shown, towards one or more finishing assemblies 102

5   (FIG. 1) that include a fuser, such as those of well known construction, and/or other finishing assemblies in parallel or in series that includes, preferably a lamination device 110 (FIG. 1). Alternatively, the lamination device 110 can be included in conjunction to one of the print modules, Mn, which in one embodiment is the fifth module M5.

10   A power supply unit 128 provides individual transfer currents to the transfer backup rollers TR1, TR2, TR3, TR4, and TR5 respectively. A logic and control unit 130 (FIG. 1; hereinafter "controller") in response to signals from various sensors associated with the electrophotographic printer 100 provides timing and control signals to the respective components to provide control of the

15   various components and process control parameters of the apparatus in accordance with well understood and known employments. A cleaning station 132 for transport web 116 is also typically provided to allow continued reuse thereof.

              Referring now to FIG. 3, there is shown a representative printing module (e.g., M1 of M1-M5). Each printing module of the electrographic printer

20   100 (FIG. 1) includes a plurality of electrographic imaging subsystems for producing one or more multilayered image or pattern. Included in each printing module is a primary charging subsystem 134 for uniformly electrostatically charging a surface 136 of a photoconductive imaging member (shown in the form of an imaging cylinder 138). An exposure subsystem 140 is provided for image-

25   wise modulating the uniform electrostatic charge by exposing the photoconductive imaging member to form a latent electrostatic multi-layer (separation) image of the respective layers. A development station subsystem 142 develops the image-wise exposed photoconductive imaging member. An intermediate transfer member 144 is provided for transferring the respective layer (separation) image

30   from the photoconductive imaging member through a transfer nip 146 to the surface 148 of the intermediate transfer member 144 and from the intermediate transfer member 144 to a receiver member (receiver member 150 shown prior to entry into the transfer nip 152 and receiver member 154 shown subsequent to

transfer of the multilayer (separation) image) which receives the respective

(separation) images 156 in superposition to form a composite image 158 thereon.

Receiver member 160 shown subsequent to the transfer of an additional layer 162

that can be, in one embodiment, a laminate L.

5   Controller 130 shown in **FIG. 3** includes a microprocessor

incorporating suitable look-up tables and control software, which is executable by

the LCU 130. The control software is preferably stored in memory associated

with the LCU 130. Sensors associated with the fusing assembly provide

appropriate signals to the LCU 130. In response to the sensors, the controller 130

10   issues command and control signals that adjust the heat and/or pressure within

fusing nip 108 (**FIG. 1**) and otherwise generally nominalizes and/or optimizes the

operating parameters of finishing assembly 102 (see **FIG. 1**) for printing multi-

channeled layers in an image 158 on a substrate for as print.

Subsequent to transfer of the respective (separation) multilayered

15   images, overlaid in registration, one from each of the respective printing modules

M1-M5, the receiver member is advanced to a finishing assembly 102 (shown in

FIG. 1) including one or more fusers 170 to optionally fuse the multilayer toner

image to the receiver member resulting in a receiver product, also referred to as a

final multi-channeled layer print. The finishing assembly 102 may include a

20   sensor 172, an energy source 174 and one or more laminators 110. This can be

used in conjunction to a registration reference 176 as well as other references that

are used during deposition of each layer of toner, which is laid down relative to

one or more registration references, such as a registration pattern.

FIG. 4 is a simplified block diagram of a first system in an

25   embodiment in accordance with the invention. System 400 includes

electrophotographic printer 100, scanning device 402, and controller 404. Printer

100 includes controller 130, exposure subsystem 140, writer marking process 406,

and one or more color modules M1, M2, ..., Mn. Exposure device controller 408

in exposure subsystem 140 provides timing and control signals to exposure device

30   410. Scanning device 402 is used to perform an off-line scanning operation in the

embodiment shown in **FIG. 4**.

As will be described in more detail with reference to **FIGS. 7-10**, system 400 corrects or compensates for one or more non-uniformities in a printed image. Printer 100 prints a target for each color channel. The printed targets are then scanned by scanning device 400. The scanned raster data is used by

5   controller 404 to generate one or more correction profiles for apparatus 100. The one or more correction profiles are stored in memory 412. Memory 412 is located in system 400 in another embodiment in accordance with the invention.

When printer 100 is to print an image, controller 130 receives the image data and exposure device controller 408 uses the one or more correction

10   profiles to correct or compensate for the non-uniformities during the exposure process by exposure device. Writer marking process 406, in conjunction with color modules M1... Mn, then produce the printed image.

Although depicted as separate controllers in **FIG. 4**, other embodiments in accordance with the invention can combine controller 130 and

15   exposure device controller 408 in a single controller. Additionally, controller 404 can be implemented as any one of a variety of controllers, including, but not limited to, a processor, a computing device, a computer, and a server. And finally, scanning device 402 can be used to perform an in-line scanning operation and be constructed within system 400 in another embodiment in accordance with the

20   invention.

Referring now to **FIG. 5**, there is shown a simplified block diagram of a second system in an embodiment in accordance with the invention. System 500 includes multiple printing systems 502, 504, 506 connected to scanning device station 508 and controller 510 through one or more network

25   connections 512. Printing systems 502, 504, 506 are implemented as printers, such as, for example, electrophotographic printers.

In this exemplary embodiment, each printing system 502, 504, 506 prints a target for each color channel that are scanned by scanner station 508. The scanned raster data is used by controller 510 to generate one or more correction

30   profiles for the respective printing system. When a printing system is to print an image, controller 510 receives the image data and uses the one or more correction profiles stored in memory 514 to correct or compensate for the non-uniformities.

Although depicted as a central controller in **FIG. 5**, other embodiments in accordance with the invention can employ individual controllers for each reproduction system. Additionally, controller 510 can be implemented as any one of a variety of controllers, including, but not limited to, a processor, a

5   computing device, a computer, and a server. And finally, memory 514 can be eliminated and a memory located in each printer to store one or more correction profiles in other embodiments in accordance with the invention.

FIG. 6 is a simplified illustration of a printed target that includes a non-uniformity in accordance with the prior art. Printer 600 produces printed

10   image 602, which includes non-uniformity 604. In **FIG. 6**, the non-uniformity is depicted as a streak that is output parallel to the direction of printing. Streaks can also be produced perpendicular to, or in any other angle, relative to the direction of printing. Additionally, different types of non-uniformities can be generated in other prior art embodiments. For example, a non-uniformity includes, but is not

15   limited to, left-to-right density non-uniformity, gloss non-uniformity, color-to-color overprint non-uniformity, and mottle-like non-uniformity.

FIG. 7 is a flowchart of a method for generating a correction profile for a printing system in an embodiment in accordance with the invention. The method of **FIG. 7** can be used to generate one or multiple correction profiles

20   for a printer. The correction profile is used to reduce or eliminate one or more non-uniformities in a printed image. Initially, a target is printed for each color module that is used by the printer (block 700). Thus, four targets are printed for CMYK printers; one target for cyan, one for magenta, one for yellow, and one for black. The target includes one or more uniform density images that extend in

25   transverse to the process direction of the printer and includes one or more different types of alignment marks in an embodiment in accordance with the invention.

Each target is rotated to an angle and then scanned by a scanning device, as shown in block 702. The angle can be any given angle. For example,

30   in one embodiment in accordance with the invention, the angle is ninety (90) degrees.

The raster data produced by the scanning device for each target is then analyzed and a correction profile created for the printer (block 704). Block

704 will be described in more detail in conjunction with **FIG. 8**. The correction profile is then stored, as shown in block 706. The correction profile can be stored, for example, in the printer itself, in a print server connected to the printer via a network connection, or in a memory connected to the printer.

5   Referring now to **FIG. 8**, there is shown a flowchart of a method for block 704 shown in **FIG. 7** in an embodiment in accordance with the invention. Initially, as shown in block 800, the one or more different types of alignment marks on each printed target are detected and used to realign the raster data from the scanning device to correspond to the pixel locations of the printer.

10   The skew angle is also determined or estimated to determine the optimal density code values for a correction profile (block 802).

Next, at block 804, an optional determination is made as to whether or not a de-screening process is to be performed on the raster data. If so, the process passes to block 806 for a de-screening process. The de-screening process

15   can be implemented as any known conventional de-screening process. By way of example only, the raster image can be input into a Gaussian filter for de-screening.

The method continues at block 808 where a multilevel profile is extracted from the raster data. The raster data is processed by a motion filter based on the estimated skew angle determined at block 802. A multilevel streak

20   extraction is then performed on the raster data at block 810, where a spline function having a non-uniform knot placement is used to model the overall density fluctuations at each density level. Streak signals are the difference between the profiles and the fitted spline curves in an embodiment in accordance with the invention. Streak signals can be represented in the code-value space and its

25   logarithmic space.

The correction profile and gain are then generated, as shown in block 812. The streak signals are decorrelated using a singular value decomposition. The first component is extracted as the correction profile and the remaining signal used to refine the correction profile to better address fine and

30   sharp edges in an embodiment in accordance with the invention.

The correction gain is generated by linearly fitting the streak signal on the extracted correction profile in the logarithmic space. The slope is used as the correction gain coefficient.

The following description details one technique for deterministically correcting for a one-dimensional non-uniformity by modifying its digital writing module. There are two classes of creating grayscale and color images on reflective substrates: continuous-tone and halftone. The color mixing

5   theory that explains how light interacts with the substrate and colorant is slightly different between the two. For example, the *Yule-Nielsen* model is designed for a halftone printing process while the *Beer-Bouguer* law assumes a homogeneous medium, and the light absorbed by the medium is proportional to its intensity. If *Ds* is the reflection density of a solid patch, the *Yule-Nielsen* model relates the

10   halftone dot area, A_h, and the measured reflection density, D, on a halftoned patch as follows:

$$A_h = \frac{1-10^{-\frac{D}{n}}}{1-10^{-\frac{Ds}{n}}} \qquad (1)$$

15   where n is determined by the actual printing process. The *Beer-Bouguer* law suggests that D is a linear function of colorant concentration, c, absorption coefficient, $K(\lambda)$, and total length of light path, w, inside the colorant:

$$D = \frac{1}{2.3026} K(\lambda)wc \qquad (2)$$

20

As a result, it can be deduced that non-uniformity in reflection density, ΔD, on a halftone print sample is caused by the variation in the dot area, ΔA. The non-uniformity in reflection density, ΔD, on a continuous-tone print sample is caused by the differential length in light path, Δw, assuming colorant concentration, c, is

25   uniform. Because it is always possible to calibrate the dot area $A_h \rightarrow \tilde{A}_h$, this analysis can be focused to the limiting case of $n \rightarrow \infty$ such that the *Yule-Nielsen* model as noted in Equation (1) is simplified as follows:

$$\tilde{A}_h = \frac{D}{D_s} \qquad (3)$$

30

As a result, ΔD is linearly correlated with $\Delta \tilde{A}_h$ in the halftone printing process, and with Δw on the continuous-tone printing process. Thus, without loss of generality, the analysis is focused on the halftone imaging process.

Let r be the radius of each halftone dot, and $\tilde{A}_h = \Pi r^2$. One unknown disturbance, Θ_i, in the printing system drives the printing system from its intended location in a color space, for instance reflection density D_i, at location x_i. We can deduce that Θ_i results in small variation δr_i in the radius, r_i, of the halftone dot at x_i. That is:

$$r_i \rightarrow r_i + \delta r_i \qquad (4)$$

where δr_i is a function of r_i. Based on the *Taylor* expansion, we can reformulate δr_i as follows:

$$\delta r_i(r_i) = \sum_{k=0}^{\infty} \alpha_{ik} r_i^{k} \qquad (5)$$

and $\{\alpha_{ik}\}_{k=0}^{\infty}$ is determined by Θi. Since δr_i is usually very small, the following equations based on Equation (3) can be derived as follows:

$$\Delta D_i = D_s \Delta \tilde{A}_h = D_s 2\pi r_i \delta r_i = \sum_{k=0}^{\infty} (2\pi D_s \alpha_{ik}) r_i^{k=1} \qquad (6)$$

In one embodiment, δr is assumed to be proportional to the current radius r as noted below:

$$\delta r_i = \alpha_{i1} r_i \qquad (7)$$

Under this assumption, Equation (6) can be simplified to:

$$\Delta D_i = 2\pi D_s \alpha_{i1} r_i^{2} = 2 D_s \alpha_{i1} \tilde{A}_h \qquad (8)$$

Equation (8) suggests that the magnitude of the streak signal ΔD_i at location x_i is

linearly increasing with respect to the linearized colorant area coverage $\tilde{A}_{hi}$. Let

$\bar{\phi}_j$ and $\bar{\alpha}$ be the estimated reflection density variation and the corresponding

streak coefficient perpendicular to the direction of the streak and/or band across

5   the full range at averaged colorant coverage A_{hj}, where $j = 1, ..., J$. Estimating

$\bar{\alpha}$ from single realization of $\bar{\phi}_j$ is very noisy and unreliable, which will results in

inferior compensation parameter for the digital writing module. This problem can

be greatly alleviated by correlating estimated reflection variation at multiple

density levels as follows:

10

$$\phi = [\phi_1 \phi_2 ... \phi_j] = 2D_s[A_{h1} A_{h2} ... A_{hJ}]\bar{\alpha} \qquad (9)$$

Equation (9) indicates that the dimensionality of Φ is 1, and the remaining J-1

dimension

15   is the null space composed by measurement/printing noise. As a result, $\bar{\alpha} = |\alpha|\eta$,

where η is the first singular vector of Φ. At last, by projecting Φ and α onto η,

Equation (9) can be simplified as follows:

$$|\phi| = 2D_s|\alpha|A_h = m_h A_h \qquad (10)$$

20

Thus, $|\alpha|$ is proportional to the estimated slope, m_h, in Equation (10). This

analysis can be further extended when α is a function of r. Assuming the

thickness of the colorant layer is fixed before multiple layers of colorant are

formed on the substrate, it can be deduced that $\tilde{A}_{hi}$ is proportional to M/A, which

25   represents the colorant mass per unit area. M/A can be controlled by the digital

writing module. For example, the theoretical analysis on the electrophotography

using conductive magnetic brush development can be approximated in first order

by the following equation (1):

30

$$A_h \propto \frac{M}{A} = \frac{C_i v V_p}{Q/M} \frac{\rho_c}{\rho_i} \frac{8\varepsilon_0}{r_i} = \alpha_0 V = \alpha_0 \Gamma(\bar{\omega}) \qquad (11)$$

where C_t is the toner concentration, v is the speed ratio factor between roller and

photoreceptor, V is the applied voltage, p represents carrier surface packing, Q/M

is the charge to mass ratio, ρ_c and ρ_t are the densities of carrier and toner

5   respectively, ε_0 is the permittivity of free space, and r_t stands for the toner radius.

$\Gamma(\overline{\omega})$ is the mapping function from the power of the digital writing module, $\overline{\omega}$,

to the applied voltage, V, on the photoreceptor. As a result, the following

relationship can be derived:

10
$$\frac{\Delta A_h}{A_h} = \frac{2\delta r}{r} = 2\alpha \propto \frac{\delta V}{V} = \frac{\delta \Gamma(\overline{\omega})}{\Gamma(\overline{\omega})} \qquad (12)$$

Equation (12) summarizes the theoretical basis to deterministically correcting a

one-dimensional non-uniformity by modifying its digital writing module.

FIG. 9 is a graphical illustration of a target having enlarged

15   alignment marks in an embodiment in accordance with the invention. As shown,

target 900 includes multiple uniform density images and two different types of

alignment marks. The uniform density images vary in tone from a darker tone

uniform density image 902 to a lighter tone uniform density image 904.

Alignment marks 906, 908 (shown enlarged for easier visibility) are used to

20   correlate the location of the printed mark to a pixel location from the exposure

device 410 (see **FIG. 4**). In the case where the exposure device is an LED

printhead, the alignment marks can be used to locate the exact LED array

locations on the printhead. The correction can be tuned for any one of the given

tone densities. For example, in one embodiment in accordance with the invention,

25   the correction is tuned for a mid-tone density.

Referring now to **FIG. 10**, there is shown a flowchart of a method

for printing an image in an embodiment in accordance with the invention. A

determination is made at block 1000 as to whether or not an image is to be

printed. If so, the process continues at block 1002 where a determination is made

30   as to whether or not a different correction profile from a current or default

correction profile is to be used when printing the image. If so, the different

correction profile is selected and the image printed using that correction profile

(blocks 1004 and 1006). An exposure controller (e.g., controller 408 in **FIG. 4**) uses the correction profile to modulate the exposure device (e.g., 410 in **FIG. 4**) to vary the densities in the printed image.

If a different correction profile is not to be used, the method passes to block 1008 where a determination is made as to whether or not the current or default correction profile is to be used when printing the image. If so, the image printed using the current or default correction profile (block 1006). If the current or default correction profile is not to be used, use of the correction profile is disabled and the image printed without the correction profile (blocks 1010 and 1012).

Returning to block 1000, if an image is not to be printed, the process passes to block 1014 where a determination is made as to whether or not a correction profile is to be updated. If so, the profile is updated at block 1016 and the method ends.

The invention has been described with reference to particular embodiments in accordance with the invention. However, it will be appreciated that variations and modifications can be effected by a person of ordinary skill in the art without departing from the scope of the invention. Additionally, even though specific embodiments of the invention have been described herein, it should be noted that the application is not limited to these embodiments. In particular, any features described with respect to one embodiment may also be used in other embodiments, where compatible. And the features of the different embodiments may be exchanged, where compatible.

CLAIMS:

1. A method of printing using a printer that includes at least one color module to be used in a printing operation, the method comprising:

5   printing a target for the at least one color module of the printer;

scanning the printed target to produce scanned raster data;

processing the scanned raster data to detect non-uniformities in the target and determine a correction profile; and

printing with at least one color module of the printer using the

10   correction profile to compensate for the non-uniformities detected in the target.

2. The method of claim 1, wherein scanning the printed target comprises:

rotating the printed target to a predetermined angle; and

15   scanning the rotated printed target to produce scanned raster data.

3. The method of claim 1 or claim 2, wherein printing with the at least one color module includes printing with a color module that includes an exposure device with gray scale capability, wherein gray scale capability

20   comprises at least one of pulse-width modulation of the exposure device and current modulation of the exposure device.

4. The method of claim 3, wherein printing with the at least one color module comprises printing with a color module that includes an LED

25   printhead with gray scale capability.

5. The method of any one of claims 1 through 4, wherein the non-uniformities include streaks on the target.

30   6. A printing system comprising:

a printer including at least one color module to be used in a printing operation;

a controller configured to print a target with the at least one color module of the printer;

a scanning device to scan the printed target;

a controller configured to process the scanned printed target to

5   detect non-uniformities in the target and determine a correction profile; and

a controller configured to provide the correction profile to the printer to compensate for the non-uniformities detected in the target when the printer prints with the at least one color module of the printer.

10   7.   The printing system of claim 6, wherein the controller that provides the correction profile to the printer is configured to disable and enable the correction profile.

        8.   The printing system of claim 6 or claim 7, wherein the

15 printer is one of a plurality of printers connected to the scanning device over a network.

        9.   The printing system of any one of claims 6 through 8, wherein the at least one color module includes an LED printhead with gray scale

20 capability.

        10.   A method of electrostatographic reproduction with a printer including at least one color module to be used in a printing operation, the at least one color module including an exposure device, and the printer including a

25 process direction, the method comprising:

printing a target for the at least one color module of the printer, the target including a plurality of alignment features and at least one uniform density image extending in a direction transverse to the process direction of the printer;

scanning the printed target at a resolution and a gray scale

30 commensurate with the exposure device of the at least one color module to obtain raster data representing the at least one density image and the alignment features of the target;

processing the raster data to detect the alignment features and realign the raster data to correspond with pixel locations of the exposure device;

processing the realigned raster data to detect non-uniformities in the at least one density image of the target occurring in a direction transverse to

5 the process direction of the printer; and

determining a correction profile that correlates the location and magnitude of the non-uniformities to individual pixel locations and exposure levels of the exposure device of the at least one color module.

10 11. The method of claim 10, further comprising printing with the at least one color module of the printer using the correction profile to compensate for the non-uniformities detected in the target by modifying the individual exposure levels of the exposure device.

15 12. The method of claim 10 or claim 11, wherein scanning the printed target at a resolution and a gray scale commensurate with the exposure device of the at least one color module to obtain raster data representing the at least one density image and the alignment features of the target comprises:

rotating the printed target to a predetermined angle; and

20 scanning the rotated printed target at a resolution and a gray scale commensurate with the exposure device of the at least one color module to obtain raster data representing the at least one density image and the alignment features of the target.

25 13. The method of any one of claims 10 through 12, wherein the non-uniformities include streaks on the target.

14. The method of any one of claims 10 through 13, wherein printing with the at least one color module includes modifying the individual

30 exposure levels of an exposure device that includes an LED printhead with gray scale capability.

15.   An electrostatographic reproduction system comprising:

a printer including at least one color module, the at least one color module including an exposure device, the printer including a process direction;

5   a controller configured to print a target with the at least one color module of the printer, the target including a plurality of alignment features and at least one uniform density image extending in a direction transverse to the process direction of the printer;

a scanning device to scan the printed target at a resolution and a

10   gray scale commensurate with the exposure device of the at least one color module to obtain raster data representing the at least one density image and the alignment features of the target;

a controller configured to process the raster data to detect the alignment features and realign the raster data to correspond with pixel locations of

15   the exposure device;

a controller configured to process the realigned raster data to detect non-uniformities in the at least one density image of the target occurring in a direction transverse to the process direction of the printer;

a controller configured to determine a correction profile that

20   correlates the location and magnitude of the non-uniformities to individual pixel locations and exposure levels of the exposure device of the at least one color module; and

a controller configured to use the correction profile to compensate for the non-uniformities detected in the target by modifying the individual

25   exposure levels of the exposure device when the at least one color module of the printer is used to print.

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FIG. 1

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FIG. 2

FIG. 3

FIG. 4

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FIG. 5

FIG. 6
(Prior Art)

Start

Printer Prints Target For Each Color Module Used By Printer —— 700

Rotate Each Target To An Angle And Scan Rotated Target Using A Scanning Device —— 702

Analyze Scanned Raster Data And Generate Correction Profile —— 704

Store Correction Profile —— 706

Stop

FIG. 7

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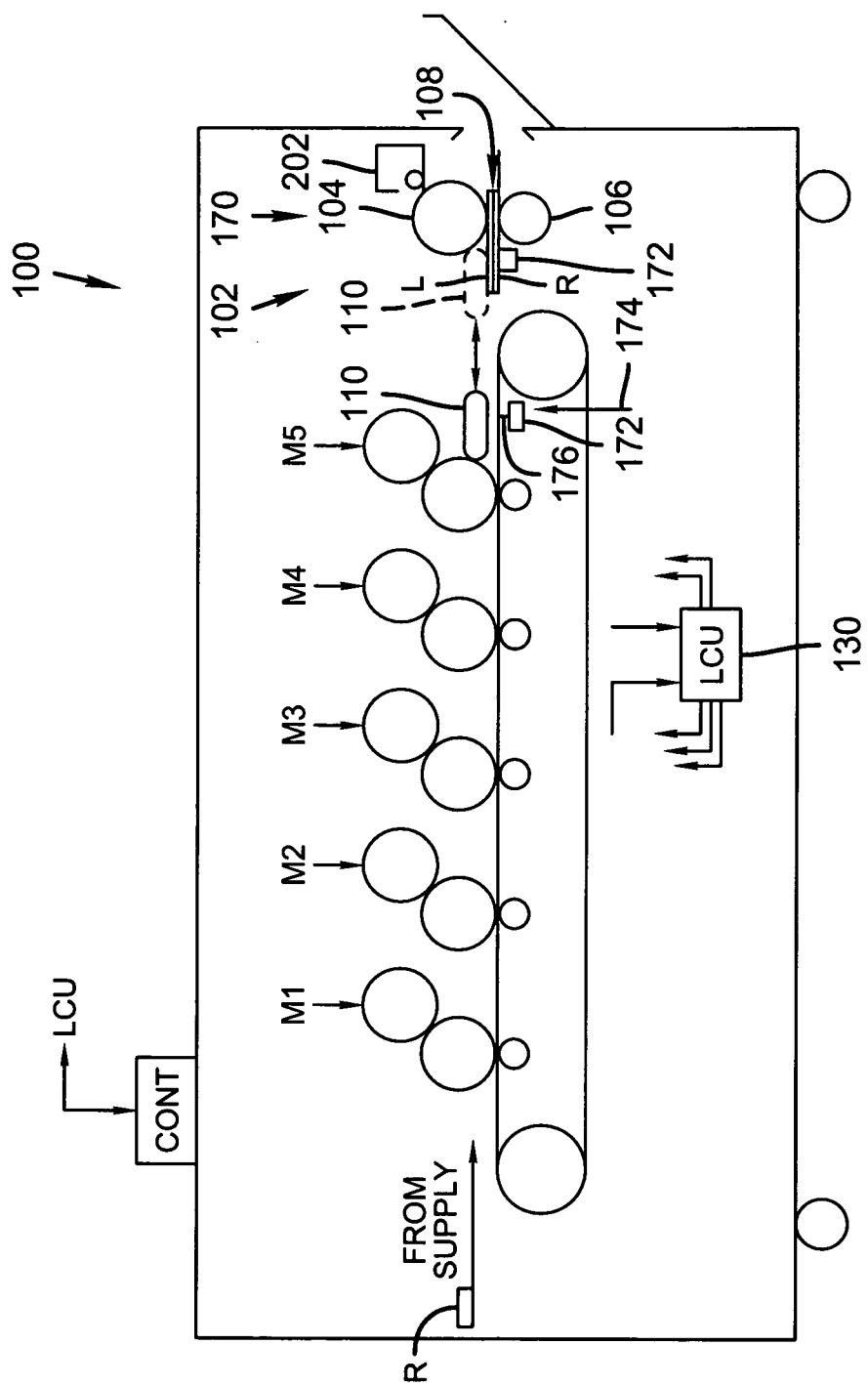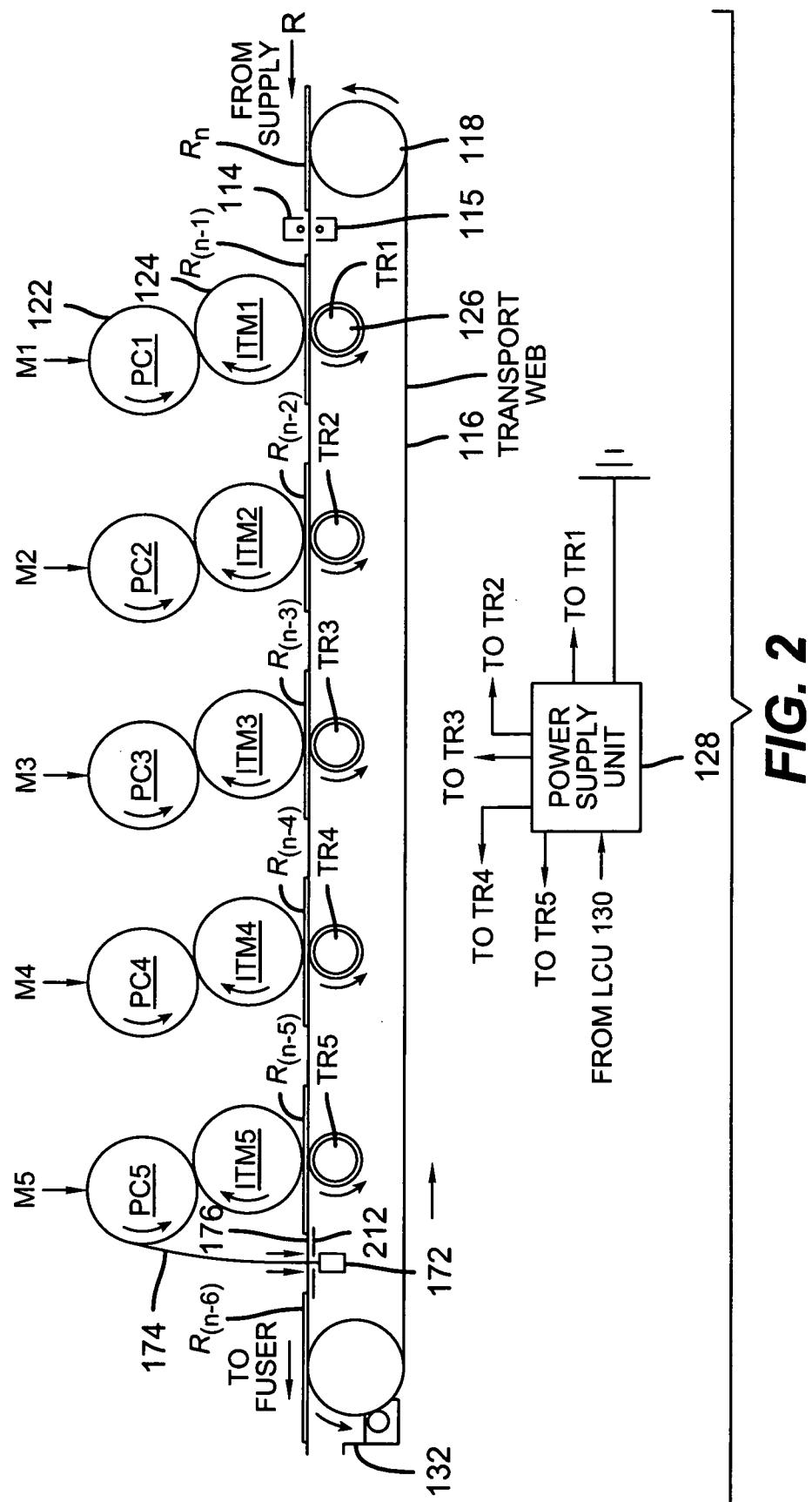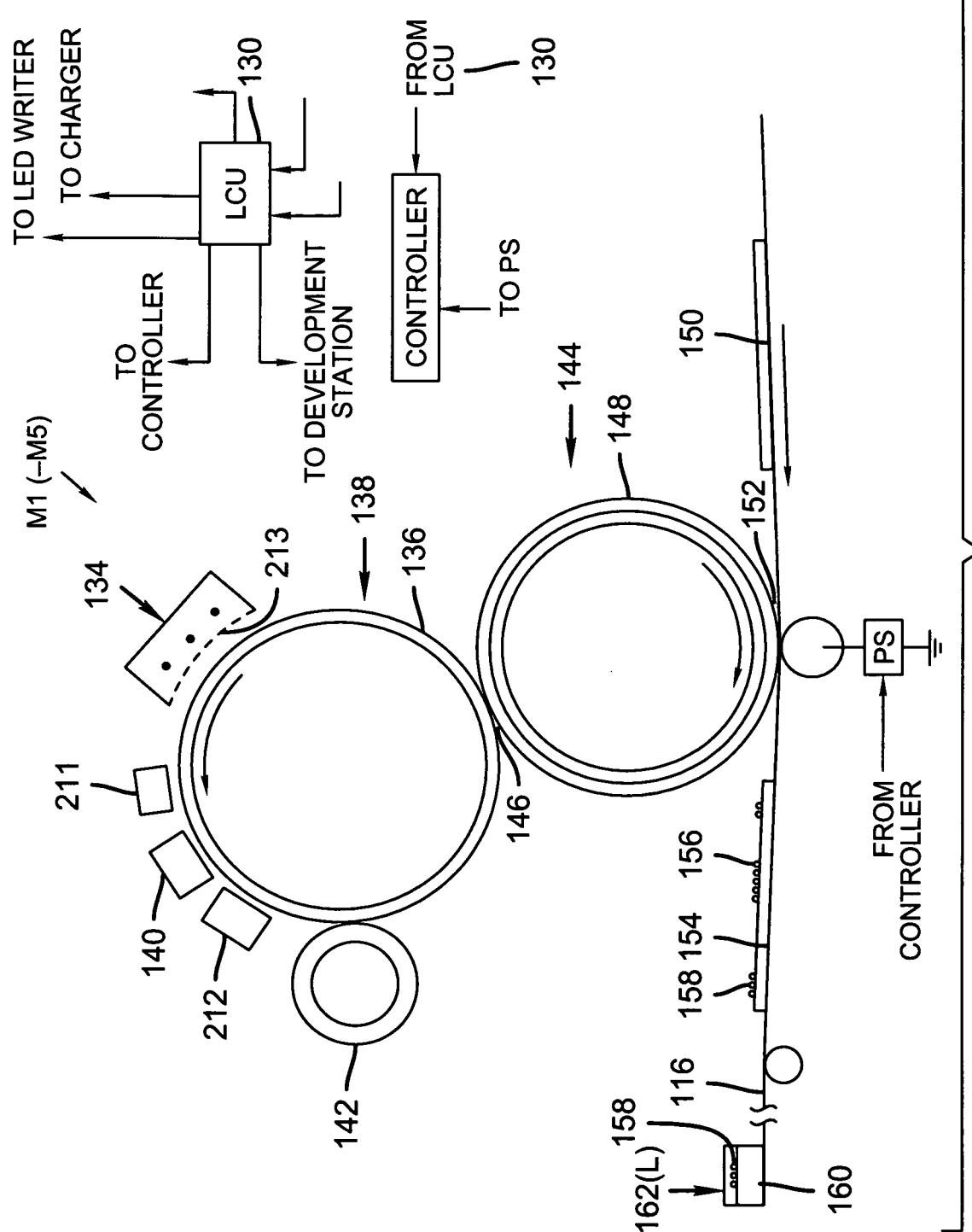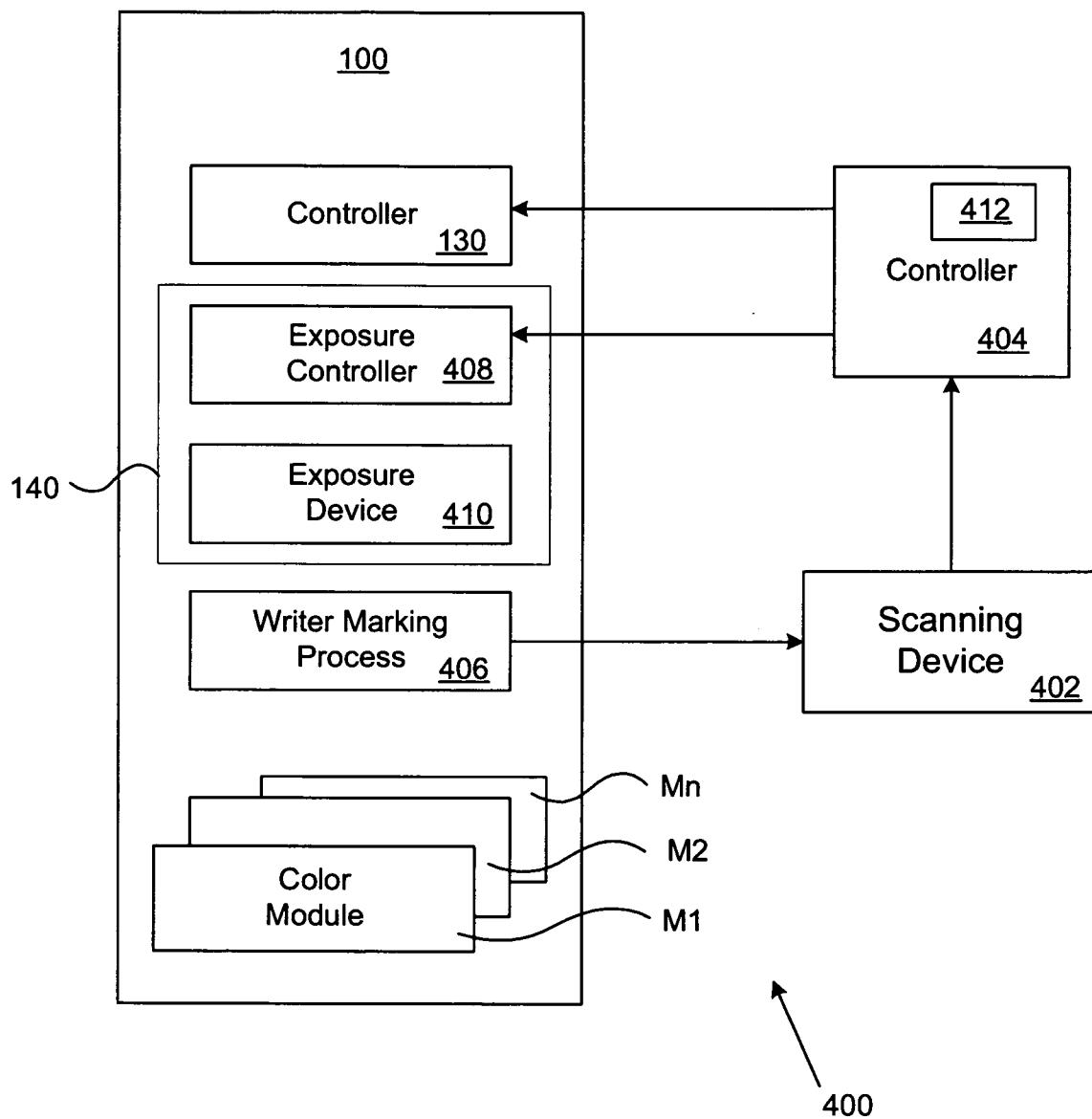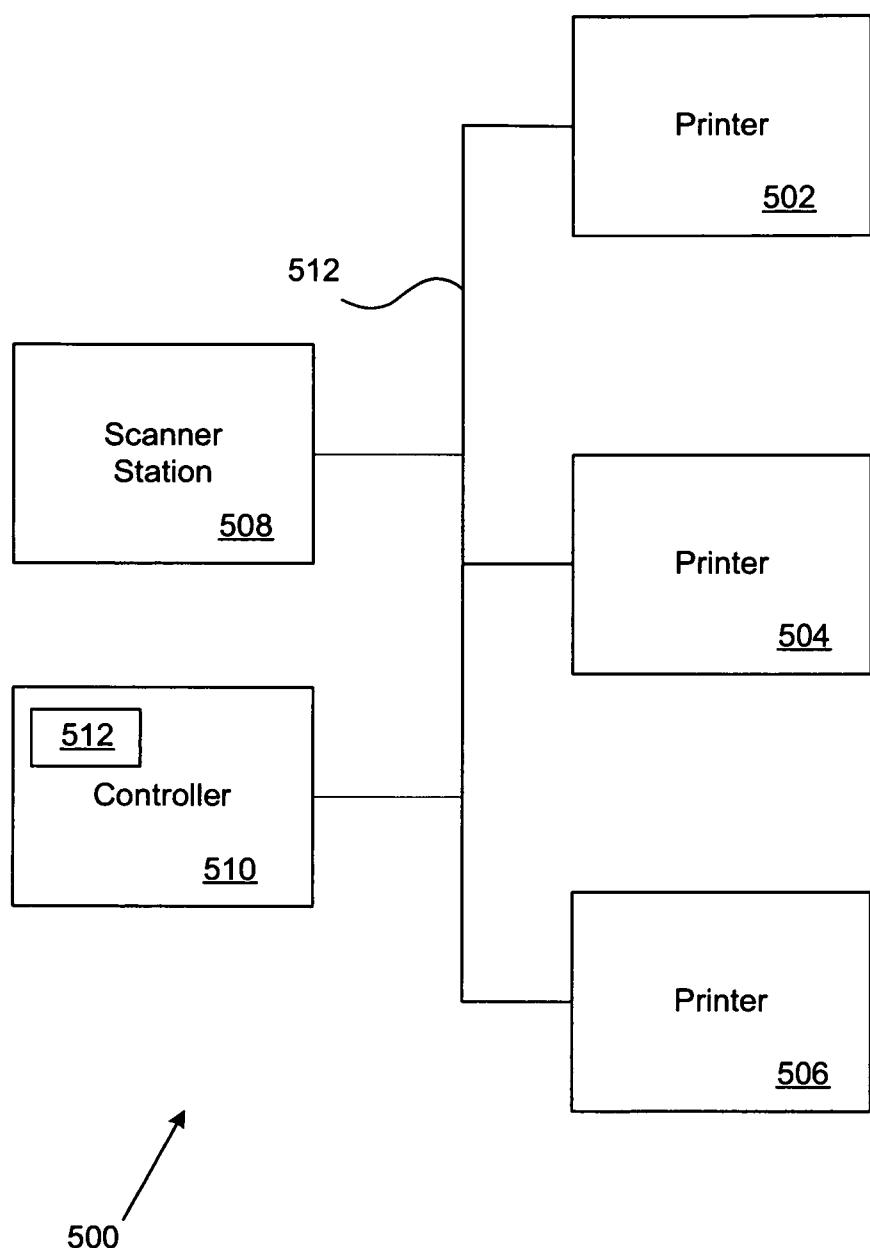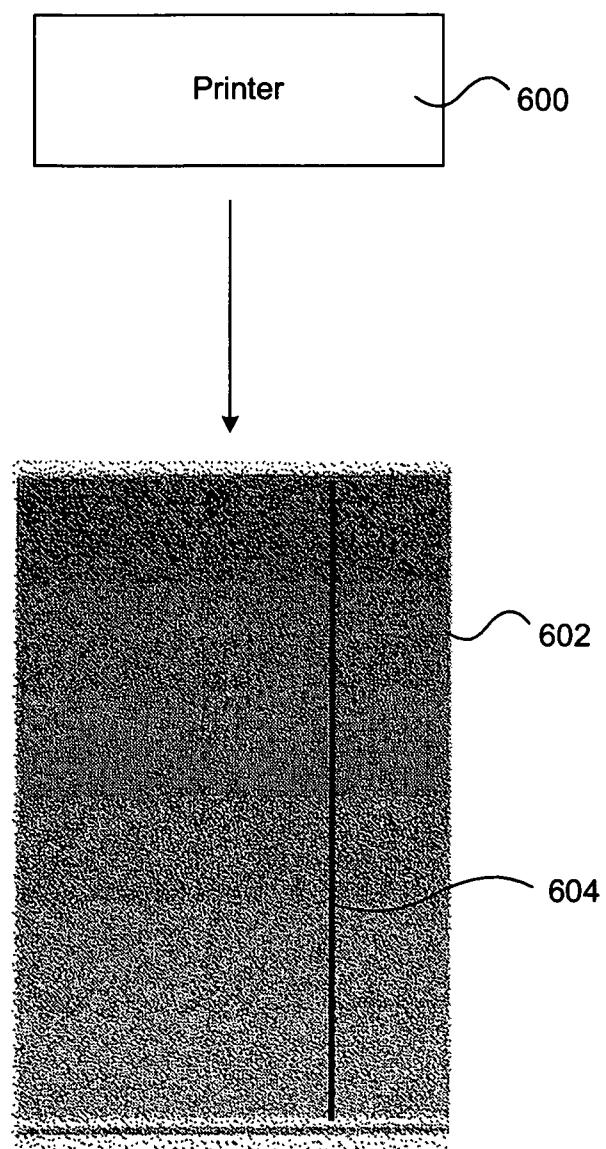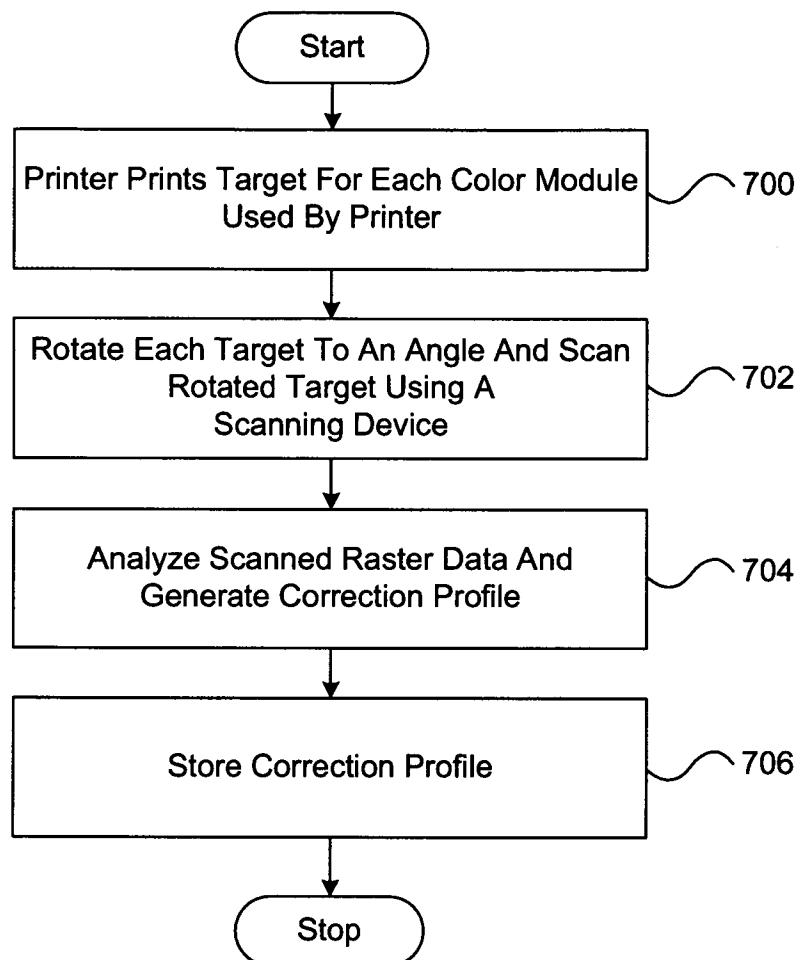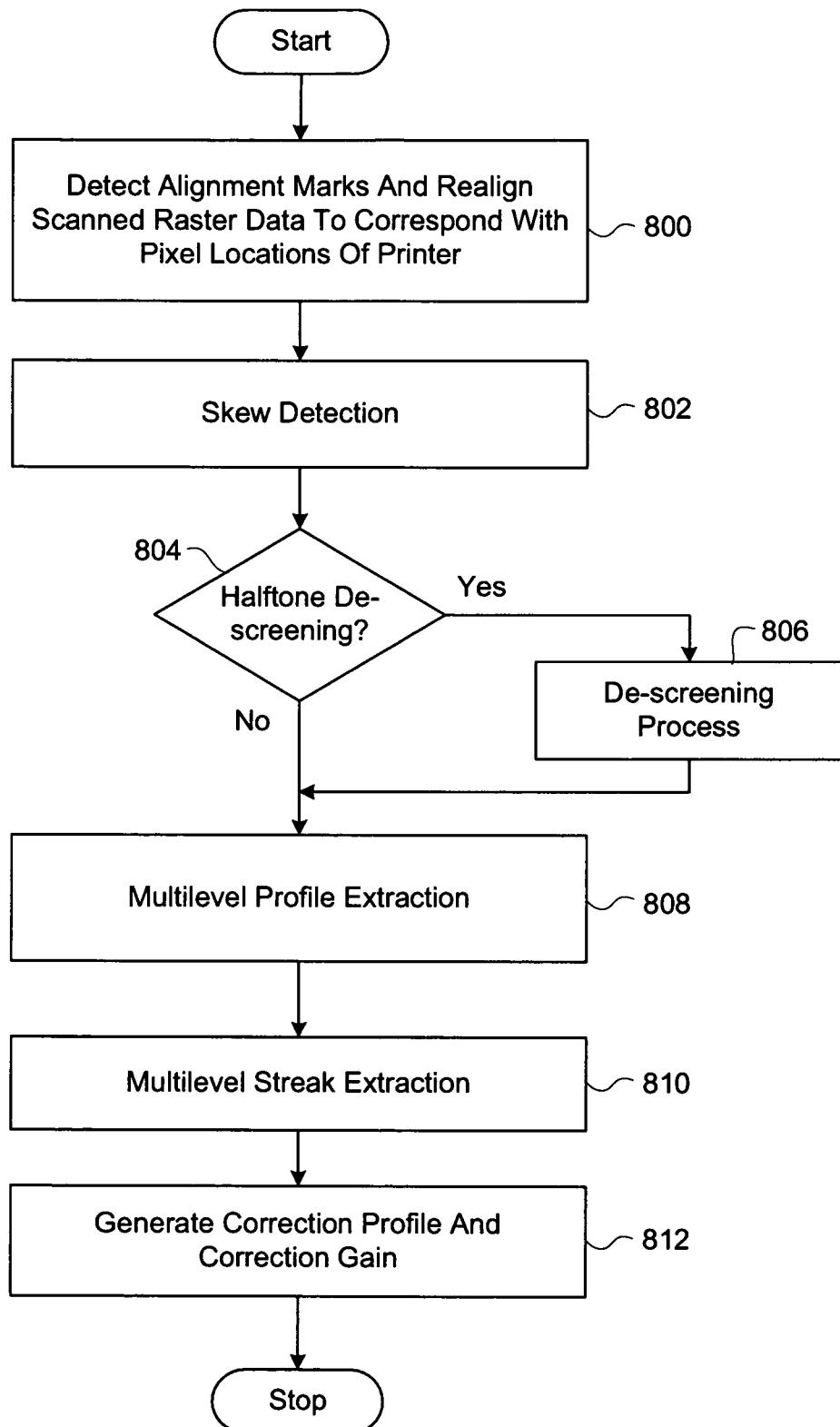
FIG. 8
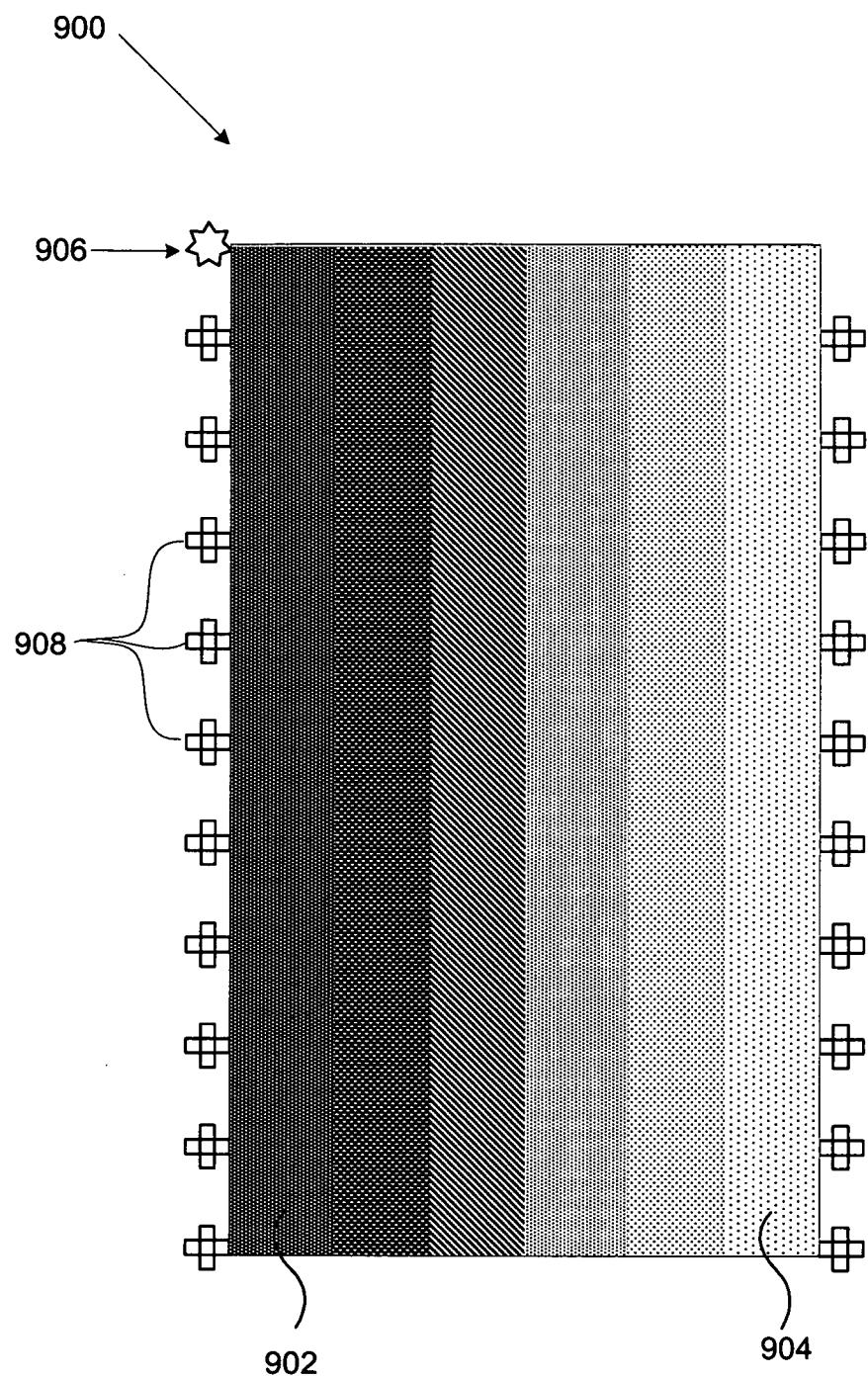
FIG. 9

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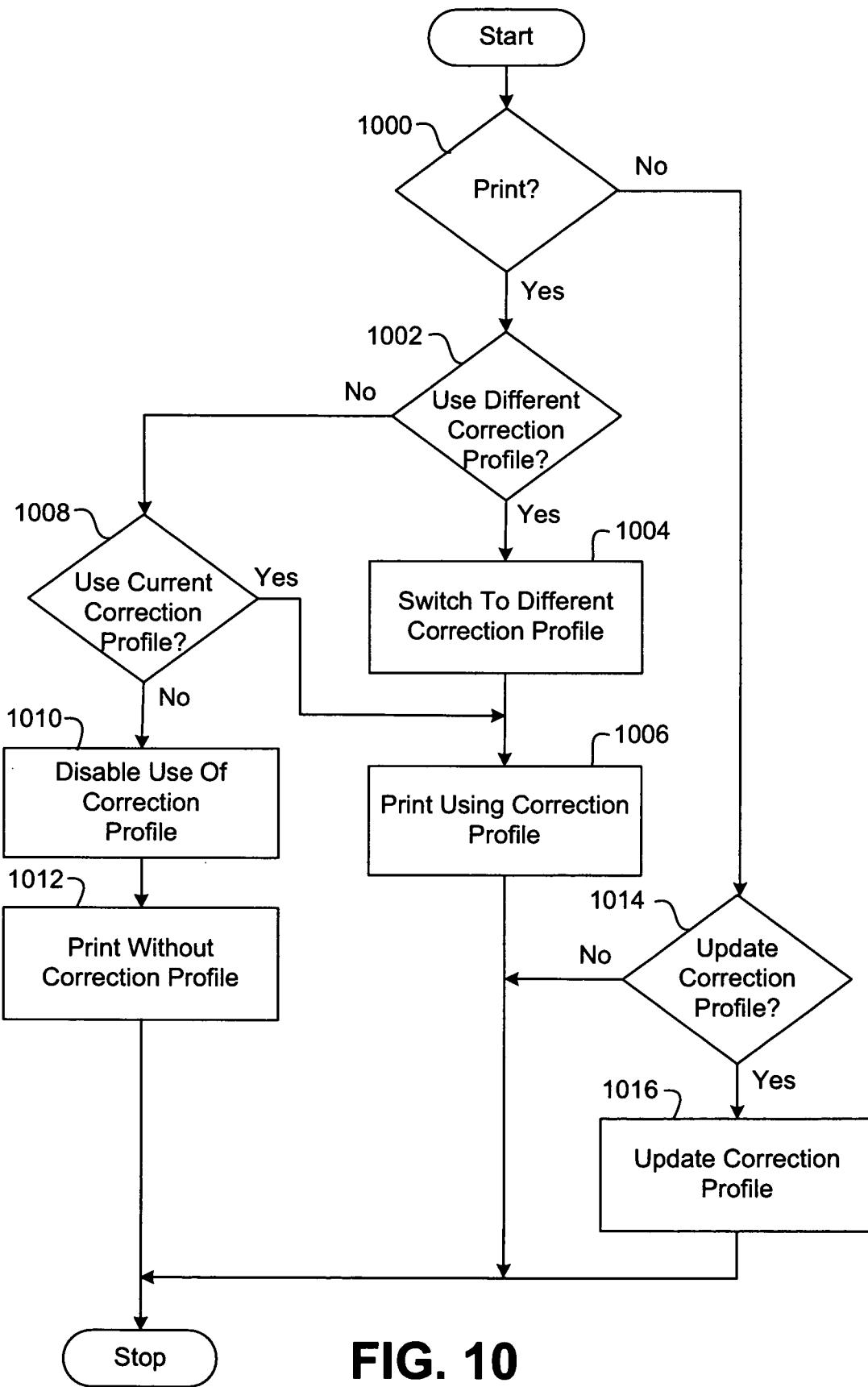
FIG. 10

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04N1/401   G06K15/12

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   G06K

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 6 452 696 B1 (BOGART ZAC [US] ET AL) 17 September 2002 (2002-09-17) column 5, line 43 - column 8, line 49	1-15
X	US 2005/099446 A1 (MIZES HOWARD A [US] ET AL) 12 May 2005 (2005-05-12) paragraphs [0035] - [0084]	1-15
X	US 2002/057470 A1 (KOIDE JUN [JP] ET AL) 16 May 2002 (2002-05-16) paragraphs [0030] - [0089]	1-15

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents :

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"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
28 January 2010	08/02/2010

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

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US 2005099446	A1	12-05-2005	JP	2005141232 A	02-06-2005
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