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(54) Title: BRIGHTNESS CORRECTION WITH REDUCED HUE-SHIFT

(57) Abstract: A method is provided of correcting brightness without, or with reduced, hue-shift of a pixel color represented as a set of primary-color values in a reproducing device's color space, by means of a composite transformation that has the property that it preserves the hueless character of gray pixels and is made up of independent primary-color related transformations. At least some of the primary-color related transformations include applying a virtual color transformation to a primary-color value of the pixel color to be brightness-corrected, thereby transforming the primary-color value into a primary-color value of a virtual gray-idealized color space. A brightness change is applied to the primary-color value in the virtual color space, and the inverse of the virtual color transformation is applied to the brightness-changed primary-color value. Thereby brightness-changed primary-color value is transformed back to a primary-color value of the reproducing device's color space.



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BRIGHTNESS CORRECTION WITH REDUCED HUE-SHIFT

FIELD OF THE INVENTION

The present invention generally relates to methods, systems and computer program products for brightness correction, and for example, to methods, systems and computer program products for brightness corrections directly performed on a printing press.

BACKGROUND OF THE INVENTION

An image to be printed on a digital printing press is usually provided by a designer who prepares and processes the image for printing, usually in the RGB color space of the device. For printing the image on a printing press, the color values are translated into the device-dependent color space of the printing press, such as a CMY (cyan, magenta and yellow) color space or the CMYK color space, which further includes black (K) as a fourth component. There are also printing presses on the market which refer to a color space with five or six components.

Before making a production run of the printing job and printing the image in quantity, generally the printer is controlled to execute a proof run and provide a sample of the printed image which is vetted to determine whether the image is satisfactory. If the proof is satisfactory, a production run of the printing job is executed. If not, brightness corrections are made to the printed image and another proof image is printed and vetted. The process is repeated until a satisfactory proof is obtained and production printing of the image is performed.

Some brightness corrections to the printed image can be satisfactorily made "on-press" by adjusting the raster image in the printer or the printer's response to the raster image. Such on-press corrections are generally one-dimensional corrections such as enhancing a single color, e.g. increasing a blue tone in the image. On-press brightness corrections are relatively conservative of labor and materiel and can

generally be made quickly and easily using a suitable "brightness correction wizard".

More complicated brightness corrections, such as brightness or contrast corrections are "multidimensional" corrections that involve interplay between a plurality of color components in the image. Generally, such corrections cannot be made satisfactorily on-press. For example, brightness and/or contrast adjustments usually require adjusting all three or four color components in a CMY or CMYK printer. When made on-press, such brightness corrections often result in undesirable and substantial shifts in hue. Multidimensional brightness corrections are therefore generally made by returning the raster image, with any corrections made thereto, off-press by the designer. The image is reconverted to an image in RGB and the designer works on the RGB image to make desired changes. After making the changes, the vector image is "re-ripped" (i.e. re-processed by the RIP into a raster image) and proofs run of the image again.

SUMMARY OF THE INVENTION

A method is provided of correcting brightness without, or with reduced, hue-shift of a pixel color represented as a set of primary-color values in a reproducing device's color space, by means of a composite transformation that has the property that it preserves the hueless character of gray pixels and is made up of independent primary-color related transformations. At least some of the primary-color related transformations include applying a virtual color transformation to a primary-color value of the pixel color to be brightness-corrected, thereby transforming the primary-color value into a primary-color value of a virtual gray-idealized color space, applying a brightness change to the primary-color value in the virtual color space, and applying the inverse of the virtual color transformation to the brightness-changed primary-color value, thereby transforming the brightness-changed primary-color value back to a primary-color value of the reproducing device's color space.

According to another aspect, a printing device is provided including a controller for correcting brightness without, or with reduced, hue-shift of a pixel

color represented as a set of primary-color values in a reproducing device's color space, by means of a composite transformation that has the property that it preserves the hueless character of gray pixels and is made up of independent primary-color related transformations. At least some of the primary-color related transformations include applying a virtual color transformation to a primary-color value of the pixel color to be brightness-corrected, thereby transforming the primary-color value into a primary-color value of a virtual gray-idealized color space, applying a brightness change to the primary-color value in the virtual color space, and applying the inverse of the virtual color transformation to the brightness-changed primary-color value, thereby transforming the brightness-changed primary-color value back to a primary-color value of the reproducing device's color space.

According to yet another aspect, a computer program product is provided which is either in the form of a machine-readable medium with program code stored on it, or in the form of a propagated signal comprising a representation of program code, wherein the program code is arranged to carry out a method, when executed on a computer system of correcting brightness without, or with reduced, hue-shift of a pixel color represented as a set of primary-color values in a reproducing device's color space, by means of a composite transformation that has the property that it preserves the hueless character of gray pixels and is made up of independent primary-color related transformations. At least some of the primary-color related transformations include applying a virtual color transformation to a primary-color value of the pixel color to be brightness-corrected, thereby transforming the primary-color value into a primary-color value of a virtual gray-idealized color space, applying a brightness change to the primary-color value in the virtual color space, and applying the inverse of the virtual color transformation to the brightness-changed primary-color value, thereby transforming the brightness-changed primary-color value back to a primary-color value of the reproducing device's color space.

Other features are inherent in the methods and products disclosed or will become apparent to those skilled in the art from the following detailed description of embodiments and its accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described, by way of example, and with reference to the accompanying drawings, in which:

Fig. 1 illustrates a printing press which is equipped with a brightness correction unit enabling on-press brightness correction without, or with reduced hue-shift, according to embodiments of the invention;

Fig. 2a shows the device-independent LAB color space in which planes perpendicular to the brightness axis refer to color sets having different hues but the same brightness;

Fig. 2b illustrates a CMY color space of a printing device with gray values located on a curved line connecting the white and black pixel color line, according to embodiments of the invention;

Fig. 2c shows two brightness correction curves, according to embodiments of the invention;

Fig. 3a shows the workflow of brightness correction, according to embodiments of the invention;

Fig. 3b schematically shows a magnified view of an extract of an image (represented in a halftoning raster) before and after the brightness correction, according to embodiments of the invention;

Fig. 4 shows gray-balance curves $M(C)$, $Y(C)$ as functions of a reference color cyan C , according to embodiments of the invention;

Fig. 5a shows an example of transforming a non-gray color pixel in an image, according to embodiments of the invention;

Fig. 5b shows a brightness correction curve transforming color values to brighter color values, according to embodiments of the invention;

Fig. 6 shows the transformation of a non-gray color pixel in an image in a three-dimensional view, according to embodiments of the invention;

Fig. 7a illustrates gray-balance curves as functions of a reference color cyan and the transformation of a gray color pixel, according to embodiments of the invention;

Fig. 7b shows the brightness correction curve of Fig. 5b indicating the transformation of the gray color values of Fig. 7a, according to embodiments of the invention;

Fig. 8 shows the transformation of a gray color pixel in an image in a three-dimensional view, according to embodiments of the invention;

Fig. 9 shows a transformation combining the transformations shown in Figs. 4, 5a and 7a with the brightness correction graph shown in Figs. 5b and 7b;

Fig. 10 shows a contrast correction function that enhances the contrast of an image, according to embodiments of the invention;

Fig. 11 illustrates a first menu of a wizard in which a user enters how many reproduced images she/he wants to be presented, according to embodiments of the invention;

Fig. 12 illustrates a second menu of the wizard in which a user is requested to change the press status to ready;

Fig. 13 illustrates a third menu of the wizard in which a user is requested to print a page, according to embodiments of the invention;

Fig. 14 illustrates a fourth menu of the wizard in which a user is requested to select her/his preferred print-out, according to embodiments of the invention;

Fig. 15 shows a preview in which three reproductions and the corresponding contrast correction curves are shown, according to embodiments of the invention;

Fig. 16 shows a preview in which five reproductions and the corresponding contrast correction curves are shown, according to embodiments of the invention;

Fig. 17 shows a preview in which nine reproductions and the corresponding contrast correction curves are shown, according to embodiments of the invention;

Fig. 18 shows a flowchart indicating the course of actions of determining a preferred color reproduction of an image to be reproduced according to embodiments of the invention; and

Fig. 19 illustrates a brightness correction computer system which provides the functionality of a brightness correction unit, according to embodiments of the invention.

The drawings and the description of the drawings are of embodiments of the invention and not of the invention itself.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 shows a printing press including a brightness correction unit. However, before proceeding with the description of Fig. 1 a few items will be discussed.

In some of the embodiments, a pixel color, represented as a set of primary-color values in a reproducing device's color space, is brightness-corrected without, or with reduced hue shift by means of a composite transformation that has the property that it preserves the hueless character of gray pixels and is made up of independent primary-color related transformations. At least some of the primary-color related transformations include applying a virtual color transformation to a primary-color of the pixel color to be brightness-corrected. Thereby, the primary-color value is transformed into a primary-color value of a virtual gray-idealized color space. A brightness change is applied to the primary-color in the virtual color space, and the inverse of the virtual color transformation is applied to the brightness-changed primary-color value. Thereby, the brightness-changed primary-color value is transformed back to a primary-color value of the reproducing device's color space.

In some of the embodiments, the term "reproducing device" refers to a printing device, such as an inkjet printer or a printing press on which a brightness correction is performed, whereas in other embodiments, the term "reproducing device" refers to a monitor, such as a cathode ray tube display operating in an RGB

color space, having brightness correction capabilities. In the following, the embodiments of the invention will be explained with the focus set on printing presses and inkjet printers.

The term "pixel" as used herein refers to a representation of a color by means of primary-colors. In additive color mixing, as used in TV displays or computer monitors, the primary-colors are red, green and blue, whereas in subtractive color mixing, as used in inkjet-printers or printing presses, the primary-colors are cyan, magenta and yellow. By covering certain areas pertaining to a pixel with dots of the primary-colors, any color may be obtained. With regard to a traditional cathode ray tube monitor, a pixel may therefore be represented as three dots of phosphors on a lighting layer. The three color values of a pixel, e.g. (40%;60%;75%), indicate how intensely the three different phosphors of the color monitor have to be fired at with electrons to obtain a certain color.

The term "gray-idealized color space" refers to a color space, in which, gray colors are obtained, if, for example, the same coverage of primary-colors are provided. This implies, that gray colors lie on a space diagonal within the color space. The adjective "virtual" as used in combination with "gray-idealized color space" indicates that this color space is not related to a specific reproducing device, but rather refers to an imaginary reproducing device in which the same coverage of the primary-colors refers to a gray color.

The difficulties arising when correcting brightness of an image rely on the fact, that a brightness correction requires all primary-colors to be changed in a certain way. Theoretically, one would have to change all primary-colors by the same offset. However, when the primary-colors of a pixel color are indeed changed by the same offset, the color obtained experiences an undesirable hue-shift since, for example, the color space of a physically existing printing press has not the property that a shift by the same offset along the primary-colors results in a brighter/darker color without any hue-shifts.

To implement a color represented on a color monitor by means of an inkjet printer is difficult since

- (i) a transformation needs to be defined from the device-dependent color space of the monitor into the device-dependent color space of the inkjet printer and
- (ii) the inkjet printer is actually unable to print a pixel color as such, since an inkjet printer is only aware of dots printed in one of its primary-colors.

In order to overcome the first difficulty, profiles are applied which define a mapping from the RGB color space of the monitor into a device-independent color space, such as the LAB color space, and from the LAB color space into the device-dependent CMY color space of the inkjet printer. To overcome the second difficulty, a pixel is resolved into a multitude of dots within a certain area (herein called "pixel area"), which may be printed by the inkjet printer, whereby each dot is only of one of the primary-colors. This technique is also referred to as "halftoning". To obtain a certain color impression in the eye of the observer, a certain area within a pixel area needs to be covered with dots of each of the three primary-colors. In principle, there are two ways of covering a certain area within a pixel area with dots of primary-colors. In a frequency modulation technique, all dots are of the same size, but the number of dots of the individual primary-colors within the pixel area varies. In an amplitude modulation technique, each pixel has a fixed number of dots of each primary-color with fixed distances between the dots, but the dots vary in size. The dots do not have sizes from a continuous set of possible sizes, but may only have sizes from a discrete set of possible sizes. It should be mentioned that the dots are arranged in a raster on the paper. In fact, a raster of dots is calculated for each of the primary-colors and each raster of dots is sprayed one after another onto the paper. In some halftoning techniques, the dots are printed at least partially on top of each other, whereas in other halftoning techniques the dots do not overlap, but lie next to each other. A specification of how densely the lines of a raster are

printed, i.e. how many lines are printed within a unit length, is normally indicated in units "lines per inch". In offset printing, a typical value is 135 to 200 lines per inch, whereas in newspaper printing 75 to 135 lines per inch are common values. The halftoning is performed in a raster image processor (RIP) which calculates a raster of dots for each of the primary-colors of the printing device. Normally, these colors are cyan, magenta, yellow and black. The raster image processor is also able to transform a vector image, in which image elements are composed of graphical primitives such as lines, circles and polygons, in a raster image which can be displayed on a computer monitor in pixel mode. For printing the image by means of an inkjet printer or a printing press, the pixel raster has to be further resolved to dots, as mentioned above. Halftoning means that an image consists of nothing more than individual dots of the primary-colors of the printing device, so that an error is introduced since the dots may only have a discrete size so that not all colors may be obtained. This error can be dispersed on neighboring dots so that the error is diffused over the entire image. A well-known error-diffusion algorithm is for example the Floyd-Steinberg algorithm. However, error diffusion also alters the original colors of the image so that the dot raster obtained is not defined by the original LAB values anymore. The effect of halftoning and error diffusion algorithms can affect what is seen compared to what was measured and predicted by the color management system (CMS). Therefore, once the rastered image has been output by the raster image processor and is available in cyan, magenta and yellow dots, the image cannot be transformed back into the LAB color space which, however, would be ideal for brightness and contrast corrections. If one resorted from the dots to the LAB values which may have been stored in the RIP (as an intermediate result), one could perform the brightness or contrast corrections there and would obtain different brightness and contrast reproductions. But then, one would have to perform the computation of the dot rasters again, which is computationally expensive, to see the final result. Therefore, in some embodiments of the invention the user is enabled to perform brightness corrections directly on the dot raster and does not have to repeat the raster image processing for

brightness/contrast – corrected color reproductions represented in the LAB color space, until one has obtained a satisfactory printout.

In some of the embodiments, a brightness correction function is provided which indicates the brightness change for a multitude of primary-color values. It should be mentioned that in some of the embodiments, the brightness correction function brightens or darkens all primary-color values (whereby the individual offset may be different for different input values), whereas in other embodiments, the brightness correction function renders some primary-color values brighter and others darker, so that the contrast of the image increases. The term "brightness correction function" may therefore also refer to a contrast correction function.

In some of the embodiments, the different pixels with their corresponding primary-color values are brightness-changed one after another, whereas in other embodiments, the different primary-colors of the image are brightness-changed one after another, i.e. not the pixels are brightness-changed one after another, but first, for example the cyan color values for all pixels, then the magenta color values of all pixels, etc.

In some of the embodiments, the virtual color transformation, the brightness change and the inverse of the virtual color transformation are stored in three individual look-up tables. When performing a brightness correction, the LUTs are applied one after the other which is a rather time-consuming approach. Therefore, in some of the embodiments, the mappings defined in the three LUTs are integrated into one look-up table that defines a mapping within the printing device's color space. In these embodiments, only one LUT is applied to perform the brightness correction of a pixel color.

In some of the embodiments, the brightness correction is performed in a controller of the reproducing device.

In other embodiments, a primary-color value indicates percentages of a pixel area that is covered by dots of the primary-color according to a halftoning technique.

In some of the embodiments, the halftoning technique is implemented either in a frequency modulation mode in which the pixel area is covered by dots having the same size but are different in number or in an amplitude modulation mode in which the pixel area is covered by dots of the same number but with different sizes.

In other embodiments, the reproducing device's color space is a CMY-color space, in which the color black is obtained by printing maximum areas within a pixel areas with each of the primary-colors cyan, magenta and yellow. For several reasons, the "black" obtained like this is not ideal and so four-color printing uses black ink additionally. The reasons for using black ink include: Maximum areas printed with cyan, magenta and yellow does not yield a pure black, but a dark murky color. Printing maximum areas with dots of each of the primary inks to obtain black, can make the paper rather wet. Moreover, text is typically printed in black and includes fine details (such as serifs); so to reproduce text using three inks without slight blurring would require impractically accurate registration (i.e. all three raster images would need to be positioned extremely precisely).

Therefore, in other embodiments, the reproducing device's CMY-color space is extended by a black component which results in a CMYK color space. The black is referred to as K for key.

In some of the embodiments, the CMYK color space is still extended by a light cyan and a light magenta component. This leads to a six-dimensional color space which is also referred to as a CMYKcm color space and improves printing quality. The utilization of a lighter cyan and magenta allows to reduce the visibility of dots in lighter zones of an image.

In other embodiments, the color space has even more primary-colors, such as in seven-color printing (red, green, blue, cyan, magenta, yellow and black) invented by Harald Kueppers.

In some of the embodiments, the virtual gray-idealized color space is a color space in which hueless gray colors lie on the space diagonal between the white and black color pixel.

In other embodiments, the gray-idealized virtual color space is a color space in which brightness of a gray color is changed by means of a shift along the space diagonal between the white and black pixel color.

In some of the embodiments, the composite transformation that has the property that it preserves the hueless character of gray pixels is determined empirically by varying the dot-percent coverage of a reference color (such as cyan in the example below) and verifying how much of the other colors has to be added to obtain a hueless gray color. Normally, one would be inclined to think that the same dot-percent coverage of the other colors has to be added to obtain a gray color, but due to the physico-chemical properties of the inks, the paper and the reproducing device, these dot-percent coverages are not identical and have to be determined by measures. The compositions of the ink colors to obtain a hueless gray color, given a certain reference color, are characteristic of a printing device.

In some of the embodiments, the composite transformation that has the property that it preserves the hueless character of gray pixels can be conceived as a mapping from a curved line connecting the white and black pixel color representing hueless gray colors in the reproducing device's color space to the space diagonal between the white and black pixel color representing corresponding gray colors in the virtual gray-idealized color space. By means of this composite transformation, non-gray pixel colors (= pixel colors not lying on the curved line) are mapped accordingly. However, the transformation is only accurate for hueless gray colors. The brightness correction according to embodiments of the invention is the worse, the farther the pixel colors to be brightness-corrected are away from a gray color value.

In some of the embodiments, a user is enabled to select a preferred image reproduction from a set of image reproductions, pertaining to different brightness correction functions, of an image to be reproduced by a reproducing device. The term "brightness correction function" may either relate to the brightness or to the contrast of an image. For changing the contrast of an image, the brightness of individual pixels is altered in that some pixels are darkened and some pixels are

brightened. In total, however, the overall brightness of the image remains constant, at least more or less. For changing the brightness of an image, the brightness of all pixels is either increased or decreased by some offset, so that the overall brightness of an image is changed.

In some of the embodiments, the composite transformation that has the property that it preserves the hueless character of gray pixels, the brightness correction function and the inverse of the composite transformation are integrated into one look-up table that can be applied to other images to be reproduced by the reproducing device. Thereby, the brightness reproduction of an image is adapted to a user's preference.

Some of the embodiments of the invention enable a user to select a preferred image reproduction from a set of image reproductions. This is performed, in some of the embodiments, by means of a wizard-guided menu. A user-selected number of image reproductions, pertaining to different brightness correction functions, are shown on one page within the wizard-guided menu. Accordingly, the user-selected number of image reproductions, pertaining to different brightness correction functions, are printed on one page by the printing device. The user prints the one or more pages containing the selected number of image reproductions and assesses them in terms of their brightness. Then, s/he selects in the wizard-guided menu the image reproduction s/he prefers.

In some of the embodiments, the brightness correction functions which correspond to the image reproductions are also shown next to the image reproductions in the wizard-guided menu.

Some of the embodiments refer to a reproducing device that includes a controller for correcting brightness without, or with reduced hue shift of a pixel color, represented as a set of color values represented in the reproducing device's color space. The brightness correction is performed in accordance with the embodiments described above.

Some of the embodiments of the computer program product with program code for performing the described methods include any machine-readable medium

that is capable of storing or encoding the program code. The term "machine-readable medium" shall accordingly be taken to include, for example, solid state memories and, removable and non removable, optical and magnetic storage media. In other embodiments, the computer program product is in the form of a propagated signal comprising a representation of the program code, which is increasingly becoming the usual way to distribute software. The signal is, for example, carried on an electromagnetic wave, e.g. transmitted over a copper cable or through the air, or a light wave transmitted through an optical fiber. The program code may be machine code or another code which can be converted into machine code, such as source code in a multi-purpose programming language, such e.g. C, C++, Java, C#, etc. The embodiments of a computer system may be commercially available general-purpose computers programmed with the program code.

Returning now to Fig. 1 which shows a printing press 1 with a brightness correction unit 2 which is able to correct colors in brightness directly on the printing press 1, without having to return the image to be printed to the designer who is able to make corrections in a device-independent color space appropriate for performing brightness or contrast corrections. The printing press 1 enables a user to make brightness or contrast corrections after a raster image processor (RIP) has converted an image source into a raster image which serves as an input for the printing press 1 by providing instructions how to implement the colors of the image in terms of sizes and positions of ink dots. The inks refer to primary-colors of the printing press 1, in the example cyan, magenta and yellow, and span the printing press's 1 color space. The printing press 1 is equipped with a video display 3 via which a wizard guided menu is presented to a user who may select color reproductions according to her/his preferences. The user's decision of a preferred color reproduction is based upon printouts of the image on the printing press 1 and not on color reproductions as shown on the video display 3. The preferred color reproduction is stored by means of a lookup table 4 and may be applied to further images to be printed. The calculation of the lookup table 4 will be explained by means of Figs. 2 to 10, whereas the wizard-guided menu will be explained in Figs. 11 to 18.

Fig. 2a shows the LAB color space 10 in form of a color cylinder. In contrast to the RGB or CMY(K) color model, the brightness information is separated from hue information. This means that there is an own axe 11 (labeled with "L") for indicating brightness and is therefore referred to as brightness axe 11 which is perpendicular to both color axes 12 and 13. Axe 12 (labeled with "a") refers to green colors in its negative domain and to red colors in its positive domain. Axe 13 (labeled with "b") refers to blue colors in its negative domain and to yellow colors in its positive domain. Hueless gray values are located on the brightness axe 11 ranging from black to white. Each plane within the LAB color space 10 which is perpendicular to the brightness axe 11 (and parallel to the a-b plane) contains colors of different hues but the same brightness. To increase the brightness of a color represented in the LAB color space one simply shifts a color point 14 parallel to the L-axe in positive direction to the L-axe 11. To decrease the brightness of a color, color point 15 is shifted in negative direction of the L-axe. In other words, the LAB color space enables changing of the brightness of a color by simply changing the L-coordinate of the color. In other words, to change the color of an image, the L-coordinate of all pixels is shifted by an offset, whereas the a and b coordinates remain unaltered.

Fig. 2b illustrates the CMY color space 17 of the printing press 1. In theory, one would expect that hueless gray values lie on a space diagonal 18. However, since the printing press 1 is a physical device using inks with physico-chemical properties that do not obey to the rules of a theoretical color space, all hueless gray values are located on a curved line 19 connecting the white and black pixel color which is determined empirically. Furthermore, in contrast to the LAB color space shown in Fig. 2a, there are no planes within the CMY color space of the printing press 1 on which colors with the same brightness are located. The idea is to define a transformation which maps hueless gray colors located on the curved line connecting the white and black pixel color 19 of the CMY color space of the printing press 1 onto the space diagonal 18 of a virtual CMY color space. By means

of this mapping, non-gray colors of the color space are transformed accordingly, as will be explained in Figs. 5a and b.

Fig. 2c shows a brightness correction curve $B_1(x)$ 20 which adds 20% to the brightness coordinate of a color point and therefore corresponds to the shift of color point 14 of Fig. 2a. It should be mentioned that a shift by 20% in positive direction refers to brightening an image in the LAB color space. However, this means that all color values being above 80%, for example color point 16, are mapped to 100% since more than 100% is not possible. Therefore, the image gets brighter, but all color points of the cylinder volume element $L \in [80..100]$ are mapped to white. This behavior is undesirable because it removes dynamic from the image in that it maps colors from a brightness between 0 and 100 to a brightness between 20 and 100. Moreover, for example all dark points with a brightness of $[0..20]$ are removed from the image, since color points of the color cylinder $[0..20]$ do not exist any more after the brightness correction curve $B_1(x)$ 20 has been applied. Therefore, another brightness correction curve, such as $B_2(x)$ 21 is preferably used. This brightness correction curve 21 has the property that the colors white and black remain invariant, and that color values from a mid range are brightened most, whereas colors in the neighborhood of white and black are less brightened. The brightness correction curve 21 does not alter the dynamic of the image since all brightnesses, from 0% to 100%, may still appear after the transformation. This difference in change of brightness for different percentage ranges may be compared with the brightness correction curve $Id(x)$ 22 which is the identity function leaving all colors unchanged.

Fig. 3a illustrates a brightness correction workflow in accordance with embodiments of the invention. In a raster image processor (RIP) 23, color values of an image pertaining to a RGB device-dependent color space 24 are changed into information (or instructions) which is understood by the printing press 1. Since the printing press 1 operates in its own CMY color space, the color values of the RGB color space are transformed by means of profiles. A first ICC-profile 25 maps color values from the RGB color space into the device-independent LAB color space 10.

By means of a second ICC-profile 27, these LAB color values are transformed into CMY color space 28 of the printing press 1. Up to here, only a color space transformation has taken place. However, the task of the RIP 23 is to tell the printing press 1 how to realize the CMY color points in terms of typography. To this end, a halftoning procedure 29 transforms colors defined in the CMY color space 17 of the printing press 1 into individual dots to be printed by the printing press 1. In terms of implementing the colors, the printing press 1 is only able to print, at a certain position, a dot of one of its primary-colors or not. It does not mix the inks of the individual primary-colors to obtain any color of the color space. Rather, by covering an area by certain percentages of dots of the individual primary-colors a color impression comes into being in the eye of the beholder. It should be mentioned that the color dots normally do not mix when being sprayed on the paper, but may overlap partially. There are two halftoning procedures; in a "frequency modulation" halftoning procedure all dots have the same size, and the number of dots sprayed by each primary-color determines the color, whereas in "amplitude modulation", a color is determined by dots of different sizes whereby the distances between the centers of individual dots is constant, but the dots have different sizes (diameters). By means of halftoning, a color impression may be implemented by three ink (cyan, magenta and yellow) dots of different sizes located close to each other. What is obtained after the halftoning 29, is a raster of dots wherein a small area is covered with dots of the primary-colors according to percentages for the individual primary-colors. More precisely, there is a raster for each of the inks and the rasters are sprayed one after the other. A raster of dots may also be referred to as a bitmap. However, the halftoning 29 also introduces some fault since only a discrete set of colors may be implemented, since the primary-color dots are only provided in discrete sizes. Therefore, an error diffusion procedure 30 is used to distribute local errors across larger parts of an image. The bitmaps obtained after the error diffusion 30 are then transmitted to the printing press 1 and are stored in the storage of the printing press 1. It should be mentioned that color management, based on profiles, only works on pixels, but not dots,

whereas the final output is created with dots. The effect of halftoning may affect what is seen compared to what was measured and predicted by the color management system. Although brightness correction could be easily done in the LAB color space, it is impossible to go back, after ripping the image, to the LAB space, and do the brightness correction there. Even if this were possible, one would have to rip the image again which is an expensive operation from a computational point of view.

Alternatively, if the color values are directly provided by the designer in a CMY raster format 31, no conversion needs to be performed on the color values, and the CMY color values are directly stored in the storage of the printing press 1 at 32. In the printing press 1, the color values are subjected to a transformation T^{-1} from the CMY color space of the printing press 1 into a virtual gray-idealized color space 33. In the virtual gray-idealized CMY color space 33, a brightness correction function, in the example brightness correction function $B(x)$ 34, is applied to the color values in the virtual color space 33. Then, a transformation T , transforms the color values of the virtual gray-idealized CMY color space 33 back into the CMY color space of the printing press 1, so that the printing press 1 has the colors coded with respect to its own color space. At 37, the image is printed and the user may assess different print-outs obtained by applying different brightness correction functions and may then opt for her/his preferred color reproduction of the image.

The transformation T is defined as a function $R^3 \rightarrow R^3$ which transforms color values from the virtual gray-idealized CMY color space 35 into the CMY color space 32 of the printing press 1. The transformation T^{-1} is a function which transforms color values from the CMY color space of the printing press 1 back into the virtual gray-idealized CMY color space. Each color component of a color point X is transformed individually by the transformations T_C , T_M and T_Y . Since cyan is used as a reference color component, the transformation T_C is the identity function and is therefore left away. Therefore, to the cyan component of a color, only the brightness correction curve 34, in this case the brightness correction curve is applied:

$$19$$

$$C' = B(C)$$

The magenta component is first transformed from the CMY color space of the printing press 1 back into the virtual CMY color space, the brightness correction curve is applied, and then the color value is retransformed into the CMY color space of the printing press 1. This is expressed by means of the following formula:

$$M' = T_M(B(T_M^{-1}(M)))$$

Similarly, the yellow component is first transformed from the CMY color space of the printing press 1 back into the virtual CMY color space, the brightness correction curve is applied, and then the color value obtained is retransformed into the CMY color space of the printing press 1. This is expressed by means of the following formula:

$$Y' = T_Y(B(T_Y^{-1}(Y)))$$

Fig. 3b schematically illustrates the brightness correction as shown in Fig. 3a. An extract of a dot raster 38 representing an image before correction is indicated, whereas the same extract of the dot raster 39 is shown after correction below. The dot raster at 38 has been calculated by the raster imaging processor 23 (steps 24 to 30 in Fig. 3a), whereas the dot raster 39 has further been subjected to the brightness correction (steps 32 to 36 in Fig. 3a) without any further processing by the raster imaging processor 23. Actually, a raster is calculated for each color individually and is printed one after the other. To avoid any Moiré-effects (formation of new undesired lines when overlaying different rasters), the rasters for the individual colors are shifted by a certain angle. In four color printing (cyan, magenta, yellow and black), the individual rasters are shifted, for example, by the following angles: yellow=0°, cyan=75°, black=135°, magenta=15°.

In the example, each set of three primary-color dots defines a color which is perceived by an observer. A color is determined by the percentage area covered by each dot. The distances between the centers of the dots remain constant, whereas their radii depend on the area required for obtaining a certain color. In the

example, the brightness correction effects that in the first cell of the upper dot raster in comparison to the first cell of the dot raster below, the radius of the cyan dot has been reduced, the magenta dot has been increased and the yellow dot has not been altered. It should be mentioned that in the example the dots are printed next to each other, whereas some halftoning techniques also allow the dots to be printed on top of each other.

Fig. 4 shows a schematic graph of values or amounts of magenta and yellow that are required to be combined with amounts of cyan in a printing press to print hueless gray pixels in an image at different brightnesses.

Cyan, by way of example, is the designated reference color component in graph 40 and the abscissa of the graph is graduated in values of C in dot-percent coverage. Dot-percent coverage for M and Y that provide a hueless gray for a given dot-percent coverage of C along the abscissa are indicated by the ordinates of gray balance curves M(C) 42 and Y(C) 43 respectively for the given dot-percent coverage of C. A gray balance curve 41 for cyan, which has a slope of one because cyan functions as the reference color component, is also given for comparison. For convenience of presentation, the color component with which a gray balance curve is associated is given in parentheses next to the numeral labeling the curve. Whereas graph 40 does not show a correspondence between a given C value and a particular brightness, (the abscissa is graduated in values of C not brightness) values of C equal to 0 and 100 substantially correspond to white (no print) and black (darkest gray printable) respectively.

By way of example, it is assumed that a gray value that requires a 50% coverage of cyan is desired. The value of each of the component curves is determined at an abscissa value of 50%. This indicates that cyan should be printed with a dot coverage of 50%, magenta with a dot coverage of about 34% and yellow with a dot coverage of about 37%.

It is noted that the magenta and yellow gray balance curves 42 and 43 shown in graph 40 are not universal. The gray balance curves will in general vary with the printing press, the particular CMY inks used to print an image using the press and

the paper on which the image is printed. The C, M(C) and Y(C) gray balance curves are represented in LUTs 45, 46 and 47 below.

Figs. 5a and b schematically illustrate performing a brightness correction, which by way of example is a brightness correction, on a non-gray color of a pixel in an image, in accordance with an embodiment of the present invention. Fig. 5a shows graph 40 shown in Fig. 4 in which, additionally, the original values (dot percent coverage) of the cyan, magenta and yellow color components of the pixel color are indicated along the ordinate of the graph by witness lines 51, 52 and 53 respectively. The ordinate corresponds to the CMY color space of the printing press 1 from which the color values are taken. Before the actual correction of the colors, the color values are transformed into the virtual CMY color space, which corresponds to the abscissa. In the example, the values for the C, M and Y color components are assumed to be equal to 30, 36 and 22. Each of these values, together with the letter indicating the color component with which it is associated, is given in parentheses next to its corresponding witness line.

In accordance with an embodiment of the invention, "C", "M" and "Y" points 61, 62 and 63 are determined that are located respectively on C, M(C) and Y(C) gray balance curves 41, 42 and 43 and have ordinates equal respectively to the ordinates 51, 52 and 53. C, M and Y points 61, 62 and 63 are graphically represented by circle inscribed plus signs and as a visualization aid, an arrow leads from each ordinate 51, 52 and 53 towards its associated C, M or Y point. The abscissas of C, M and Y points 61, 62 and 63 are then determined. For C, M and Y points 61, 62 and 63, the abscissas are respectively equal to 30, 47 and 34 and are indicated on graph 40 by abscissa witness lines 71, 72 and 73. The color component and value of the abscissa associated with a given abscissa witness line 71, 72 and 73 is given in parentheses next to the witness line. It is noted that as a result of the pixel color being non-gray, at least two of the abscissas of the C, M and Y points corresponding to the color component values of the pixel color have different values. Were the pixel color to be gray, all the abscissas would have a same value, as is shown in Figs. 7a and b. The color values 71, 72 and 73 are now in the virtual

color space, in which gray colors lie on the space diagonal and in which a brightness correction is performed according to the brightness correction curve shown in Fig. 5b.

The brightness correction to be applied to the original pixel color having C, M and Y values is, for example, defined by a schematic graph 78 shown in Fig. 5b. In graph 78 a "brightness correction curve" $B(x)$ 80 provides a relationship between an "input" dot percent coverage of a pixel color in the image that is to be brightness corrected and a brightness corrected "output" dot percent coverage for the pixel color. The abscissas of C, M and Y points 61, 62 and 63 are transformed responsive to brightness correction curve 80 to provide a new "brightness corrected" value for the abscissa of each color component C, M and Y of the pixel color. The new brightness corrected abscissas for C, M and Y are equal to the ordinates of brightness correction curve $B(x)$ 80 at respectively the "old" abscissas 71, 72 and 73 determined from the gray balance curves 41, 42 and 43 shown in Fig. 5a. It should be mentioned that the brightness correction curve $B(x)$ 80 maps color values from the virtual color space into the virtual color space, i.e. a change of the color space does not take place.

The ordinates in Fig. 5b corresponding to abscissas 71, 72 and 73 are equal respectively to 65.5, 84 and 71.5 and are indicated in Fig. 5b by ordinate witness lines 81, 82 and 83. To aid in visualization, dashed vertical and horizontal lines connect corresponding abscissas and ordinate witness lines.

To determine new brightness corrected values for the pixel color, new brightness corrected C, M and Y points 91, 92 and 93 on gray balance curves 41, 42 and 43 respectively in Fig. 5a are located. The new brightness corrected points, graphically represented as "diamond inscribed" plus signs, have abscissas equal respectively to the brightness corrected abscissas 81, 82 and 83 determined from brightness correction curve 80 (Fig. 5b). The brightness corrected values for the C, M and Y color components of the brightness corrected pixel color are equal to the ordinates of new, brightness corrected C, M and Y points 91, 92 and 93. For these brightness corrected points, the ordinates and thereby the new brightness corrected

C, M and Y values are equal respectively to 68, 62.5 and 55.5, which are indicated by ordinate witness lines 101, 102 and 103. As a visualization aid, an arrow leads from each brightness corrected C, M and Y point 91, 92 and 93 to its associated ordinate witness line 101, 102 or 103. Dashed horizontal and/or vertical lines connect each old C, M and Y point 61, 62 and 63 with its corresponding brightness corrected C, M and Y point 91, 92 and 93.

Fig. 6 illustrates the transformation T^{-1} (mentioned in Fig. 3a) of a non-gray color from the color space of the printing press into the virtual gray-idealized CMY color space in a three-dimensional view. In the virtual gray-idealized CMY color space, the space diagonal 110 refers to the color space in which all hueless gray colors lie on the space diagonal, whereas the curved line 111 refers to the CMY color space of the printing press 1. Mathematically, the curved line may be represented in a parameterization as follows:

$$Gray(C) = \begin{pmatrix} C \\ M(C) \\ Y(C) \end{pmatrix}$$

where C, M(C) and Y(C) are the gray balance curve 41, 42 and 43, shown in Fig. 4.

By means of the mapping T, all points of the space diagonal 110 (the gray values of the virtual gray-idealized color space) are mapped onto the curved line connecting the white and black pixel color 111 (the gray values of the color space of the printing press 1). A mapping with this property may also be used to map non-gray colors accordingly. In the example, non-gray color 112 pertaining to the color space of the printing press 1 is mapped on its corresponding color in the virtual gray-idealized CMY color space. To this end, a plane 113 is regarded which is parallel to the C-M plane and which includes the non-gray color 112. Then the two points of intersection 114 and 115 of the space diagonal 110 and the curved line 111 are regarded and the difference in direction to C is calculated, which is referred to as ΔY 116. Then, a plane 117 is regarded which is parallel to the C-Y plane and all points of the plane 117 have the same M values as point 112. Then, the two

intersection points 118 and 119 of the space diagonal 110 and the curved line 111 are regarded and the difference in direction to C is calculated, which is referred to as ΔM 120. Consequently, the point 112 to be transformed is shifted by ΔY 116 in positive direction of the Y-axis, and by ΔM 120 in positive direction of the M-axis. The point obtained 121 corresponds to the point 112 (pertaining to the color space of the printing press 1) in the virtual color space. This point 121 may then be transformed by means of the brightness correction curve and may then be retransformed to the color space of the printing press 1. (The last two steps are not depicted in Fig. 6.)

Figs. 7a and b are similar to Figs. 5a and 5b respectively. However, instead of a brightness correction of a *non-gray* pixel, Fig. 7a shows the graph 40 in which values of C, M and Y color components of a *gray* pixel in an image are indicated along the ordinate of the graph by witness lines 131, 132 and 133. The C, M and Y values of the gray pixel color are assumed, by way of example, to be equal to 38.5, 26 and 22.8 respectively. Corresponding C, M and Y points 141, 142 and 143 on gray balance curves 41, 42 and 43 respectively are indicated graphically by plus signs inscribed in circles. Fig. 7b shows graph 78 and brightness correction curve 80 shown in Fig. 5b, which is used, as in the case of non-gray pixel color, to perform the brightness correction of the gray pixel color.

The C, M and Y points on the gray balance curves in graph 40 corresponding to a gray color have a same abscissa in the graph, as noted in the discussion of Fig. 5a. For the instant gray color illustrated in Fig. 7a, C, M and Y points 141, 142 and 143 respectively have a same abscissa, which has a value equal to 36 and is indicated by abscissa witness line 150. As a result, when applying the brightness correction defined by curve 80 in Fig. 7b to the gray pixel color, the new brightness corrected abscissa has a same value for all three components. For the C, M and Y points 141, 142 and 143 shown in Fig. 7a, the brightness corrected abscissa is equal to 73 and is indicated by ordinate witness line 150.

New brightness corrected C, M and Y points 151, 152 and 153 corresponding to the brightness corrected abscissa determined from graph 78 in Fig.

7b are represented graphically in graph 7a by diamond inscribed plus signs. The brightness corrected values for the C, M and Y components 131, 132 and 133 of the gray pixel are equal to 74, 54 and 57.9 respectively and are indicated by witness lines 161, 162 and 163 respectively. Since all the brightness corrected C, M and Y points have a same abscissa the brightness corrected gray pixel color is also a gray color and the correction preserves the non-hue gray quality of the original pixel color.

In the above examples of a color transformation, in accordance with an embodiment of the present invention, the combinations of color component values that provide gray colors are referenced to one of the color component values, which in the instant case is the C color component. However, methods of performing a brightness correction in accordance with an embodiment of the invention, the color components may be referenced to any suitable reference variable for which, for a given value of the reference variable, the associated values of the color components provide a gray color. For example, a suitable reference variable may be brightness.

Fig. 8 shows in a tree-dimensional view how a gray color point 170 located on the curved line connecting the white and black pixel color 111 is going to be transformed into the virtual color space. To this end, a plane 171 is considered which is parallel to the C-M plane and has the same Y-value as point 170. The intersection between the diagonal 110 and the plane 171 is point 172, and the distance between point 170 and point 172 is ΔY 173. Another plane 174 is considered which is parallel to the C-Y plane and has the same M-value as the point to be transformed 170. The distance between the point 175 and the point 170 direction to C is considered as ΔM 176. The point 170 can now be shifted by ΔM 176 in direction to M, and by ΔY in direction to Y. Thereby, the point 170 is transformed into point 176 located on the diagonal 110 and represents a gray value in the virtual color space.

Fig. 9 shows a combined brightness correction graph 180 corresponding to gray balance graph 40 (Figs. 4, 5a or 7a) and brightness correction graph 78 (Figs. 5b, 7b) which converts a dot-percent coverage input value for a color component

into a brightness corrected dot-percent coverage output value. Graph 180 includes C brightness correction curve 80 shown in Figs. 5b and 7b and in addition M and Y brightness correction curves 186 and 188. Graph 180 is useable to perform the same function as graphs 40 and 78 and provides the same results. For example, in performing the brightness correction illustrated using Figs. 5a and b, original C, M and Y values 30, 36 and 22 were brightness corrected to corresponding brightness corrected values 68, 62.5 and 55.5 respectively. The same results are obtained using graph 180 by determining the ordinates of C, M and Y brightness correction curves 80, 186 and 188 respectively for values along the abscissa of the graph equal to the original C, M and Y values 68, 62.5 and 55.5 respectively. In Fig. 9 abscissa witness lines 191, 192 and 193 indicate the original C, M and Y input values. Corresponding output brightness corrected C, M and Y values are indicated by ordinate witness lines 201, 202 and 203 respectively. Dashed vertical and horizontal lines connect corresponding input and output C, M and Y values.

It is noted that whereas in the above description input C, M and Y dot-percent coverage values are converted to brightness corrected output values using graphs, the graphs may of course be expressed as suitable LUTs 194, 195 and 196 and the LUTs used to perform the brightness corrections. It is also noted that methods of brightness correction in accordance with embodiments of the present invention may be used to perform brightness corrections other than brightness corrections. For example, contrast brightness corrections may be performed on pixel colors in an image similarly to the manner in which brightness corrections in accordance with an embodiment of the invention are performed.

Fig. 10 shows a schematic graph 208 having a contrast correction curve 210 that defines a contrast correction. As in the case of brightness correction curve 80, contrast correction curve 210 provides a relationship between an input dot-percent coverage and an output dot percent coverage. Curve 210 is used similarly to the manner in which curve 80 is used, i.e. to provide a new abscissa for an old abscissa of color component values of a pixel color. The curve 210 has a S-shape which is typical of contrast correction curves. In a first interval, i.e. interval [0%..25%] the

contrast between two pixels lying within this interval is decreased. The contrast correction curve does a compression in this interval, since the slope s of the contrast correction curve is between zero and one. In a second interval, i.e. interval [25%...75%] the contrast between two pixels lying within this interval is increased which corresponds to a dilatation, since the slope s of the contrast correction curve is above one in this interval. In a third interval [75%..100%], the contrast between two pixels lying in this interval is decreased. The contrast correction curve performs a compression in this interval, and the slope s of the contrast correction curve is between zero and one.

It should be understood that the shape of a brightness correction curve, such as curves 80 and 210, to be implemented in accordance with the present invention is practically unconstrained so long as it is single valued. Brightness correction that preserves gray balance and at least approximately color balance, may be implemented in accordance with the present invention using substantially any single valued brightness correction curve.

The following Figs. 11 to 17 pertain to a graphical user interface by means of which a user may select her/his preferred brightness correction.

In Fig. 11 a first page "Settings" of an interactive brightness correction wizard 220 is shown, which enables the user to select in a print settings menu 221, whether s/he wishes to have a single preview, three preview, five previews or nine previews printed on one page. If the user decides to print each preview on a single page, s/he is enabled to select in box "Steps" how many previews she/he wants to print. The steps number has to be odd, larger than 3 and less than 11. In a color settings menu 222 the user is enabled to choose whether s/he wants to make correction for a single separation or for all of them together. In the first case, s/he will choose the separation name from the combo – box together with the ink. This combo-box is enabled, if single separation correction mode check box is ticked. If the job is not of the CMYK or CMY color set, the single separation mode is forced: the check box is disabled and ticked and the combo-box is always enabled. A press operator defines the type of corrections, which are to be done in the bottom part of

the wizard dialogue. The contrast range is bounded from -15 to 15 , and the brightness range is limited to -20 and 20 . The brightness and contrast check boxes cannot be ticked simultaneously. The "Next" button is enabled only if one of the brightness or contrast check boxes are ticked. When "Cancel" button is pressed, the whole process is canceled without any job modification. At this stage, there is no need in confirmation.

Fig. 12 shows a second brightness correction wizard menu page, referred to as "Go to ready". This page is activated only, if the press is not in the ready state, when the "Next" button of the "Settings" (Fig. 11) or "Results" page (Fig. 13) is pressed.

Fig. 13 illustrates a third brightness correction wizard menu page, referred to as "Print". It is activated, if the press is in the ready state after the "Settings", "Results" and "Go to Ready" pages. The sentence "Click the Print button to proof the page" is changed to "Click the print button to proof the element" in the case when element correction was chosen.

Fig. 14 illustrates a fourth wizard menu page, named "Results". This page appears each time, when a print is stopped. It is similar to the first wizard menu page "Settings" shown in Fig. 11. In addition to this page, it has a graphical user interface for choosing the best printed configuration. When the "Finish" button is pressed, the following pop-up will appear: "Your look-up tables are going to be changed." with two options: OK and Cancel.

When single preview (Mode A) per page is chosen, amount of printing samples is defined by number, entered into edit box "Steps" (see Fig. 11). In other case (Mode B), it is defined by number of samples per page. It is assumed that c_{min} , c_{max} , b_{min} , b_{max} are contrast and brightness range values as it appears in the dialog. The steps number can be defined when single page preview mode is chosen or is hard coded otherwise. It is assumed that the operator has chosen to use contrast corrections with N steps. Then, when none of the range values is zero, $N-1$ contrast LUTs will be generated with the following parameters:

29

$$c_i = c_{\min} + \frac{c_{\max} - c_{\min}}{N-1}(i-1)$$

where i runs from 1 to N . The original configuration $c_0=0$ is to be added and inserted in the way, which conserves ascending order of the whole sequence:

$$c_1 < c_2 < \dots < c_0 < \dots < c_{N-1}$$

In the case, when one of the minimum or maximum range values are chosen to be zero, the number of calculated samples is raised by 1 and there is no need to add the original configuration.

Fig. 15 illustrates on the left side the placement of three preview images on a single page, and the corresponding brightness correction curves are shown on the right side. In this case, the new element maximal height is given by the following formula

$$h_{\text{new}} = \frac{H - \delta - 3d}{3}$$

where d is distance between elements. It is assumed that δ is real page margin. The scaling factor S_3 is

$$S_3 = \begin{cases} 1, & \text{if } h_{\text{new}} \geq h \\ h_{\text{new}} / h, & \text{otherwise} \end{cases}$$

On the right side of Fig. 15, one sees the corresponding contrast correction curves being applied on the images.

Fig. 16 shows on its left side the placement of five preview images on a single page, and the corresponding brightness correction curves are shown on the right side. In this case, one has to consider both new element maximal width w_{new} and height h_{new} , which are calculated as follows:

$$\begin{cases} h_{\text{new}} = \frac{H - \delta - 3d}{3} \\ w_{\text{new}} = \frac{W - 2\delta - d}{2} \end{cases}$$

The resulting scale factor is defined as maximal between horizontal and vertical scaling factors:

$$S_5 = \max(S_5^v, S_5^h)$$

Fig. 17 shows on its left side the placement of nine preview images on a single page, and the corresponding brightness correction curves are shown on the right side. In this case, the maximal width and height of the image element is given by the following expression:

$$\begin{cases} h_{new} = \frac{H - \delta - 3d}{3} \\ w_{new} = \frac{W - 2(\delta + d)}{2} \end{cases}$$

Furthermore, whereas in the above examples pixel colors are assumed to be printed using a CMY set of printing inks (i.e. color components), other sets of printing inks may be used in the practice of the present invention. For example, printing ink sets including RGB inks or printing

Fig. 18 illustrates a flowchart of the course of actions of on-press brightness corrections. At 240, the user is enabled to set print settings which means that he selects how many previews he wishes to print on a single page. At 241, it is ascertained whether the press is ready. If the press is ready, then the user is asked to change the press status to ready at 242. At 243, the print pages are printed on the press, and at 244, the user is prompted to assess the print-outs. In a menu, similar to the settings page, he chooses the best configuration of the printed previews at 245. At 246, when the finish button in the results page is pressed, the following pop-up will appear "Your job look-up tables are going to be changed." The user selects OK to confirm the changing of the look-up tables or presses "Cancel" in order to avoid the changing of the look-up tables.

Fig. 19 is a diagrammatic representation of a computer system which provides the functionality of the brightness correction unit 2 of Fig. 1, and is therefore denoted as "brightness correction computer system 2". Within the brightness correction computer system 2 a set of instructions, for causing the computer system to perform any of the methodologies discussed herein, may be executed. The brightness correction computer system 2 includes a processor 250, a main memory 251 and a network interface device 252, which communicate with each other via a

bus 253. Optionally, it may further include a static memory 254 and a disk drive unit 255. A video display 3, an alpha-numeric input device 256 and a cursor control device 257 may form a brightness correction user interface. The network interface device 252 connects the brightness correction computer system 2 to the Internet. A set of instructions (i.e. software) 258 embodying any one, or all, of the methodologies described above, resides completely, or at least partially, in or on a machine-readable medium, e.g. the main memory 251 and/or the processor 250. A machine-readable medium on which the software 258 resides may also be a data carrier 259 (e.g. a non-removable magnetic hard disk or an optical or magnetic removable disk) which is part of disk drive unit 255. The software 258 may further be transmitted or received as a propagated signal 260 via the Internet through the network interface device 252.

Thus, the embodiments of the invention described above allow for an on-press contrast or brightness correction without any transformations into a LAB color space, whereby hueless gray values are only changed in brightness or contrast and non-hueless gray values are mapped approximately.

All publications and existing systems mentioned in this specification are herein incorporated by reference.

Although certain methods and products constructed in accordance with the teachings of the invention have been described therein, the scope of coverage of this patent is not limited thereto. On the contrary, this patent covers all embodiments of the teachings of the invention fairly falling within the scope of the appended claims either literally or under the doctrine of equivalents.

CLAIMS

1. A method of correcting brightness without, or with reduced, hue-shift of a pixel color represented as a set of primary-color values in a reproducing device's color space, by means of a composite transformation that has the property that it preserves the hueless character of gray pixels and is made up of independent primary-color related transformations, at least some of which comprising:

applying a virtual color transformation to a primary-color value of the pixel color to be brightness-corrected, thereby transforming the primary-color value into a primary-color value of a virtual gray-idealized color space,

applying a brightness change to the primary-color value in the virtual color space, and

applying the inverse of the virtual color transformation to the brightness-changed primary-color value, thereby transforming the brightness-changed primary-color value back to a primary-color value of the reproducing device's color space.

2. A method of correcting brightness without, or with reduced, hue-shift of an image comprising pixel colors, represented as a set of primary-color values in a reproducing device's color space, wherein a brightness correction function is used for defining brightness changes to be applied, the method comprising:

for the different pixels:

individually applying the method of claim 1 to the primary-color values of the pixel with the brightness change defined in the brightness correction function.

3. A method of correcting brightness without, or with reduced, hue-shift of an image comprising pixel colors, represented as a set of primary-color values in a reproducing device's color space, wherein a brightness correction function is used for defining brightness changes to be applied, the method comprising:

for the different primary-colors:

individually applying the method of claim 1 to the pixels with the brightness change defined in the brightness correction function.

4. The method of any one of the preceding claims, wherein the virtual color transformation, the brightness change and the inverse of the virtual color transformation are stored in a look-up table individually.

5. The method of any one of the preceding claims, wherein for each primary-color, the virtual color transformation, the brightness change, and the inverse of the virtual color transformation are integrated into one look-up table, thereby defining a mapping within the reproducing device's color space.

6. The method of any one of the preceding claims, wherein the reproducing device is a printing press or an inkjet printer.

7. The method of any one of the preceding claims, wherein the method is performed in a controller of the reproducing device.

8. The method of any one of the preceding claims, wherein a primary-color value indicates percentages of a pixel area that is covered by dots of the primary-color according to a halftoning technique.

9. The method of any one of the preceding claims, wherein the halftoning technique is implemented either in a frequency modulation mode in which the pixel area is covered by dots having the same size but are different in number or in an amplitude modulation mode in which the pixel area is covered by dots of the same number but with different sizes.

10. The method of any one of the preceding claims, wherein the reproducing device's color space is a CMY-, CMYK- or CMYKcm - color space.

11. The method of any one of the preceding claims, wherein the printing device's color space has more than three components.

12. The method of any one of the preceding claims 1, wherein the virtual gray-idealized color space is a color space in which hueless gray pixel colors lie on the space diagonal between the white and black pixel color.

13. The method of any one of the preceding claims, wherein the virtual color space is a CMY-color space in which brightness of a gray color is changed by means of a shift along the space diagonal between the white and black pixel color.

14. The method of any one of the preceding claims, wherein the composite transformation that has the property that it preserves the hueless character of gray pixels is determined empirically and is characteristic of the reproducing device.

15. The method of any one of the preceding claims, wherein the composite transformation that has the property that it preserves the hueless character of gray pixels maps a curved line connecting the white and black pixel color representing hueless gray colors in the reproducing device's color space to the space diagonal between the white and black pixel color representing corresponding gray colors in the virtual gray-idealized color space.

16. A method of enabling a user to select a preferred image reproduction from a set of image reproductions, pertaining to different brightness correction functions, to be reproduced by a reproducing device, the method comprising:
providing different brightness correction functions,
performing for each brightness correction function the following two activities:

- a) applying the method of claim 2 or 3 to with the brightness changes defined in the brightness correction function to obtain an image reproduction,
- b) reproducing the image reproduction with the reproducing device, and enabling the user to select her/his preferred image reproduction.

17. The method of claim 16, wherein the composite transformation that has the property that it preserves the hueless character of gray pixels, the brightness correction function and the inverse of the composite transformation are integrated into one look-up table that can be applied to other images to be reproduced by the reproducing device thereby providing a user-preferred brightness reproduction.

18. The method of claim 16 or 17, wherein the selection of the preferred image reproduction is performed by means of a wizard-guided menu.

19. The method of claim 18, wherein a user-selected number of previews of image reproductions pertaining to the different brightness correction functions are shown on one page within the wizard-guided menu on a display and are printed on one sheet of paper by the reproducing device.

20. The method of claim 19, wherein the correction functions corresponding to the image reproductions, are additionally shown within the wizard-guided menu.

21. A reproducing device comprising a controller for correcting brightness without, or with reduced, hue-shift of a pixel color represented as a set of primary-color values in a reproducing device's color space, by means of a composite transformation that has the property that it preserves the hueless character of gray pixels and is made up of independent primary-color related transformations, at least some of which comprising:

applying a virtual color transformation to a primary-color value of the pixel color to be brightness-corrected, thereby transforming the primary-color value into a primary-color value of a virtual gray-idealized color space,

applying a brightness change to the primary-color value in the virtual color space, and

applying the inverse of the virtual color transformation to the brightness-changed primary-color value, thereby transforming the brightness-changed primary-color value back to a primary-color value of the reproducing device's color space.

22. A computer program product which is either in the form of a machine-readable medium with program code stored on it, or in the form of a propagated signal comprising a representation of program code,

wherein the program code is arranged to carry out a method, when executed on a computer system of correcting brightness without, or with reduced, hue-shift of a pixel color represented as a set of primary-color values in a reproducing device's color space, by means of a composite transformation that has the property that it preserves the hueless character of gray pixels and is made up of independent primary-color related transformations, at least some of which comprising:

applying a virtual color transformation to a primary-color value of the pixel color to be brightness-corrected, thereby transforming the primary-color value into a primary-color value of a virtual gray-idealized color space,

applying a brightness change to the primary-color value in the virtual color space, and

applying the inverse of the virtual color transformation to the brightness-changed primary-color value, thereby transforming the brightness-changed primary-color value back to a primary-color value of the reproducing device's color space.

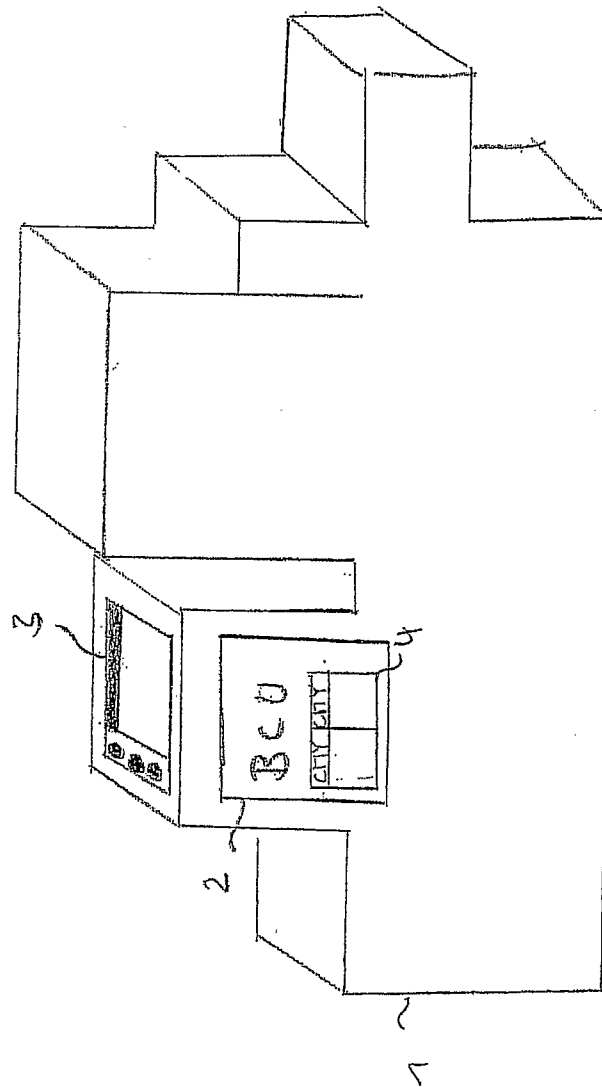


Fig. 1

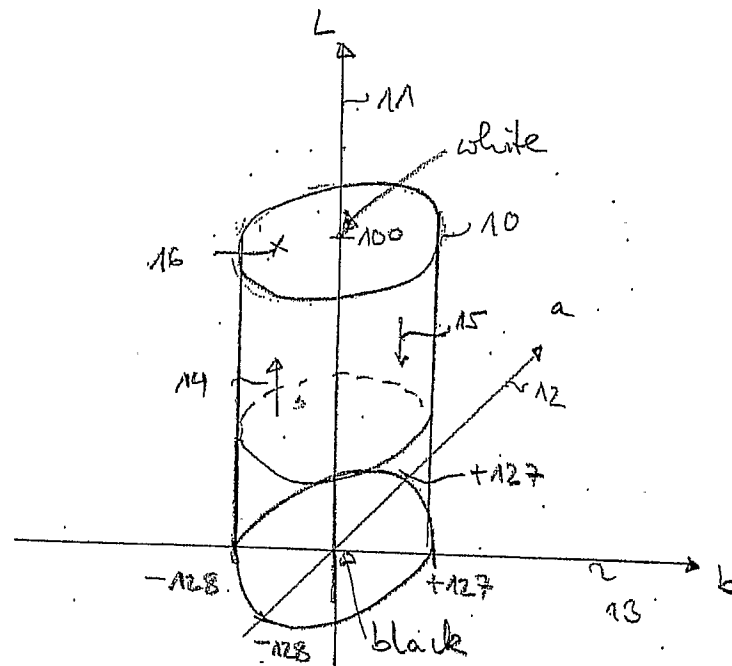


Fig. 2a

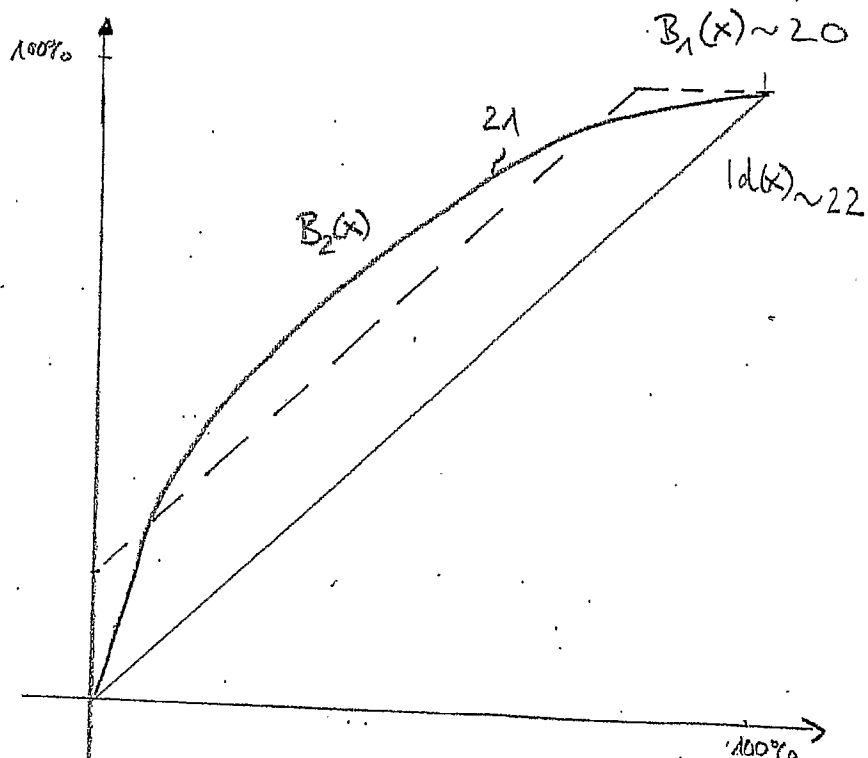


Fig. 2c

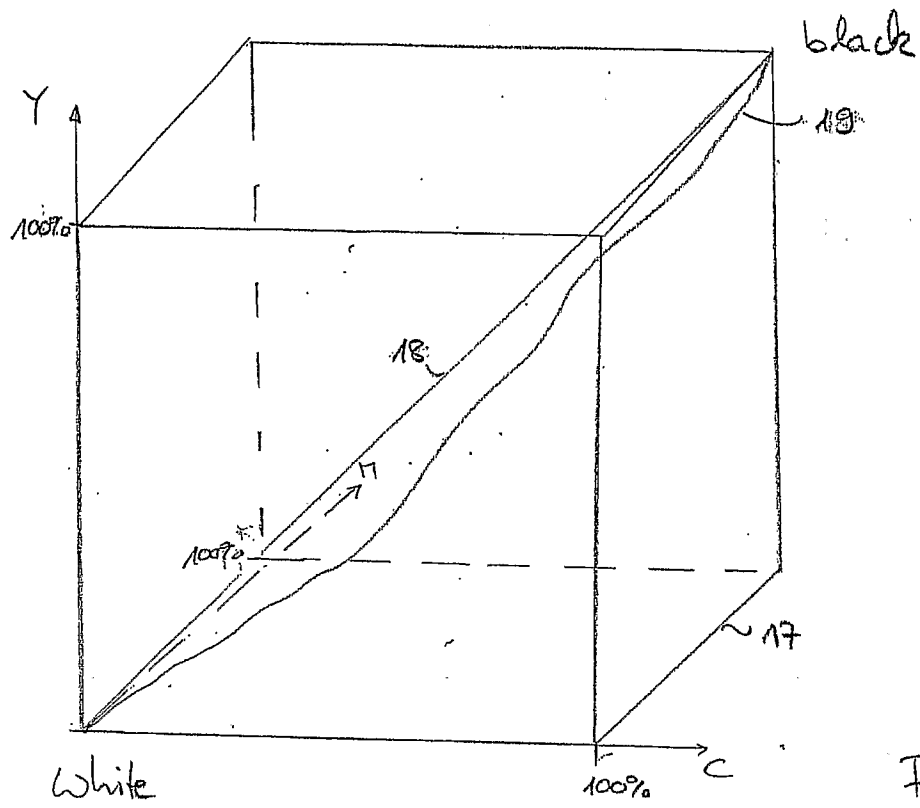
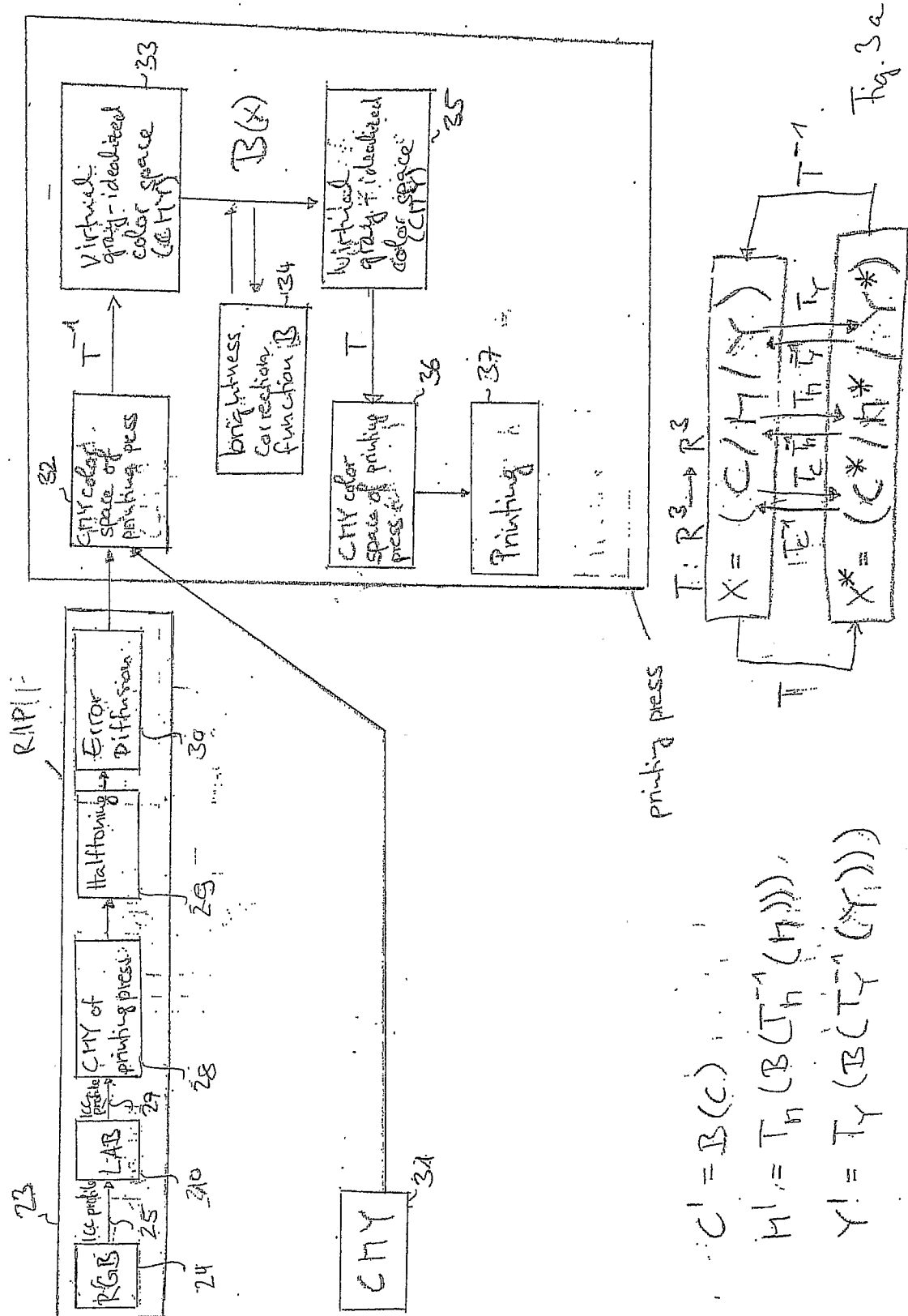
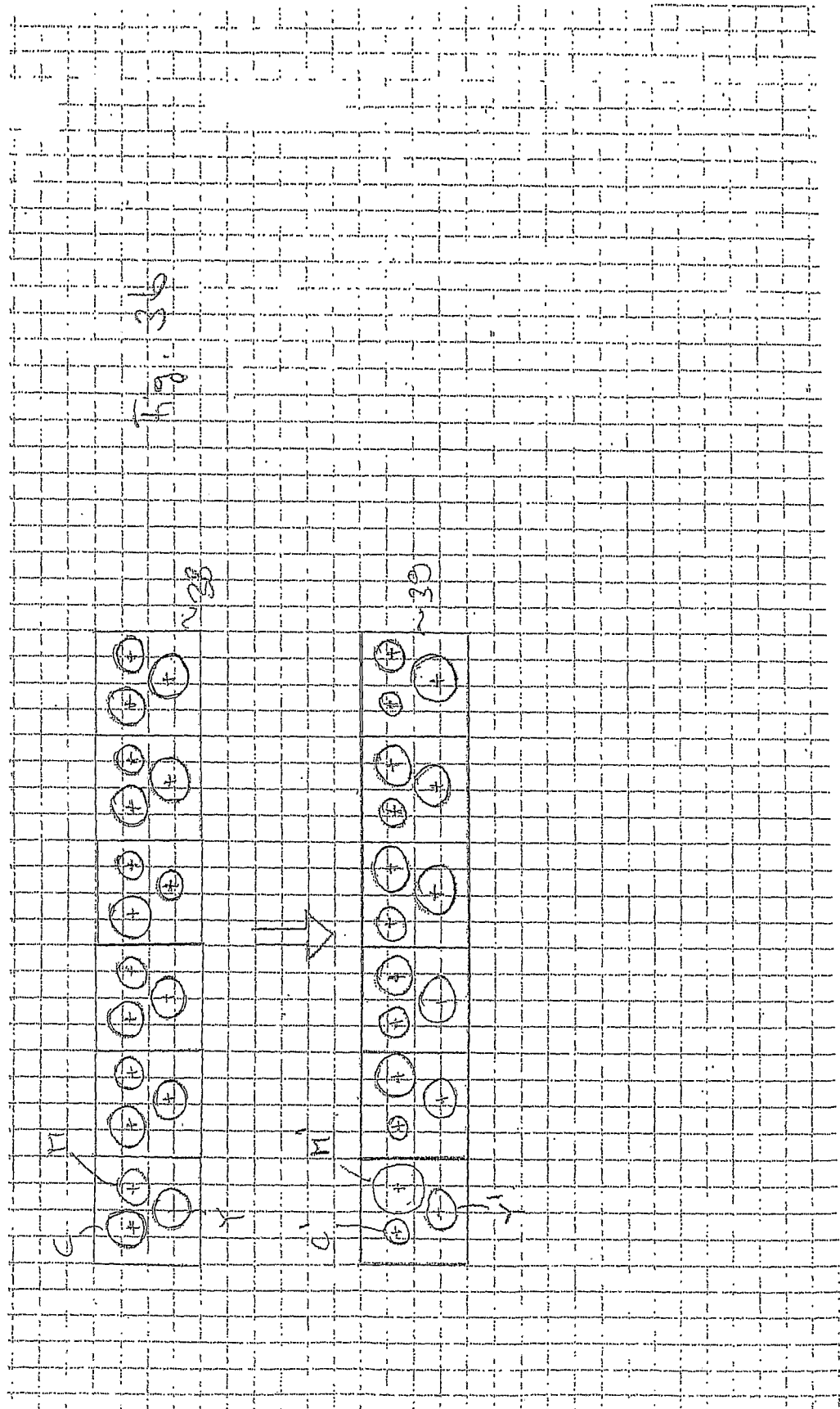
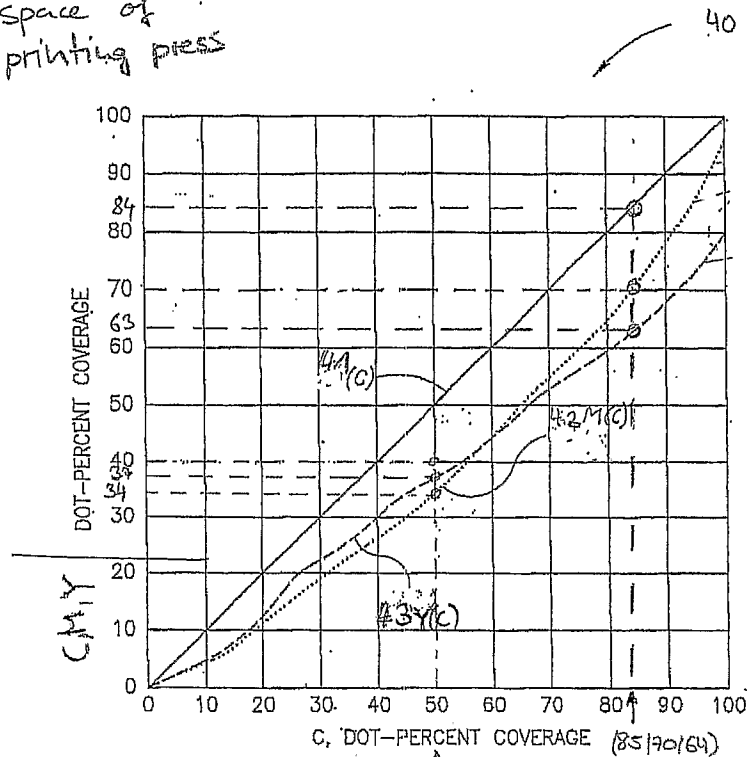


Fig. 2b





CMY color
space of
printing press



45 ~

C:

1.0	1.0
2.0	2.0
3.0	3.0
4.0	4.0
...	...

46 ~

M:

1.0	0.7
2.0	1.4
3.0	2.2
4.0	3.5
5.0	4.1
...	...

47 ~

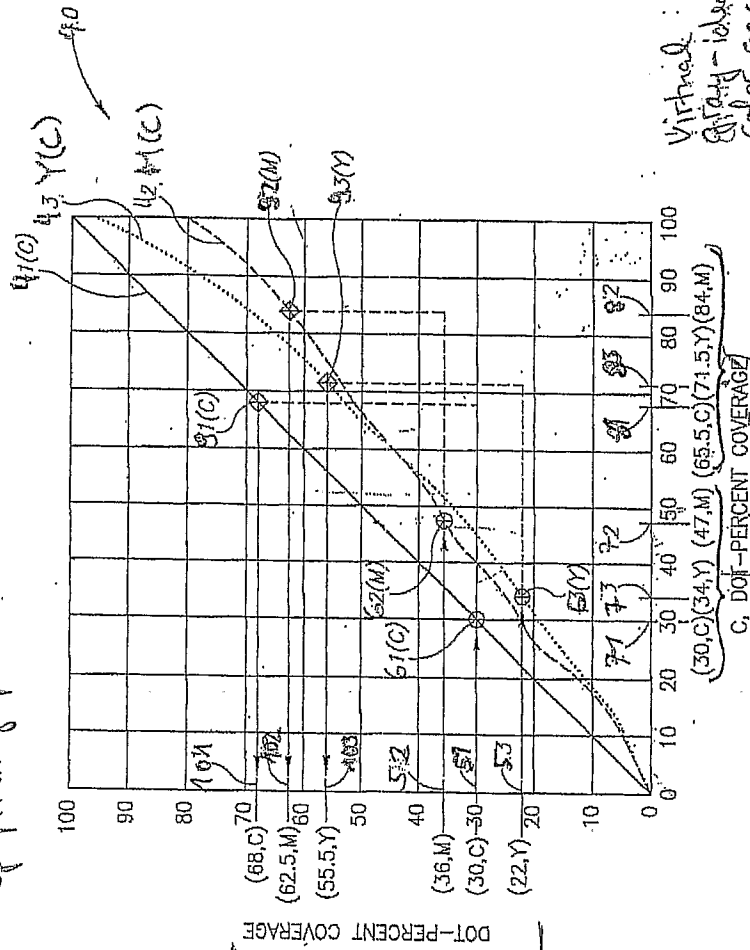
Y:

1.0	0.8
2.0	1.6
3.0	2.3
4.0	3.1
5.0	4.0
...	...

virtual
gray-
idealized
color space
(CMY)

Fig. 4

CMY color space
of printing press



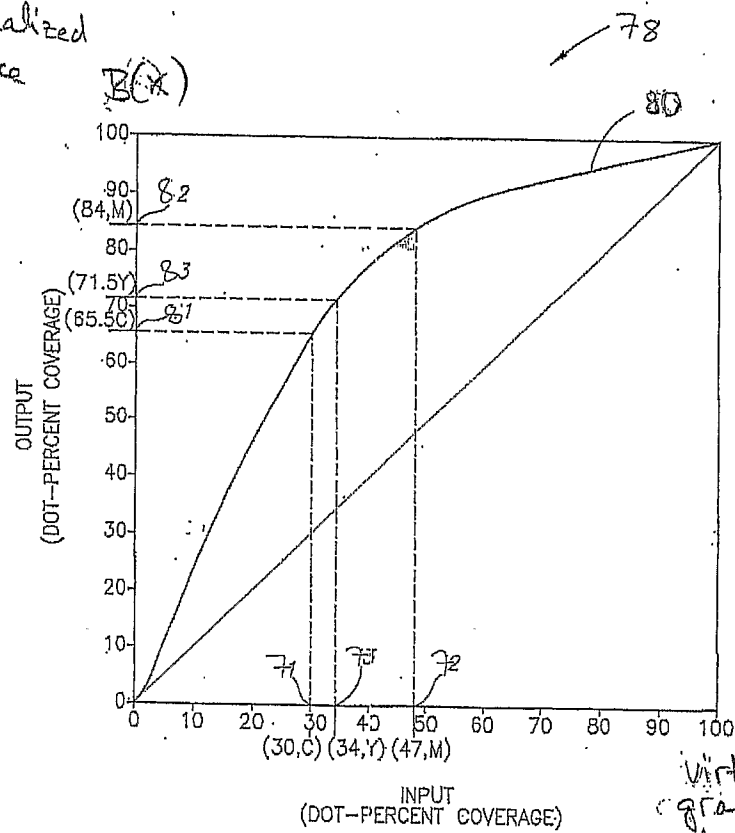
Virtual
idealized
color space (CMY)

- ③ Brightness
corrected values
- ① Original values
of CMY color
components
(20, 36, 22)

② Brightness
correction
function Fig. 5b

Virtual
gray-idealized
color space
(C, M, Y)

(2)



Brightness correction function

Virtual
gray-idealized
color space
(C, M, Y)

Fig. 5b

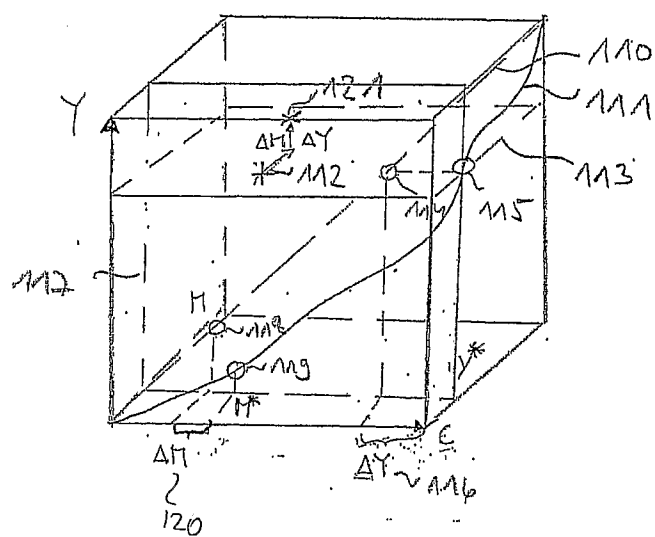
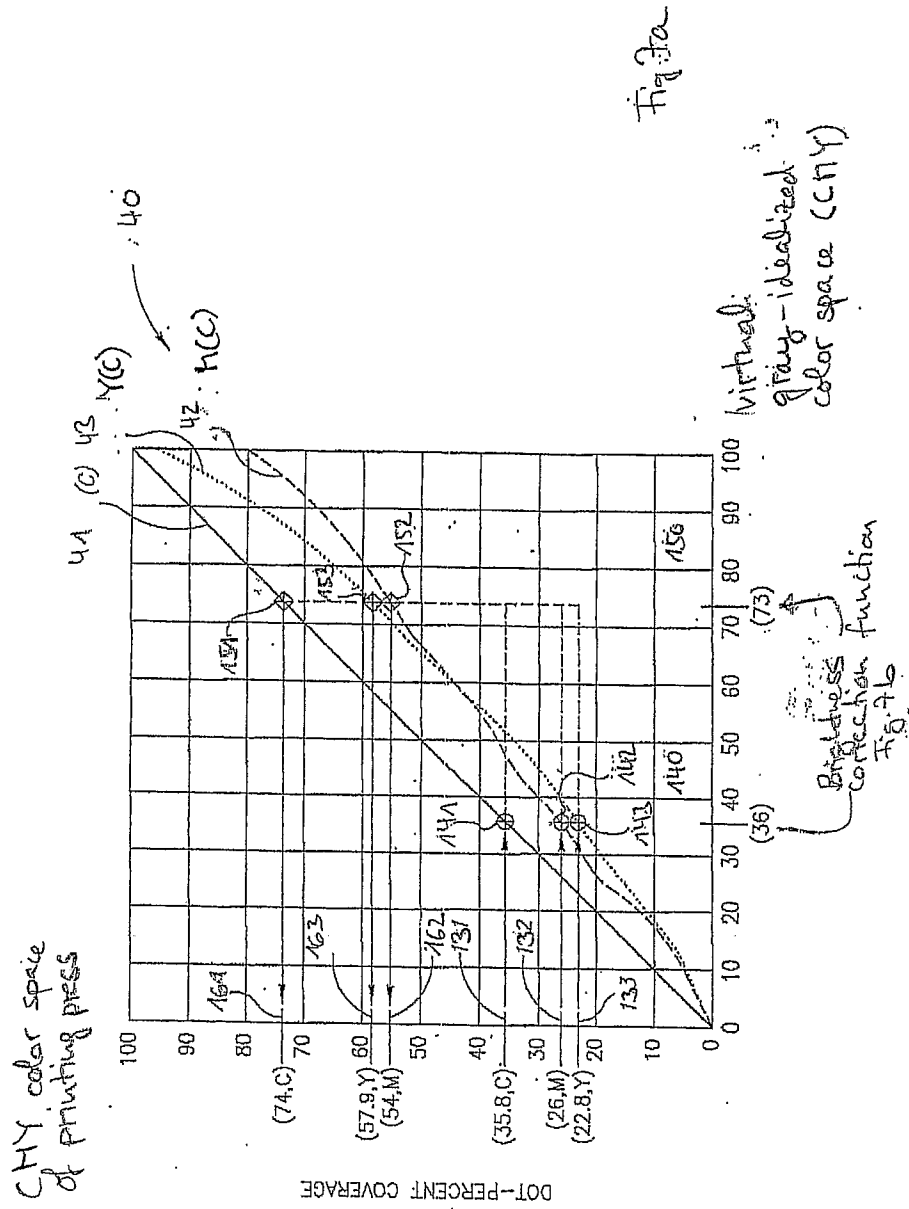
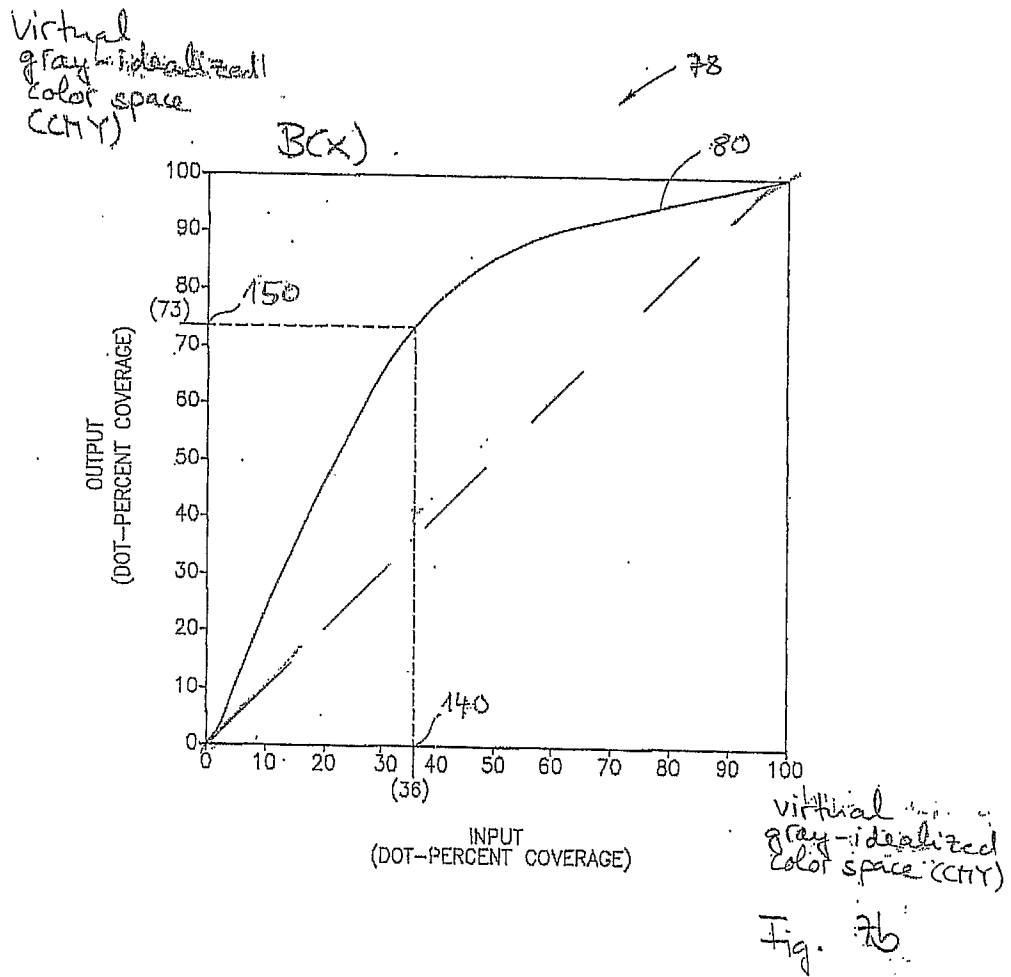


Fig. 6





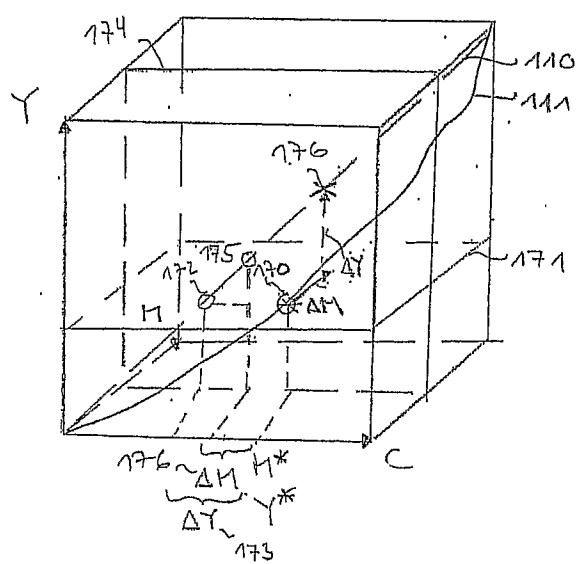
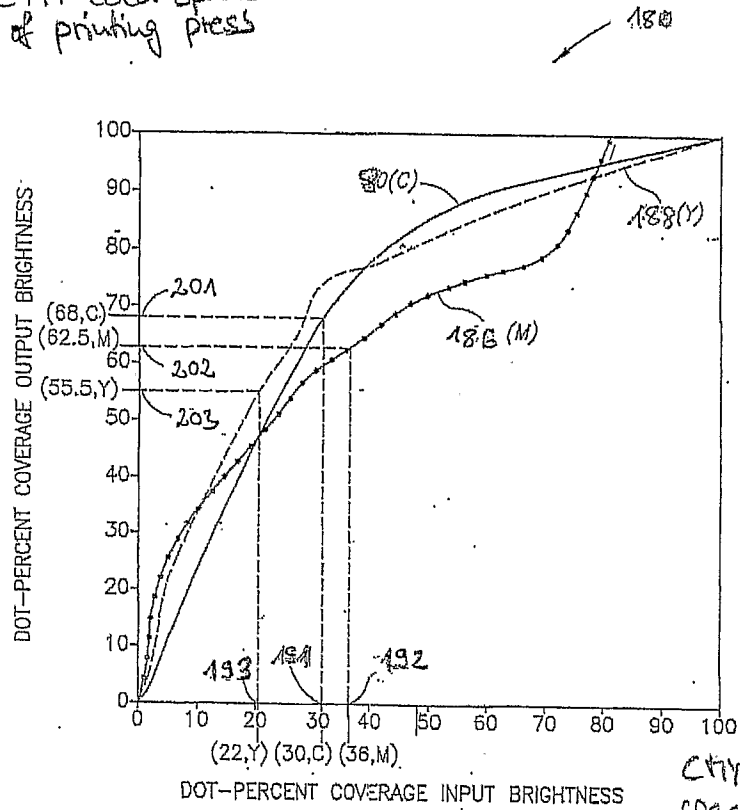


Fig. 8

CMY color space
of printing press



C:

1.0	1.4
1.5	1.7
2.0	2.2
2.5	2.8
3.0	3.2
3.5	3.8
4.0	4.3
4.5	4.8
5.0	5.2
5.5	5.8
6.0	6.8
...	...

M:

1.0	1.5
1.5	2.0
2.0	3.0
2.5	3.5
3.0	4.0
3.5	4.5
4.0	5.0
4.5	5.8
5.0	6.5
...	...

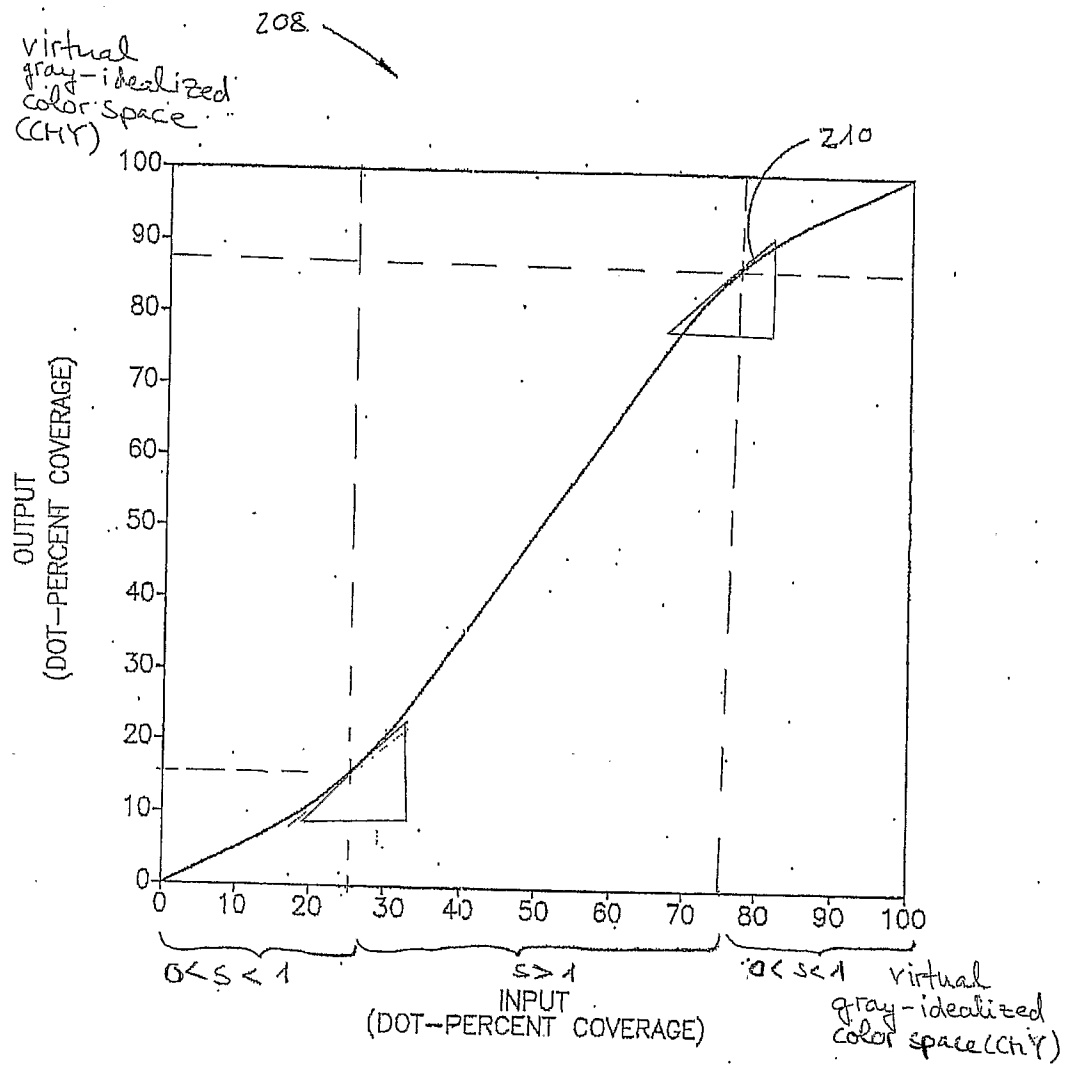


Fig. 10

Interactive color correction wizard
220

Settings
Go to ready
Print
Results

Print settings
221

☒ Single preview on page - Steps: 5

☐ Five previews on page

☐ Three previews on page

☐ Nine previews on page

Color correction operations
222

☒ Single separation correction mode Magenta

☐

☐ Contrast

From -10 To 10

☐ Brightness

From -15 To 15

Back
Next
Cancel
Help

Fig. 11

Interactive Color Correction Wizard			
Settings	<u>Go to ready</u>	Print	Results
Change the press status to ready.			
Back	Next	Cancel	Finish Help

Fig. 12

Interactive Color Correction Wizard					
Settings Go to ready <u>Print</u> Results Click the print button to proof the page.					
<table border="1"> <tr> <td>Back</td> <td>Next</td> <td>Cancel</td> <td>Finish</td> <td>Help</td> </tr> </table>	Back	Next	Cancel	Finish	Help
Back	Next	Cancel	Finish	Help	

Fig. 13

Interactive Color Correction Wizard

Settings Go to ready Print Results

Print Settings

- ☐ Single preview on page - Steps:

Fig. 14

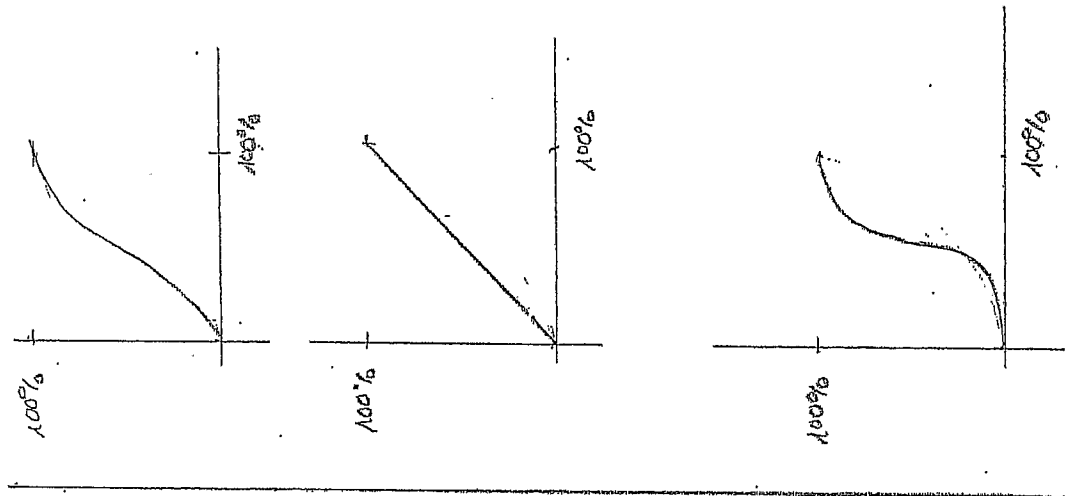
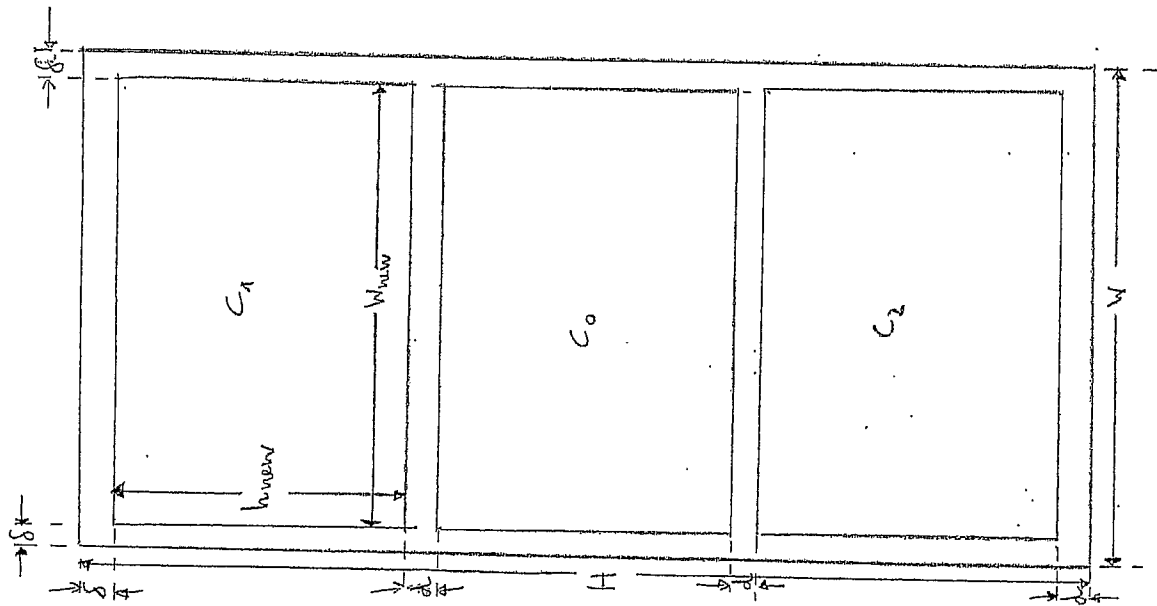
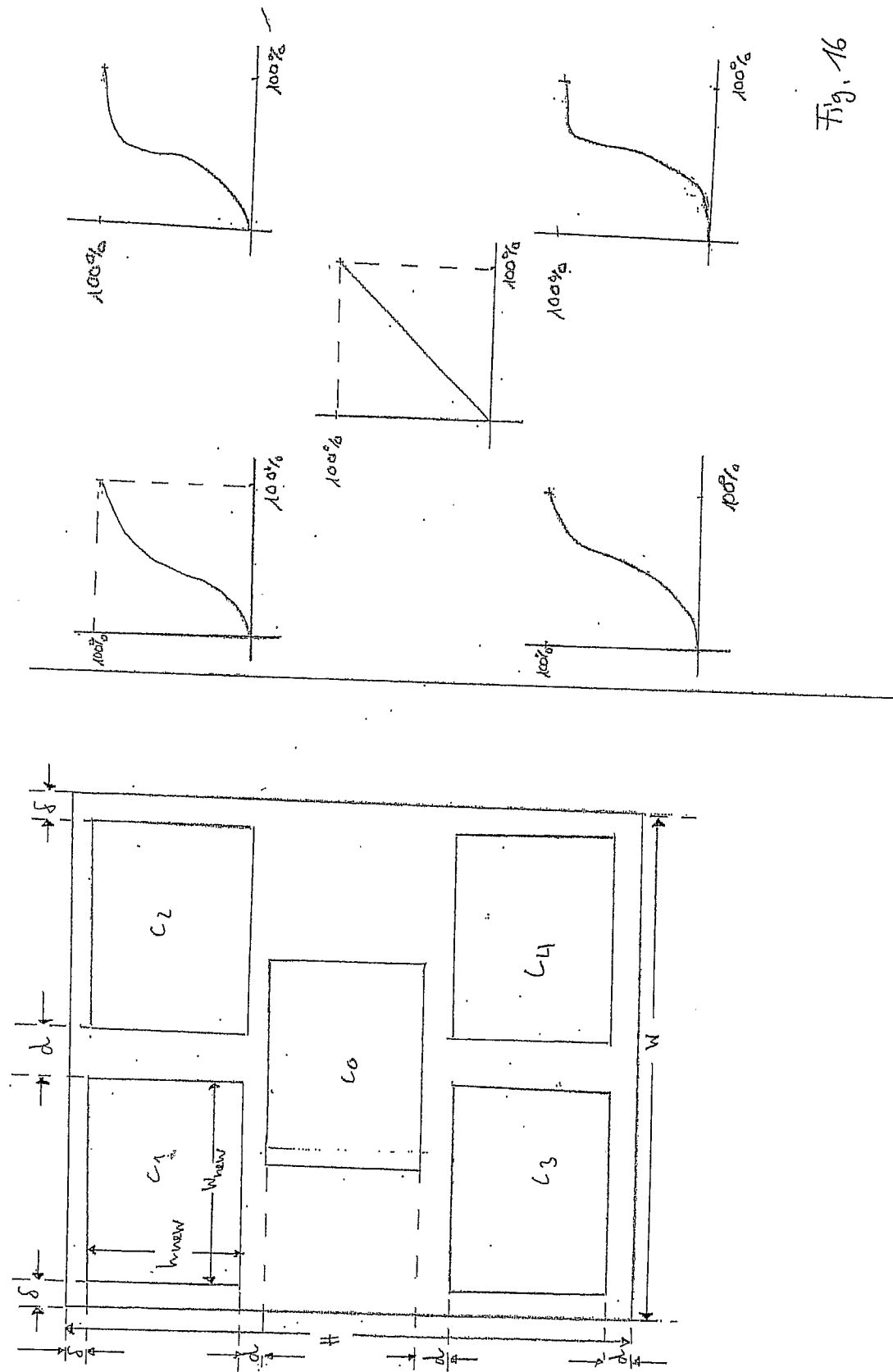


Fig. 15



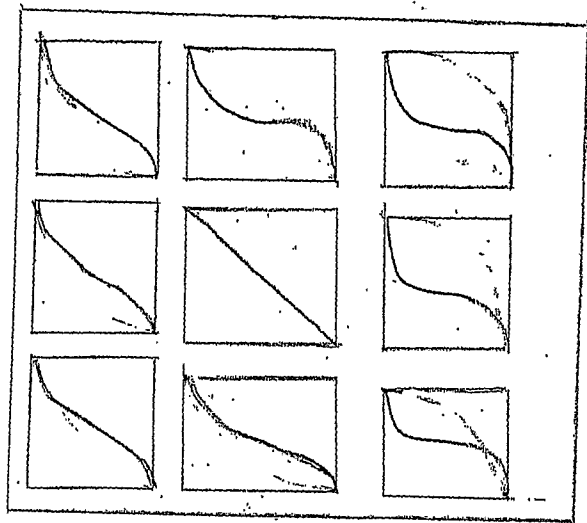
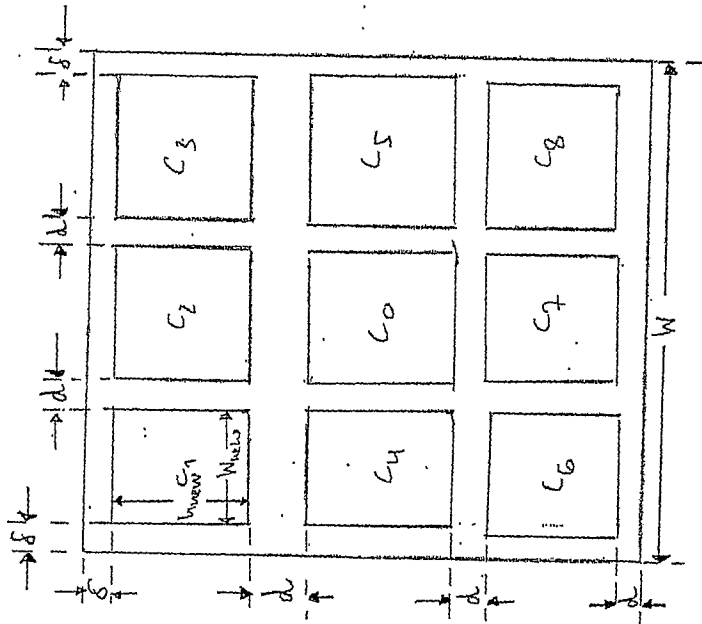


Fig. 17

22/23

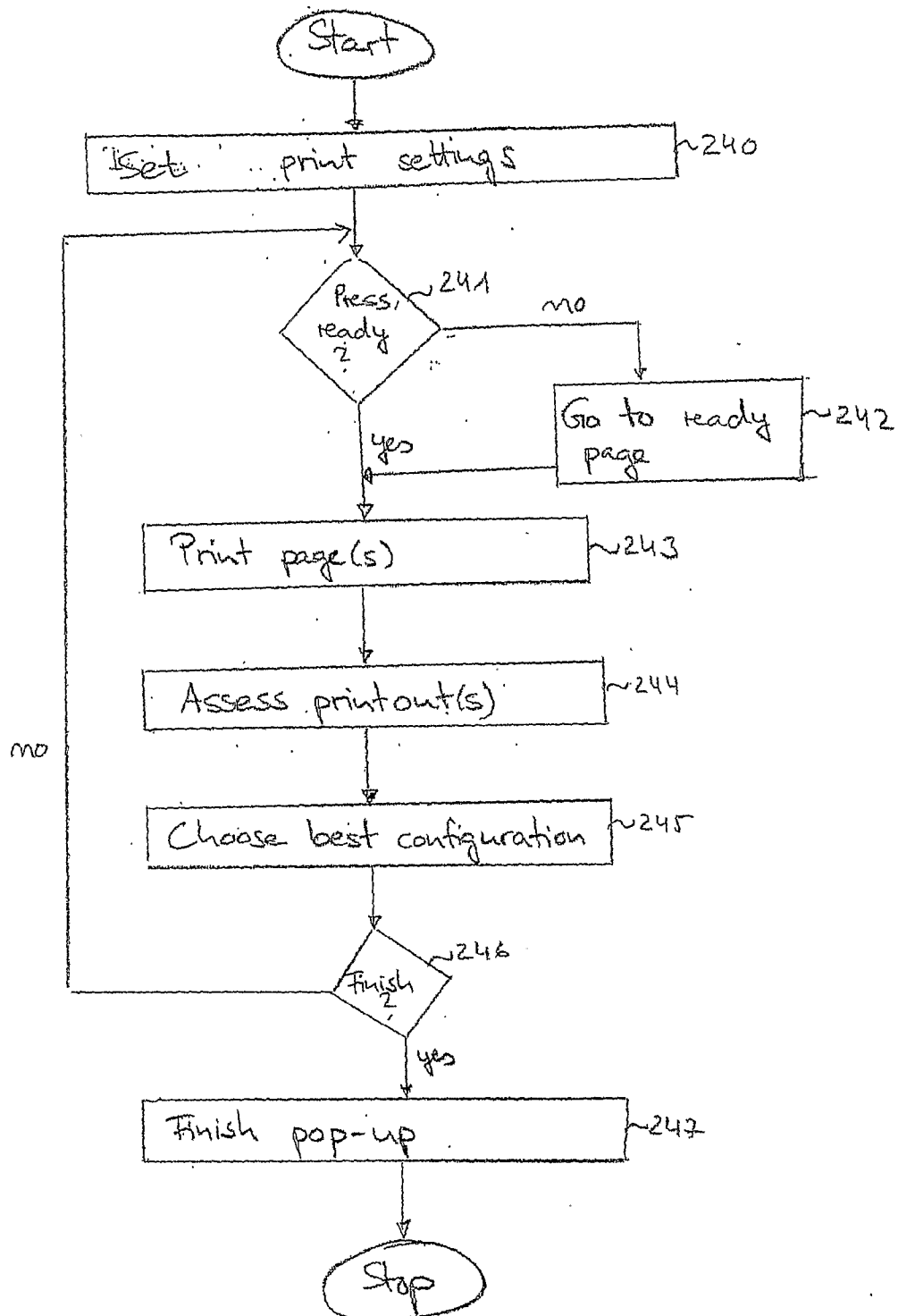


Fig. 18

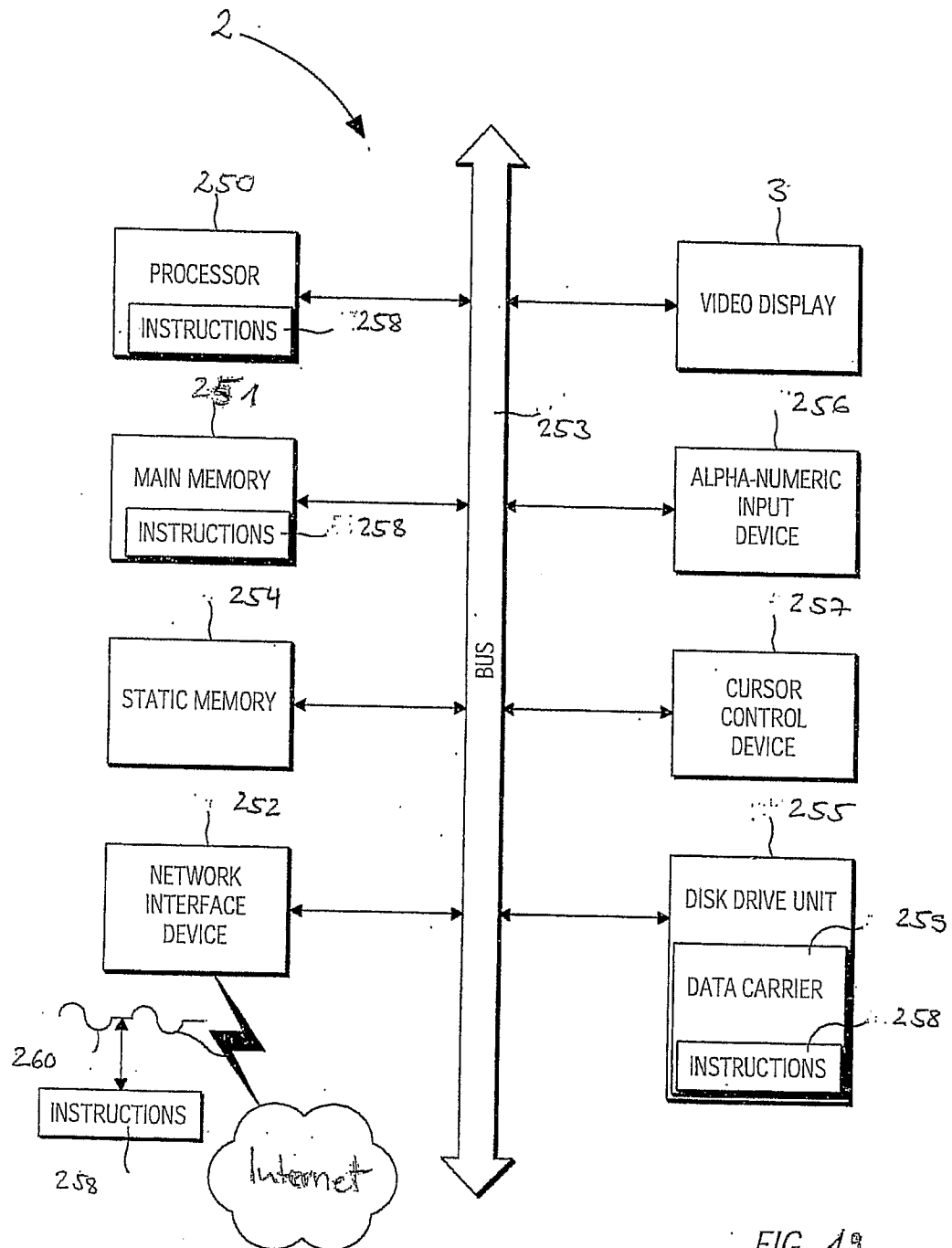


FIG. 13