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(54) **Toner sequence to minimise noise**

(57) A method and an apparatus for reproducing a continuous tone image by application of at least two different types of marking particles to a receiving substrate, the method including the steps of:

- subdividing the continuous tone image into image portions;
- determining a plurality of printing combinations, each printing combination optionally including a set of tone curves and including a printing sequence for applying the different types of marking particles to the receiving substrate;
- determining, for at least two printing combinations and for at least one selected image portion, visual quality characteristics (N_1, N_2, N_3, G_1, G_2, G_3) that depend on the selected image portion and on the printing combination;
- selecting, based on the visual quality characteristics, a selected printing combination for the selected image portion;
- printing the selected image portion according to the selected printing combination.

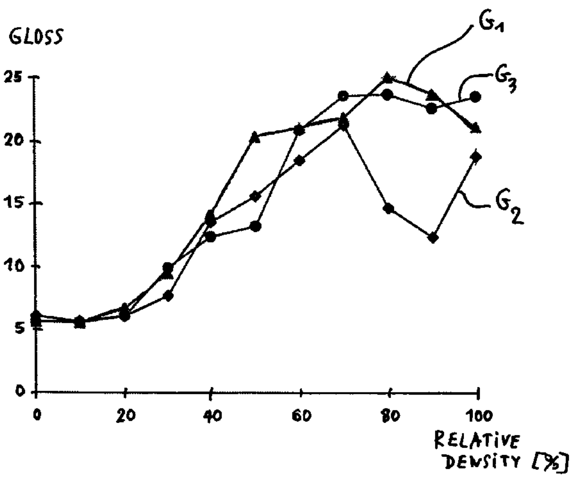

Fig. 3

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to methods and apparatuses for printing reproductions of continuous tone images. The methods are particularly suitable for electro(stato)graphic printing. The reproduction is printed on a receiving substrate which may be opaque or transparent.

BACKGROUND OF THE INVENTION

[0002] Electro(stato)graphic printing methods are well accepted in an "office-environment" since these methods, used in e.g. electrophotographic copiers and electrographic printers, and in Direct Electrostatic Printing (DEP), are convenient, fast and clean and since they do not need liquid solutions or dispersions. Moreover, since electro(stato)graphic methods may use solid particles that typically have a particle diameter between 1 and 10 µm as marking particle, it is possible to achieve very high resolution in electro(stato)graphy. However, these methods are not used as much as would be expected, considering their convenience. Most of these printing methods have a drawback when reproducing a continuous tone image or contone image, i.e. an image that contains tone levels with no perceptible quantization to them - e.g. 256 tone levels. The drawback referred to is that most electro(stato)graphical imaging systems are not intrinsically capable of forming continuous tone and that hence special measures have to be taken; e.g. the electronic continuous tone image may be specially treated, such as by a dither method, before the print is made. This drawback has hampered the use of these very convenient printing methods in those imaging areas where it is important to accurately print continuous tone images, as e.g. in the printing industry, in medical imagery, etc.

[0003] Continuous tone printing in electrophotographic printing by a laser beam is described in the Journal of Imaging Technol., Volume 12, n° 6 December 1986 on pages 329 to 333 in an article entitled "Electrophotographic colour Printing Using Elliptical Laser Beam Scanning Method". In this article, a dot matrix method is described, that is combined with pulse-width modulation of the laser beam (to be able to introduce in each dot of the matrix several density levels) and with an elliptical laser beam; the method aims to achieve a continuous tone reproduction with sufficient resolution and linearity over a tone range of 256 levels. Although, with such a printing system, quality continuous tone prints can be made, there are still some problems to be addressed. On an electrostatic photoreceptor there is a threshold level of toner adhesion: this means that in the low density areas, where the electrostatic latent image is weak and is situated just above that threshold, the system shows inherently some instability in the low density areas on the print. Also, since the low density areas are printed using very few toner particles, the granularity (in other terms graininess or noise) in the low density areas becomes easily objectionable for high quality prints.

[0004] In Proceedings of the International Congress on Advances in Non-Impact Printing Technologies, San Diego, Nov. 12 - 17, 1985, no. Congress 5, 12 November 1989, Moore J., pages 331-341, Kunio Yamada et al., "Improvement of halftone dot reproducibility in laser-xerography", the author discusses graininess of the xerographic process, mainly influenced by dot growth.

[0005] Patent Abstracts of Japan, vol. 7 no. 290 (P-245), **JP-A-58 162 970**, discloses an electrostatic developing device for obtaining a recorded continuous tone image with improved gradation. A second toner is added to a first toner in a single development station, thus obtaining a mixed toner. The second toner has the same colour and a lower colour density (about 1.0 black density) than the first toner (about 1.8 black density). The mixed toner is applied to the recorded copy image. However, the gain in density resolution of the printed image is rather limited.

[0006] **US-A-5 142 337** discloses a binary printing process wherein a second toner is used that comprises a mixture of opaque black, opaque white and clear toner; the second toner is printed on top of a first toner comprising black toner. In this method also, the gain in density resolution of the printed image is rather limited.

[0007] A method for printing a continuous tone image on a receiving substrate by electro(stato)graphic printing methods is described in patent application **EP-A-768 577**. This method comprises the steps of partitioning a surface of the receiving substrate into a plurality of disjunctive addressable locations (i.e. adjacent, non-overlapping addressable locations) and applying to at least one addressable location at least two types of toner that have substantially the same chromaticity. As an example, a greyish and a black toner may be applied. Preferably, the different types of toner are applied in an apparatus with different toner stations, of which at least two toner stations contain toner particles with the same chromaticity but a different amount of colorant (e.g. a greyish and a black toner).

[0008] However, when trying to save toner in this method, a problem of lower image quality and higher noise level is encountered, as will now be discussed. To obtain higher optical density levels, increasing amounts of toner may be applied to the receiving substrate. The different types of toner having substantially the same chromaticity - for example a first greyish toner and a second black toner - may be deposited in superposition upon each other. In the example, toner may be saved by partially replacing greyish toner by black toner in the areas on the receiving substrate that have higher density levels. In the above patent application **EP-A-768 577**, several toner deposition methods are disclosed.

According to one toner deposition method, to obtain the lower density levels, the amount of deposited first toner - e.g. greyish toner - is gradually increased up to a maximum value $a_{1,max}$ while no second toner - e.g. black toner - is being applied. Then, to obtain the higher density levels, the amount of first toner remains at its maximum value $a_{1,max}$ and a gradually increasing amount of second toner a_2 is applied. Another toner deposition method, that saves toner, differs from the above method as follows. To obtain the higher density levels, the amount of first toner - e.g. greyish toner - is gradually decreased from $a_{1,max}$ to zero, while the amount of second toner - e.g. black toner - is increased. Thus, a high density level D_{high} will be obtained by the former deposition method with first and second toner amounts $a_{1,max}$ and a_2, while the latter deposition method, that saves toner, will obtain D_{high} with first and second toner amounts $a_1^* < a_{1,max}$ and $a_2^* > a_2$; in the example, the latter deposition method will use some more black toner but will save an appreciable amount of greyish toner, so that the total amount of deposited toner is smaller than in the former deposition method. A disadvantage of the latter deposition method, that saves toner, is that the noise level is increased and that gloss is uneven. Gloss may e.g. be measured by a Minolta Multi-Gloss 268 meter, set at the 60° geometry. That gloss is uneven is especially visible for an observer who holds the receiving substrate approximately in a horizontal plane and looks at it under an angle of about 45° with the receiving substrate and against the incident light, that may have an incident angle of about 45° with respect to the receiving substrate. The uneven gloss and the higher noise level result in a lower perceived quality to an observer.

OBJECTS OF THE INVENTION

[0009] It is an object of the present invention to provide a printing method and an apparatus allowing to reproduce continuous tone images with reduced noise and reduced graininess.

[0010] It is an object of the present invention to provide a printing method and an apparatus allowing to reproduce continuous tone images with less uneven gloss.

[0011] Another object is to provide a printing method which significantly reduces the amount of deposited marking particles.

[0012] It is an object of the present invention to provide a method for electro(stato)graphic printing that allows to reproduce continuous tone images with reduced noise and reduced graininess.

[0013] It is an object of the present invention to provide a method for electro(stato)graphic printing that allows to reproduce continuous tone images with less uneven gloss.

[0014] Another object is to provide a method for electro(stato)graphic printing which significantly reduces the amount of deposited toner.

[0015] Another object is to provide a method for electro(stato)graphically printing images obtained during medical diagnosis.

[0016] Other objects and advantages of the present invention will become clear from the description hereinafter.

DEFINITION AND EXPLANATION OF TERMS

[0017] A "continuous tone image" or "contone image" may be a monochrome contone image, such as a black-and-white image or a blue image, or it may be a colour contone image. A monochrome contone image is an image containing so many tone levels (e.g. 256 tone levels) that no quantisation is perceptible on the reproduced image. A colour contone image is a colour image that may be separated, as known in the art of colour separation, into two or more individual contone images, each individual contone image containing information for only one printing colour and containing so many tone levels (e.g. 256 tone levels) that no quantisation is perceptible on the reproduced image. In the traditional CMYK colour system, a colour contone image is separated into four individual contone images in the colour components cyan, magenta, yellow and black, abbreviated CMYK. In electro(stato)graphic printing, the colour contone image is then reproduced by applying four different types of toner, i.e. cyan, magenta, yellow and black toner, onto a receiving substrate.

[0018] The "receiving substrate" may be a separate sheet or it may be a continuous web; it may be made of paper, of plastic, it may be a laminate of both; it may be transparent or opaque; several kinds of receiving substrate are described in patent application **EP-A-768 577**.

[0019] The term "microdot" is used for the smallest dot that can be addressed by the printing device for application of a specific amount of marking particles. The receiving substrate can be partitioned into a plurality of adjacent, non-overlapping or disjunctive microdots. Usually the shape of each microdot is square; their shape may however also be rectangular, hexagonal, etc. Preferably the marking particles are deposited within the boundaries of the microdot, but it is possible that marking particles, intended for a specific microdot, partially or fully fall within a neighbouring microdot. Thus, although the microdots are disjunctive from each other, it is possible that marking particles or conglomerates of marking particles of adjacent microdots are not disjunctive.

[0020] A "pixel" is a constituting element of a digital (or electronic) image, which is in this application a continuous tone image. A digital image is typically represented by a rectangular matrix of pixels, each having an electronic pixel value (e.g. from 0 to 255). Each electronic pixel value corresponds to a required optical density of the printed image, at the image location which corresponds to the location of the pixel within the matrix. The location of each pixel within the matrix also corresponds to a specific location on the receiving substrate. These locations may be equidistant or not. A pixel in the electronic image may correspond to a microdot on the receiving substrate. When halftone techniques are used, a pixel in the electronic image may correspond to a halftone dot or a portion thereof on the receiving substrate. This correspondence depends among other things upon resolution (pixel resp. dot resolution is the number of pixels resp. dots per unit length, e.g. per inch or per mm). Usually, the pixel resolution in the electronic image and the dot resolution of the microdots or of halftone dots printed on the receiving substrate do not match, i.e. they are not equal or one is not a multiple of the other. In that case, techniques such as interpolation may be used in "converting" the pixel matrix in the electronic image into the dot matrix on the receiving substrate.

[0021] A "halftone cell" usually contains a fixed number of microdots, so that an acceptable number of optical density levels are achievable per halftone cell by forming a "halftone dot". A large halftone dot or a halftone dot having a high optical density or a combination of both is required for reproducing high density regions. A halftone dot is formed by a set of adjacent microdots, each microdot having an optical density different from the background density. The background may have the optical density D_{MIN} of the receiving substrate; in that case, the microdots belonging to the halftone dot have an optical density D_M higher than the background: $D_M > D_{MIN}$ If the background has the highest possible density, D_{MAX}, such microdots have a lower optical density: $D_M < D_{MAX}$. Because of the restricted contone capabilities of most electro(stato)graphical imaging systems - usually only sixteen different optical density levels are achievable per microdot - often, especially for applications in the graphics sector, a process of halftoning is applied to the electronic contone images. Because each microdot can get more than two toner concentrations in the halftone scheme, this type of halftoning is called multilevel halftoning. Two major types of multilevel halftoning exist: halftone dot size modulation and frequency modulation. For halftone dot size modulation, halftone dots, comprising a plurality of microdots, are usually laid out on a periodic grid having a screen ruling and a screen angle. In order to achieve a higher optical density, more microdots carrying toner are added to the halftone dot. For halftone dot size modulation, adjacent microdots are preferably, but not necessarily, arranged in cells, called halftone cells for autotypical screening techniques. More information on halftone techniques can be found in patent application **EP-A-769 577**.

[0022] A "marking particle" is a particle that is applied to the receiving substrate by the printing device for reproducing the continuous tone image. In electro(stato)graphic printing, the marker particles are toner particles. Liquid electrostatographic development (using a dispersion of solid toner particles in a dielectric liquid) as well as dry electrostatographic developers may be used. The dry developers can be mono-component developers (comprising toner particles, but no carrier particles) as well as multi-component developers (comprising toner and carrier particles). In inkjet printing, the marking particles are liquid ink droplets.

[0023] A "tone curve" indicates how to convert pixel values into device values (which are also called engine values). The device values are sent to the printing device and indicate which amount of marking particles are to be used to print a microdot. The tone curve indirectly gives the relation between a specific pixel value and the amount of marking particle. In the printing device, the conversion according to a tone curve is generally implemented by means of a lookup table or LUT. The most simple tone curve is one that maps tone values t linearly to device values d, e.g. $d = t$ for mapping $t = [0, 255]$ to $d = [0, 255]$, or e.g. $d = 1023/255 * t$ for mapping $t = [0, 255]$ to $d = [0, 1023]$. In the first case ($d = t$), the LUT may be absent. Fig. 1a shows a set 10 of three tone curves 11, 12 and 13; these tone curves correspond to respectively a first, a second and a third type of marking particles. Tone curve 12 converts pixel value n into device value $d_{n,2}$ for the second type of marking particles. Tone curve 13 converts pixel value n into device value $d_{n,3}$ for the third type of marking particles. Tone curve 11 indicates that device value $d_{n,1}$ is zero, i.e. no marking particles of the first type are used for printing a pixel with pixel value n.

[0024] A "printing sequence" is a sequence in which the different types of marking particles are applied to the receiving substrate; e.g. CMYK and YMCK are printing sequences if types of marking particles in the traditional CMYK colour system are used.

[0025] A "printing combination" is a combination of optionally a set of tone curves and of a printing sequence, according to which the different types of marking particles are applied to the receiving substrate. Different types of marking particles may be applied according to the same printing sequence but according to a different set of tone curves, or according to the same set of tone curves but different printing sequences. Referring to Fig. 1a and Fig. 1b, the first, second and third type of marking particles may e.g. be applied according to a first printing combination comprising the set 10 of tone curves and a first printing sequence: (first, second, third type of marking particles), i.e. the first type of marking particles is applied first to the receiving substrate, then the second and then the third type. The same types of marking particles may also be applied according to a second printing combination which comprises the first printing sequence and another set, set 20, of tone curves. As will be discussed below, the visual quality characteristics of a printed image may differ when it is printed according to the first (Fig. 1a) respectively according to the second (Fig. 1b) printing combination.

[0026] The term "image portion" is used in this document for a portion of the electronic continuous tone image that is related to printing combinations: an image portion is printed according to a specific printing combination. Preferably, the image portions of an image do not overlap each other, and all fractions of the image belong to exactly one image portion. The number of image portions may be one, i.e. the whole image is printed according to one specific printing combination.

[0027] The term "image subportion" is used in this document for a subportion of an electronic continuous tone image (or of an image portion) that is related to the determination of "visual quality characteristics": a "subportion visual quality value", for a specific printing combination, is e.g. a noise value and/or a gloss unevenness value of a printed image of an image subportion, the printed image being printed according to the specific printing combination. Visual quality characteristics and related terms are discussed in detail below. An image or an image portion may be subdivided into image subportions. Preferably, image subportions do not overlap each other. Preferably, all image subportions together constitute the complete image or image portion that was subdivided; i.e. there is no fraction of the image or of the image portion that does not belong to one of the image subportions.

[0028] Two types of marking particles have "substantially the same chromaticity" if they have a chromaticity difference obeying the following inequality:

$$\sqrt{(\Delta a^*)^2 + (\Delta b^*)^2} \leq 20$$

when expressed in the CIE's L* a* b* space. Chromaticity describes objectively hue and saturation of a colour, and may be measured in terms of CIE x,y or u',v' (cfr. "The reproduction of colour in photography, printing & television" by R.W.G. Hunt, 4th edition 1987, ISBN 0 86343 088 0, pp. 71-72). If the first type of marking particles has colour values (L_1,a^*_1,b^*_1) and the second type has colour values (L_2,a^*_2,b^*_2), then Δa^* and Δb^* are defined as:

$$\Delta a^* = a^*_2 - a^*_1$$

$$\Delta b^* = b^*_2 - b^*_1.$$

The chromaticity of marking particles, when applied to a receiving substrate (e.g. fused to the receiving substrate in case of toner particles), may be different from the chromaticity of the original marking particles; therefore, the chromaticity referred to is the one of the marking particles appearing on the receiving substrate.

[0029] The term "visual quality characteristics" is used in this document for characteristics that are determined on a printed image, e.g. a toner image, for a specific printing combination, and that give a valuable indication of the quality of the printed image as perceived by an observer. Preferably, the visual quality characteristics are gloss unevenness characteristics and/or noise characteristics. The former, the latter, or both may be determined in order to obtain the visual quality characteristics of the printed image, for a specific printing combination. The visual quality characteristics of a printed image depend upon the printing combination used and they also depend upon the reproduction method, i.e. the type of printing device. The visual quality characteristics of images printed by electro(stato)graphic printing methods, where the marking particles are toner particles, and of images printed by e.g. inkjet, where the marking particles are liquid ink droplets, are quite different, because the printing process is different. The relation between the visual quality characteristics and the parameters influencing the printing process is different for e.g. electro(stato)graphic printing and for inkjet.

[0030] The "gloss" of a printed image is a characteristic of the image that is related to the reflection of light by the image. Gloss may e.g. be measured by a Minolta Multi-Gloss 268 meter, set at the 60° geometry. Fig. 3 shows measured gloss values, G_1, G_2, and G_3, for three different printing combinations. A printed image has "gloss unevenness" if gloss changes significantly within a small area of the image. In Fig. 3, gloss changes significantly for curve G_2 in the higher density values, i.e. from 60 % to 100 %. Thus, if an image is printed according to the printing combination to which the measured gloss values G_2 correspond, then the image will exhibit gloss unevenness if it contains relatively small areas of high density (i.e. larger than 60 %) where the density is not constant. Unevenness of gloss in a printed image is especially visible for an observer who holds the receiving substrate approximately in a horizontal plane and looks at it under an angle of about 45° with the receiving substrate and against the incident light, that may have an incident angle of about 45° with respect to the receiving substrate. Evenness of gloss is especially important in image areas having a substantially constant density, and for the high densities because in the high densities only little light is reflected. Therefore variations of this small amount of reflected light are especially disturbing and may result in a low perceived image quality.

[0031] "Noise" is an unwanted signal that is superimposed upon a desired signal. Noise may be random and may be caused by uncontrolled fluctuations in the process, e.g. in the printing process. Noise in a printed image may be determined by measuring a "perceived" standard deviation of a substantially constant density, as described in **EP-A-768 577**; this method is called "perceived noise metric" and the determined noise values are called the "perceived visual noise values". Other methods to determine noise are conceivable, e.g. the method described by R. Ulichney in "Digital Halftoning", Cambridge MA, MIT Press, 1987.

[0032] The "perceived noise metric" can be summarised as follows:

- 2 dimensional microdensitometry at various density levels;
- visual transfer function (= frequency filter);
- transformation to perceived densities;
- calculation of mean value "x" and standard deviation "σ";
- the perceived visual noise value at level "x" = the standard deviation "σ";

this is now discussed in detail, by means of an example.

[0033] In the example, at various density levels patches having a substantially constant density were printed. The printing was done on paper and the density patches were measured in reflection mode. The homogeneity of the patches was measured. The homogeneity of a patch of even densities was expressed with respect to the visibility of density differences, i.e. to the way a human observer would perceive these differences. Therefore, the measured values of density variations were recalculated and transformed to density variations as perceived by a human observer.

[0034] In practice, a sample of even density patches printed on paper was scanned in the direction of the movement of the receiving substrate with a slit of 2 mm by 27 μm and a spatial resolution of 10 μm. The sampling distance was 1 cm and 1024 data points were sampled. The sampling proceeded in reflection mode and the reflectances where measured.

[0035] The obtained scan of the reflectances was converted to a "perceived" image by means of a perception model. This conversion comprises the following steps :

(i) applying visual filtering, describing the spatial frequency characteristics of the "early" eye, i.e. only taking in account the receiving characteristics of the eye. The used filter was the one as described in detail by J. Sullivan et al. in IEEE Transactions on Systems, Man and Cybernetics, vol. 21, n° 1 p. 33 to 38, 1991. Contrary to the filter described in said reference, the filter was not levelled off to a value of one for frequencies lower than the frequency of maximum sensitivity of said early eye. This means that in measurement, a band-pass filter was used, instead of a low-pass filter in the reference cited above. The viewing distance was 25 cm.

(ii) transforming the reflectances (R), that have been transformed in step (i) by the filtering, to visual densities (D_{vis}), by following formulae :

$D_{vis} = 2.55 \times (1 - R^{1/3})$ when the reflectance (R) is higher than or equal to 0.01, and

$D_{vis} = 2.00$ when the reflectance (R) is lower than 0.01, while the eye can differentiate reflectances below 0.01.

[0036] In the thus obtained "perceived" image the standard deviation of the density fluctuation (σ_D) was calculated. This standard deviation is the "perceived visual noise value".

[0037] In the above example, microdensitometry is used; the method may however also be applied for larger areas. The perception model that is used is parameterized: the impact of viewing conditions can be investigated, such as the viewing distance - 25 cm in the above example - or the illumination level. Instead of transforming the reflectances (R) directly into visual densities (D_{vis}), the transformation may be carried out via an intermediate variable, the perceived lightness index L∗ (from CIE's L* a* b* space).

[0038] Fig. 2, which is discussed in detail below, shows a set of perceived visual noise values as a function of density for three different printing combinations; the viewing distance was 10 cm.

SUMMARY OF THE INVENTION

[0039] The invention may be applied to any reproduction method of a continuous tone image by a printing device, such as thermal wax printing, inkjet printing, offset printing; the invention is however especially useful for electro(stato)graphic printing methods, because of the characteristics of these printing methods and of the used marking particles, which are in this case toner particles. In this document, the invention will be disclosed in particular with respect to electro(stato)graphic printing methods.

[0040] The invention is particularly concerned with two electro(stato)graphic printing methods. One is classical electrography, wherein an electrostatic latent image, on a latent image bearing member, is developed by toner particles, whereafter the developed image may be transferred to a final substrate. Another method is Direct Electrostatic Printing (DEP), wherein toner particles are imagewise deposited on a substrate without the use of an electrostatic latent image.

[0041] In a method in accordance with the invention, in a first phase visual quality characteristics are determined for different printing combinations according to which a continuous tone image may be reproduced. Then, in a second phase, these visual quality characteristics are used in determining the selected printing combinations that will be used to print the image or image portions thereof. Finally, in a third phase, the continuous tone image is reproduced.

[0042] First, the invention is disclosed for the case wherein the printing combinations are simply printing sequences and the visual quality characteristics are simply noise characteristics. Thereafter, the invention is disclosed for the general case, i.e. printing combinations and visual quality characteristics.

[0043] In a method in accordance with the invention, at least two different toner types are used to reproduce a continuous tone image by means of electro(stato)graphic printing. A method in accordance with the invention may be applied to a colour or to a monochrome continuous tone image; to reproduce a monochrome continuous tone image, two or more toner types are used that have substantially the same chromaticity, e.g. a greyish and a black toner for a black-and-white continuous tone image. An advantage of using two or more toner types for a black-and-white image is that the total tonal range, from white over grey to black, may be subdivided into a larger number of subranges. The subranges may overlap each other and are preferably smaller than the total tonal range. A toner type corresponds to each subrange. Since each toner type only has to cover a subrange smaller than the total tonal range, the printing stability and the noise characteristics of the printed image are improved. Patent application **EP-A-768 577** discloses further measures to improve printing stability.

[0044] According to a first aspect of the invention, reproduction with reduced noise of a continuous tone image by a printing device is realised by a method that comprises the following steps:

- a number of printing sequences are determined according to which the different types of toner that are used may be applied to the receiving substrate;
- the continuous tone image is subdivided into a number of image portions. Each image portion will be printed according to a specific printing sequence. In a possible embodiment of the invention, there is only one image portion, i.e. the one image portion is the complete continuous tone image;
- at least one image portion is subdivided into one or more image subportions;
- for at least one image subportion, a noise value is determined of a toner image of the image subportion; this noise value is called a subportion noise value. A subportion noise value depends upon the printing sequence. Subportion noise values are preferably determined for all possible printing sequences;
- for at least one image portion, a selected printing sequence is chosen out of the possible printing sequences. The choice is based upon the subportion noise values of at least one subportion in the concerned image portion and for at least two, and preferably for all, of the possible printing sequences. Preferably, the choice is based upon the subportion noise values of all subportions in the concerned image portion. Possibly, other factors may be taken into account (e.g. : "do not apply toner X last"). Choosing a selected printing sequence, based upon the subportion noise values, may be done in different ways, some of which are discussed below;
- finally, at least one image portion is reproduced according to the selected printing sequence of the concerned image portion.

[0045] An advantage of the subdivision into image portions is that different image portions may be printed according to different selected printing sequences. Take, for example, an image that contains a portion of dark blue sky of a nearly uniform hue, a portion of beach, and various other portions. To obtain a reproduction of this image with reduced noise and better quality, the sky may be printed according to a first printing sequence and the beach according to a second printing sequence, different from the first.

[0046] Determining noise characteristics for different printing sequences, i.e. the first phase in a method in accordance with the invention, is done before the toner image of the continuous tone image is applied to the receiving substrate. The determined noise characteristics depend upon the characteristics of the image, but also on the kind, and especially on the size, of the "basic units" of which noise values are determined, i.e. the image subportions.

[0047] In a first preferred embodiment, determining the noise characteristics is directly based upon the characteristics of the image to be printed, while in a second preferred embodiment it is indirectly based upon the characteristics of the image: first the image is classified in a class of images, and then the noise characteristics of toner images of this class of images are taken into account.

[0048] In the first preferred embodiment, the size of the image subportions into which a selected image portion is subdivided may vary. Preferably, each image subportion comprises one or more pixels. Two image subportions may each comprise another number of pixels. The subportion noise value is the noise value of the printed image of the subportion of the electronic image. The subportion noise values of a printed image, e.g. a toner image, of the image subportions may be determined by measuring the noise values of a number of toner test patches, printed according to different printing sequences; this is explained in detail below.

[0049] In the second preferred embodiment, determining the noise characteristics is indirectly based upon the characteristics of the image. First the continuous tone image, or a portion thereof, is classified in a class of images, as e.g.

the class "black-and-white medical images", or the class "black-and-white medical images: X-ray image of a thorax". The classes are preferably defined in such a way that toner images of the images belonging to the same class have substantially equal noise characteristics; these substantially equal noise characteristics are then called the "class noise characteristics". The class noise characteristics may be obtained from the noise characteristics of toner images of a number of images belonging to each class, for a number of printing sequences. Also for determining class noise characteristics it may be useful to measure the noise values of a number of toner test patches, printed according to different printing sequences, which is explained in detail below.

[0050] In the second preferred embodiment, after an image portion is classified in a class of images, the noise characteristics of the specific image portion are determined from the class noise characteristics; preferably, they are set equal to the class noise characteristics. Hence, classification of the specific image portion may directly determine its selected printing sequence (which is based upon the noise characteristics of the specific image portion for the different printing sequences).

[0051] The invention can also be applied for printing combinations instead of for printing sequences; in the above discussion, "printing sequence" may simply be replaced by "printing combination". Instead of determining noise characteristics, a subportion noise value, etc., visual quality characteristics may be determined, respectively a subportion visual quality factor, etc. In a method according to the invention, the visual quality values may be noise values and/or gloss unevenness values. For one or for more subportions, subportion noise values may be determined while for one or more other subportions, gloss unevenness values are determined. In another embodiment, for at least one subportion both subportion noise values and subportion gloss unevenness values are determined.

[0052] The invention may be applied when reproducing monochrome continuous tone images by using at least two different types of toner, e.g. a greyish and a black toner. The invention may also be applied when reproducing a colour continuous tone image by using at least two different types of toner that have substantially the same chromaticity, such as a first cyan toner C and a second cyan toner C′.

[0053] According to a second aspect of the invention, which is especially useful when using at least two types of toner (and preferably three or more types of toner) that all have substantially the same chromaticity, the amount of deposited toner can be reduced significantly while the printed image has a very acceptable noise level and good gloss evenness, resulting in a high perceived image quality.

[0054] Embodiments of an apparatus according to the invention are disclosed in the detailed description below.

[0055] In the Example discussed in detail hereinafter, 25 % of toner is saved when printing medical images, using a light-grey, a mid-grey and a dark-grey toner. To obtain the higher density levels, the amount of light-grey toner is decreased while the amount of dark-grey toner increases, which results in saving toner; moreover the selected printing sequence is such that the mid-grey toner is printed last, which results in a very acceptable noise level and good gloss evenness.

[0056] Further advantages and embodiments of the present invention will become apparent from the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0057]

Fig. 1a and Fig. 1b each show a set of tone curves;
Fig. 2 shows measured noise values for different printing combinations;
Fig. 3 shows measured gloss values for different printing combinations.

DETAILED DESCRIPTION OF THE INVENTION

[0058] As mentioned already above, in a method in accordance with the invention, in a first phase visual quality characteristics are determined for different printing combinations according to which a continuous tone image may be reproduced. Then, in a second phase, these visual quality characteristics are used to determine selected printing combinations for printing selected image portions. Finally, in a third phase, the continuous tone image is reproduced. The first and the second phase will now be discussed more in detail. Again, first the special case is discussed of printing sequences and noise characteristics, while thereafter printing combinations and gloss unevenness characteristics are discussed.

[0059] Determining the noise characteristics involves the determination of subportion noise values. In the first preferred embodiment, mentioned above, the subportions are preferably pixels or groups of pixels. In this first embodiment, the subportion noise values of a toner image of at least one pixel or group of pixels (and preferably of all pixels) in a specific image portion are taken into account to determine the selected printing sequence for the specific image portion. In the second preferred embodiment, mentioned above, an image portion is classified in a class of images and the class noise characteristics are taken into account to determine a selected printing sequence. Both the subportion noise values and the class noise characteristics may be determined for a plurality of printing sequences by printing a number of test patches and by performing noise measurements on the printed test patches. This is now explained by means of an example.

[0060] Take for example four toner types, for the four traditional colours CMYK, and suppose that for each colour 256 tone levels may be achieved by means of multilevel halftoning. The number of required measurements may be kept within an acceptable limit as follows. For each colour, within the tone range, from e.g. 0 to 255, a limited number of tone levels are chosen, e.g. five tone levels: 0, 63, 127, 191, 255. In this way, the total number of colour combinations is limited to 5 x 5 x 5 x 5 = 625 combinations for measurement purposes, instead of the $256^4 \equiv 4 \times 10^9$ original colour combinations that can be printed. For each printing sequence, 625 test patches corresponding to the 625 combinations are printed. The number of possible printing sequences is calculated by using a factorial: 4! = 24 printing sequences of the four colours CMYK. Remark: since tone level 0 is among the chosen tone levels, not only all combinations of the four colours, but also all combinations of three colours and of two colours are printed; this is of importance since in a four colour image only three or two colours may be used in some portions of the image. Thus, if 625 test patches are printed on a sheet of receiving substrate, 24 sheets must be printed, each sheet corresponding to one printing sequence. On an A4 sheet, measuring 210 mm x 297 mm, 21 patches by 30 patches, measuring 9 mm x 9 mm each, may be printed. Finally, on every sheet a noise value of each test patch is determined by a measurement on this test patch; this noise value may be the perceived visual noise value, as discussed above. The subportion noise value of a toner image of a pixel, for a specific printing sequence, is then the determined noise value of the test patch with a colour value "nearest" to the electronic pixel value; e.g. for a pixel with electronic pixel values for (cyan, magenta, yellow, black) = (100, 50, 200, 20) and for the printing sequence KCMY, the corresponding test patch is the one with tone levels (cyan, magenta, yellow, black) = (127, 63, 191, 0), for the same printing sequence KCMY. The above example illustrates how to determine subportion noise values. Of course, instead of four types of toner, as in the example, another number of toner types may be used, the number of measurements may be limited less or more than in the example, the criterion for a test patch colour value being "nearest" to an electronic pixel value may be different, e.g. a minimum ΔE value according to CIE. To a person skilled in the art, it is clear from the above example how to determine subportion noise values for other printing conditions. Preferably, the test patches are printed on the same type of receiving substrate and by the same printing device as the continuous tone image.

[0061] In case a subportion comprises two or more pixels, the subportion noise values may be determined from a combination of the electronic pixel values of the pixels constituting the subportion; the combination may e.g. be an average or a weighted average of the individual pixel values. The (weighted) average is calculated toner type per toner type, resulting in four average electronic pixel values in the above example: one value for cyan, one for magenta, and so on. Once a single set of electronic pixel values is available, the subportion noise value is determined in the same way as for a subportion comprising a single pixel, which is discussed above.

[0062] Class noise characteristics may be determined as follows. The class noise characteristics of a specific class of images for a specific printing sequence may be calculated, e.g. as an average, from the "image noise characteristics" of toner images of a number of images (or image portions) belonging to the specific class, and this for the specific printing sequence. The "image noise characteristics" may be determined by subdividing the images or images portions belonging to the class into image subportions. The subportion noise values of these image subportions may be determined as explained above. The "image noise characteristics" may be determined from the subportion noise values in the same way as the noise value of a specific image portion is determined, which is explained immediately below Table I.

[0063] A second phase in a method in accordance with the invention involves using noise characteristics in selecting, out of possible printing sequences, the selected printing sequences that will be used to print the image or image portions thereof. The selection is based upon the subportion noise values.

	Image portion 1			Image Portion 2	...
	Subportion 1	Subportion 2	Subportion 3	Subportion 4	...
Printing sequence A	noise value (1,A)	noise value (2,A)	noise value (3,A)	noise value (4,A)	
Printing sequence B	noise value (1,B)	noise value (2,B)	noise value (3,B)	noise value (4,B)	
Printing sequence C	noise value (1,C)	noise value (2,C)	noise value (3,C)	noise value (4,C)	
...					

Table I: Example of subportion noise values for different printing sequences

[0064] In a preferred embodiment, a selected printing sequence is determined as follows. In a first step, a noise value of a specific image portion for a specific printing sequence is determined from some, and preferably from all, subportion noise values in the specific image portion and for the specific printing sequence. In Table I, the used subportion noise value are in a horizontal row, for example noise values (1,B), (2,B) and (3,B) for image portion 1 and for printing sequence B. The noise value of the specific image portion may simply be the average of the subportion noise values for the specific printing sequence, it may be a weighted average (larger weights may be assigned to image subportions having higher electronic pixel values which correspond to higher optical densities, because very often noise is more disturbing in the higher density area), etc. Then, in a second step, the noise values of the specific image portion are compared with each other for different printing sequences (e.g. printing sequences A, B and C in Table I) and the selected printing sequence may be determined as the printing sequence for which the noise value of the specific image portion is the smallest. However, as mentioned above, other factors may also be taken into account in determining the selected printing sequence, e.g. a toner type having a low (colour) transparency may preferably not be printed last.

[0065] In another preferred embodiment, in a first step the subportion noise values in a vertical column of Table I are combined together, for example noise values (2,A), (2,B) and (2,C) for image subportion 2. These noise values may be combined together to make a list of the best N printing sequences for a specific image subportion, wherein the "best" printing sequences are the ones with the lowest noise values. As an example, N = 3 and the best printing sequence gets one point, the second best two points, the third gets three points. Then, in a second step, the selected printing sequence for a specific image portion is determined from these lists, for all or for some image subportions in the specific image portion. In the example, the points are added for each printing sequence, and the selected printing sequence may be the one with the lowest total number of points. Again, other factors may also be taken into account in determining the selected printing sequence.

[0066] It is clear that the selected printing sequence for a specific image portion may be determined from the subportion noise values according to other algorithms than the ones given above. For example, a set of threshold noise values may be defined, and the subportion noise values are compared, printing sequence per printing sequence, to these threshold noise values. First, the highest threshold noise value out of the set is taken, and that printing sequence is eliminated, to which the largest number of subportions correspond that have a subportion noise value higher than the highest threshold value. Then, for the printing sequences that are left, the subportion noise values are compared to a second threshold noise value out of the set, lower than the highest threshold value, which again results in elimination of a printing sequence, and so on, until one printing sequence is left, which is the selected printing sequence.

[0067] The invention can also be applied for printing combinations instead of for printing sequences; in the above discussion, "printing sequence" may simply be replaced by "printing combination". If, instead of determining subportion noise values, gloss unevenness values are to be determined, the gloss level of at least two and preferably of three patches is measured, and the gloss unevenness is determined from these gloss levels. Preferably, the patches of which the gloss level is measured have tone levels that are "near" each other (as defined above; e.g. a minimum ΔE value according to CIE). Determining gloss unevenness is discussed in detail in the Example hereinafter.

[0068] Printing different image portions of an image according to different selected printing sequences may be realised as follows. The term "different printing sequences" means that a first image portion is printed according to a first printing sequence and a second image portion is printed according to a second printing sequence, different from the first one. In a first class of printing devices, the printing stations for applying marking particles of different types occupy a fixed position in space. To this first class belong classical electro(stato)graphic printing devices, wherein, as is known in the art, toner stations occupying a fixed position each apply a specific type of toner to a receiving member. This receiving member may be the receiving substrate, or it may be an intermediate member, from which the toner image is transferred to the final receiving substrate in a subsequent step. The receiving member moves with respect to the toner stations, so that a complete toner image, extending in two dimensions, is applied to a surface of the receiving substrate (either directly, or indirectly via an intermediate member). For this first class of printing devices, different printing sequences may be realised by adding extra toner stations (e.g. seven toner stations CMYCMYK allow printing sequences such as CMYK, MYCK, YCMK) or by multiple passages of the receiving member. In case of multiple passages, an intermediate endless belt or an intermediate drum may be used that moves at least twice past the toner stations. For example, two passages past four toner stations CMYK allow the same printing sequences as a single passage past eight toner stations CMYKCMYK. In a second class of printing devices, the printing stations move in a first direction (e.g. parallel to the width of the receiving member) and the receiving member moves in a second direction (e.g. in the direction of its length). Classical inkjet printers, with moving inkjet printing heads, are a well known example of this second class. Another example are DEP printing devices for wide format printing, as disclosed in e.g. EP-A-0 849 645; such DEP printing devices have a shuttle that travels over the receiving member and that comprises the toner stations or a portion thereof. For this second class of printing devices, different printing sequences may be realised by multiple passages of the printing head or the shuttle over the receiving member.

[0069] An first embodiment of an apparatus according to the invention is capable of printing a first image according to a first printing sequence and a second image according to a second printing sequence, different from the first one. Another embodiment of an apparatus according to the invention is capable of printing different image portions of an image according to different printing sequences. An apparatus according to the invention comprises control means that generate control signals for controlling the printing means of the apparatus and for determining the printing sequence. In the above example of the printing device with seven toner stations CMYCMYK, a first set of control signals may control the device to use e.g. the first four toner stations CMYK, for printing according to the printing sequence CMYK, while a second set of control signals, different from the first set, may control the use of the third, fourth, fifth and last station for printing according to the printing sequence YCMK. In a printing device having only four toner stations, e.g. CMYK, two different sets of control signals may be used to allow for multiple passages of the receiving member in at least one printing sequence, so that images may be printed according to different printing sequences by using different sets of control sequences. In case of moving printing stations (i.e. the second class of printing devices discussed above), two different sets of control signals, for controlling the inkjet printing heads or the shuttle in the DEP printing device, may be used to allow for printing different image portions in an image according to different printing sequences. Thus, an apparatus in accordance with the invention comprises control means for generating a first set of control signals for printing a first image or a first image portion according to a first printing sequence, and for generating a second set of control signals, different from the first set, for printing a second image or a second image portion according to a second printing sequence, different from the first printing sequence

[0070] An image may be subdivided into image portions as follows. The subdivision may be made arbitrarily, it may be made manually, based upon the image characteristics (e.g. the sky and the beach in the example mentioned hereinbefore are preferably assigned to different image portions). Preferably, the subdivision of the image into image portions is based upon the noise characteristics of the image and is such that the image subportions in an image portion have substantially the same noise characteristics. Such a preferred subdivision may be carried out as follows. First, the image is subdivided into image subportions and, for each image subportion, the subportion noise values n_A, n_B, n_C, etc. are determined for the different printing sequences A, B, C, etc. Then, the subportion noise values for a specific image subportion are put in a table $(x,y,n_A,n_B,n_C,...)$, wherein x and y are the location of the specific image subportion in the image. Now the image subportions may be grouped into image portions by using an appropriate algorithm, such as region-oriented segmentation, described in "Digital Image Processing", second edition, by Rafael C. Gonzalez and Paul Wirtz, Addison-Wesley, 1987, pages 368 ff.

[0071] The invention may be applied for reproducing single-sided images and for reproducing double-sided images. In reproducing single-sided images, the image is applied to one surface of the receiving substrate. In reproducing double-sided images, a first image is applied to a first surface of the receiving substrate and a second image is applied to a second surface of the receiving substrate, opposite to the first surface. When printing double-sided images, either only the first image may be printed according to the invention, or both the first and the second image may be printed according to the invention.

[0072] The marking particles used in a method according to the invention all contribute to the colour of the printed image. Colourless particles may be used to apply a colourless layer, usually on top of the printed image. Typical examples of colourless toner particles and of colourless layers, and different ways to apply such a layer are disclosed in EP-

A-629 921, EP-A-486 235, US-A-5 234 783, US-A-4 828 950, EP-A-554 981, WO 93/07541 and Xerox Research Disclosure Journal, Vol.16, N° 1, p. 69 (January/February 1991).

Example

[0073] Multigrey images were printed in a Sharp JX 8200 laser printer. This printer is a colour printer, but it was used to print medical images using three greyish toner types: a light-grey, a mid-grey and a dark-grey toner (therefore the term "multigrey" is used). The cyan, magenta and yellow toners in the laser printer were replaced by:

- a dark-grey toner having an optical density of D = 1.76;
- a mid-grey toner having an optical density of D = 0.72;
- a light-grey toner having an optical density of D = 0.36;

(the optical densities being determined for approximately 0.5 mg/cm^2 toner) while the black toner remained in the first toner station of the laser printer (and is hence applied first to the receiving substrate, before the above three greyish toners are applied). The black toner is only used for annotation; it is not used in printing the image itself and it will therefore not be mentioned any more in the discussion below. If a specific greyish toner is mentioned to be printed first, this means therefore that the specific greyish toner is applied to the receiving substrate before the other greyish toners are applied (but after the black toner).

[0074] The multigrey images were printed according to three different printing combinations: a first "up up up" printing combination, a second "old up up down" printing combination wherein toner is saved but which prints images having bad noise characteristics and uneven gloss, and a third "new up up down" printing combination in accordance with the invention, which saves toner and which prints images having a good noise level and good gloss evenness.

[0075] In the first printing combination, called "up up up", the printing sequence is: first dark-grey toner is applied, then mid-grey toner and finally light-grey toner, and set 10 of tone curves, shown in Fig. 1a, is used: tone curve 11 for dark-grey toner, curve 12 for mid-grey and curve 13 for light-grey toner. This printing combination is theoretically best with respect to reducing noise, but it requires quite large amounts of toner. Figures 2 and 3 show respectively measured noise values N_1 and measured gloss values G_1 for this first printing combination. In Fig. 1a, tone curves 11, 12 and 13 correspond respectively to dark-grey, mid-grey and light-grey toner. Fig. 1a shows that, for the lowest pixel values, only light-grey toner is used (see tone curve 13). For medium pixel values, mid-grey toner is used and a maximum amount of light-grey toner (see tone curves 12 and 13). For high pixel values, dark-grey toner is used and a maximum amount of mid-grey and of light-grey toners (see tone curves 11, 12 and 13).

[0076] In order to save toner, in the second printing combination, called "old up up down", the same printing sequence is used as in "up up up", i.e. first printing dark-grey toner, then mid-grey toner and finally light-grey toner, but now set 20 of tone curves, shown in Fig. 1b, is used: tone curves 21, 22 and 23 correspond respectively to dark-grey, mid-grey and light-grey toner. As is clear from Fig. 1b, tone curve 23 has a descending portion or "down"-going portion, and tone curves 21 and 22 go "up" (hence the name "up up down"). Tone curve 23 has a descending portion in order to save toner: the amount of light-grey toner is decreased and is replaced by a (smaller) extra amount of dark-grey toner. That an extra amount of dark-grey toner is used, is not clear when comparing the tone curves in Fig. 1b with those in Fig. 1a. In fact, as known in the art, a calibration step is carried out, customarily by inserting an extra lookup table between the original pixel values and the tone curves. The purpose of the calibration step is to attain the desired optical densities on the receiving substrate, for all input pixel values. In this second printing combination, calibration will result in applying more dark-grey toner.

[0077] As is shown by Fig. 2 and Fig. 3, the noise values N_2 and the gloss evenness (see the gloss values G_2) are worse then the values N_1 and G_1 for the first printing combination. When the printed images are examined, the perceived quality of the images printed according to the second printing combination is not satisfactory.

[0078] In the third printing combination, called "new up up down", the same tone curves of Fig. 1b are used as in the second printing combination, but now the printing sequence is: first printing dark-grey toner, then light-grey and finally mid-grey toner.

[0079] Fig. 2 shows that the noise values N_3 for the third printing combination are comparable to the noise values N_1 for the first printing combination (i.e. "up up up"), while the noise values N_2 for the second printing combination are much worse, especially for the higher densities. Fig. 2 was obtained by performing measurements according to the "perceived noise metric" on a wedge, printed beforehand on paper (i.e. the test patches as discussed above are a grey wedge in this case). Fig. 2 is a graph of the obtained perceived visual noise values as a function of visual density D_{vis}. The viewing distance was set to 10 cm.

[0080] Fig. 3 shows gloss values that were measured by a Minolta Multi-Gloss 268 meter, set at the 60° geometry, on the same wedge used for the measurements shown in Fig. 2. In Fig. 3, the measured gloss values are shown as a function of relative density, i.e. the density divided by the maximum density, and expressed in percent (i.e. the maximum density is 100 %). Fig. 3 shows that the gloss values G_3 and G_1 for the third and for the first printing combinations are comparable, while the gloss values G_2 for the second printing combination show an important gloss unevenness for the higher densities - i.e. where gloss unevenness is especially disturbing.

[0081] From Figures 2 and 3, the third printing combination is chosen as the selected printing combination for the class of black-and-white medical images. The choice is a compromise between visual quality and saving toner; the first printing combination has even better visual quality than the third one, but it requires approximately 25 % more toner, as will be discussed below.

[0082] That the third printing combination offers good visual quality characteristics can also be explained theoretically. Especially for the high densities, the gloss characteristics G_3 and the noise characteristics N_3 are much better than G_2 respectively N_2 of the second printing combination. For these high densities, tone curve 22 in Fig. 1b shows that a maximum amount is used of mid-grey toner, i.e. the toner type that is applied last in the third printing combination. Thus, the top layer, i.e. the mid-grey toner layer, is substantially uniform. On the contrary, in the second printing combination, the light-grey toner is printed last; thus in this case the top layer is not uniform since tone curve 23, for the light-grey toner, is descending for the high densities. The noise and the gloss characteristics of a printed image are determined to a large degree by the properties of the topmost toner layer.

[0083] Therefore, the mid-grey toner should be printed last and not the light-grey toner, if the toner curve of the light-grey toner has a descending portion, which is the case for tone curve 23 in Fig. 1b. Of course, this aspect of the invention is not limited to greyish toners; as mentioned before, tone types having substantially the same chromaticity, such as two cyan toner types C and C′, may be used instead of greyish toner types.

used toner [mg]	light-grey	mid-grey	dark-grey	total
image: Thorax	117.007	126.440	73.255	316.70
image: P2	159.125	216.065	134.810	510.00

Table II: Used toner quantities for two images printed according to the third printing combination

used toner [mg]	light-grey	mid-grey	dark-grey	total
image: Thorax	203.107	130.053	83.720	416.88
image: P2	294.917	219.108	170.329	684.35

Table III: Used toner quantities for two images printed according to the first printing combination

[0084] Tables II and III show that the third printing combination requires 25 % less toner than the first printing combination, for printing two black-and-white medical images. The quantity of used toner was determined by measuring the weight difference between paper on which an image was printed and fused, and paper on which no image was printed but that was fused.

[0085] Having described in detail preferred embodiments of the current invention, it will now be apparent to those skilled in the art that numerous modifications can be made therein without departing from the scope of the invention as defined in the appending claims.

Parts list

[0086]

10, 20	set of tone curves
11,12,13	tone curves

21,22,23	tone curves
G_1, G_2, G_3	gloss values
N_1, N_2, N_3	noise values

Claims

1. A method for reproducing by a printing device a continuous tone image by imagewise application of at least two different types of marking particles to a surface of a receiving substrate, the method comprising the steps of:

- determining a plurality of printing combinations, each printing combination optionally comprising a set (10, 20) of tone curves (11, 12, 13, 21, 22, 23) and comprising a printing sequence for applying said different types of marking particles to said surface of said receiving substrate;
- selecting at least one image portion in said continuous tone image;
- selecting at least one image subportion in at least one selected image portion;
- determining, for at least one selected image subportion in said selected image portion and for at least two printing combinations out of said plurality of printing combinations, a subportion visual quality value of a printed image of said selected image subportion;
- selecting, for said selected image portion, a selected printing combination out of said plurality of printing combinations, the selection being based on said subportion visual quality values;
- applying to said surface of said receiving substrate a plurality of said different types of marking particles according to said selected printing combination, for reproducing said selected image portion.

2. The method according to claim 1, wherein said continuous tone image comprises exactly one image portion.

3. The method according to claim 1 or claim 2, wherein said selected image subportion is identical to said selected image portion, the method further comprising the steps of:

- classifying said selected image portion in a class of images;
- determining class visual quality characteristics of printed images of continuous tone images belonging to said class of images;

and wherein said step of determining a subportion visual quality value is based on said class visual quality characteristics.

4. The method according to any one of the preceding claims, wherein said subportion visual quality value is a noise value.

5. The method according to any one of the preceding claims, wherein said subportion visual quality value is a gloss unevenness value.

6. The method according to any one of the preceding claims, wherein two of said different types of marking particles have a chromaticity difference obeying the following inequality:

$$\sqrt{(\Delta a^*)^2 + (\Delta b^*)^2} \leq 20$$

when expressed in the CIE's L* a* b* space.

7. The method according to any one of the preceding claims, wherein said marking particles are toner particles.

8. A method for reproducing by a printing device a continuous tone image by imagewise application of at least two different types of toner particles to a surface of a receiving substrate, wherein a first one and a second one of said different types of toner particles have a chromaticity difference obeying the following inequality:

$$\sqrt{(\Delta a^*)^2 + (\Delta b^*)^2} \leq 20$$

when expressed in the CIE's L* a* b* space, and wherein said first toner particles have an optical density D_1 and said second toner particles have an optical density D_2 with $D_2 < D_1$, the method comprising the steps of:

- determining a set (20) of tone curves (22, 23) for the first and the second toner types, wherein the tone curve (23) for the second toner type comprises a descending portion;
- applying said second toner type to said surface of said receiving substrate;
- applying said first toner type to said surface of said receiving substrate after application of said second toner type.

9. The method according to the preceding claim, wherein a third one and said second one of said different types of toner particles have a chromaticity difference obeying the following inequality:

$$\sqrt{(\Delta a^*)^2 + (\Delta b^*)^2} \leq 20$$

when expressed in the CIE's L* a* b* space, and wherein said third toner particles have an optical density D_3 with $D_3 > D_1$, the method further comprising the step of:

- applying said third toner type to said surface of said receiving substrate before application of said first toner type.

10. Use of a method according to any one of the preceding claims for printing reproductions of diagnostic images.

11. An apparatus comprising means for performing the method according to claim 8 or to claim 9.

12. An apparatus for reproducing a continuous tone image by imagewise application of at least two different types of marking particles to a surface of a receiving substrate, the apparatus comprising:

- printing means for applying said different types of marking particles to said surface of said receiving substrate according to a printing sequence;
- control means for generating control signals for controlling said printing means and for determining said printing sequence; characterised in that said control means are for generating a first set of control signals for printing an image according to a first printing sequence, and for generating a second set of control signals, different from said first set, for printing an image according to a second printing sequence, different from said first printing sequence.

13. An apparatus for reproducing a continuous tone image by imagewise application of at least two different types of marking particles to a surface of a receiving substrate, said continuous tone image comprising a plurality of image portions, the apparatus comprising:

- printing means for applying said different types of marking particles to said surface of said receiving substrate according to a printing sequence;
- control means for generating control signals for controlling said printing means and for determining said printing sequence; characterised in that said control means are for generating a first set of control signals for printing a first image portion out of said plurality of image portions according to a first printing sequence, and for generating a second set of control signals, different from said first set, for printing a second image portion out of said plurality of image portions according to a second printing sequence, different from said first printing sequence.

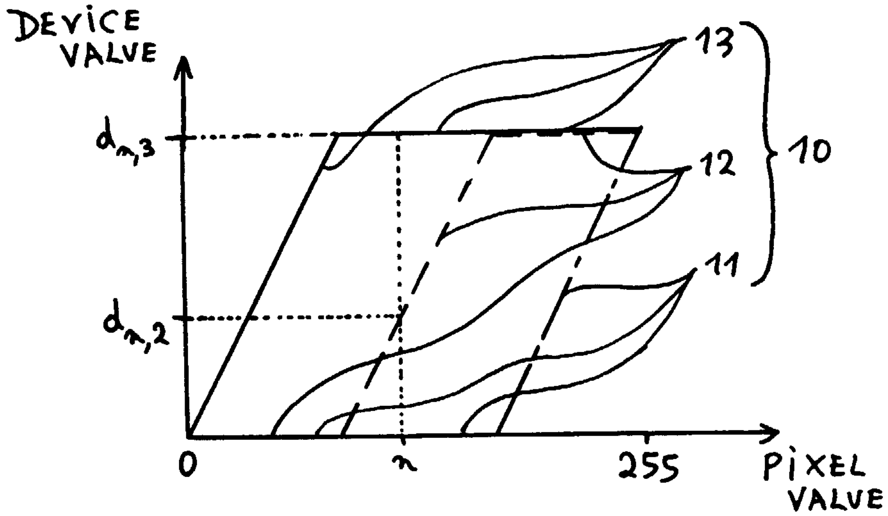
DEVICE
VALUE
$d_{n,3}$
$d_{n,2}$
13
12
11
10
0
n
255
PIXEL
VALUE

Fig. 1a

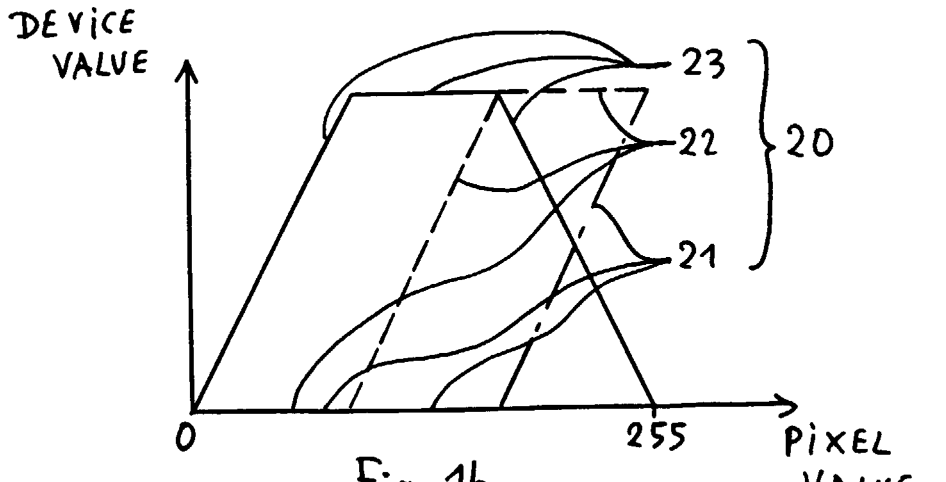
DEVICE
VALUE
23
22
21
20
0
255
PIXEL
VALUE

Fig. 1b

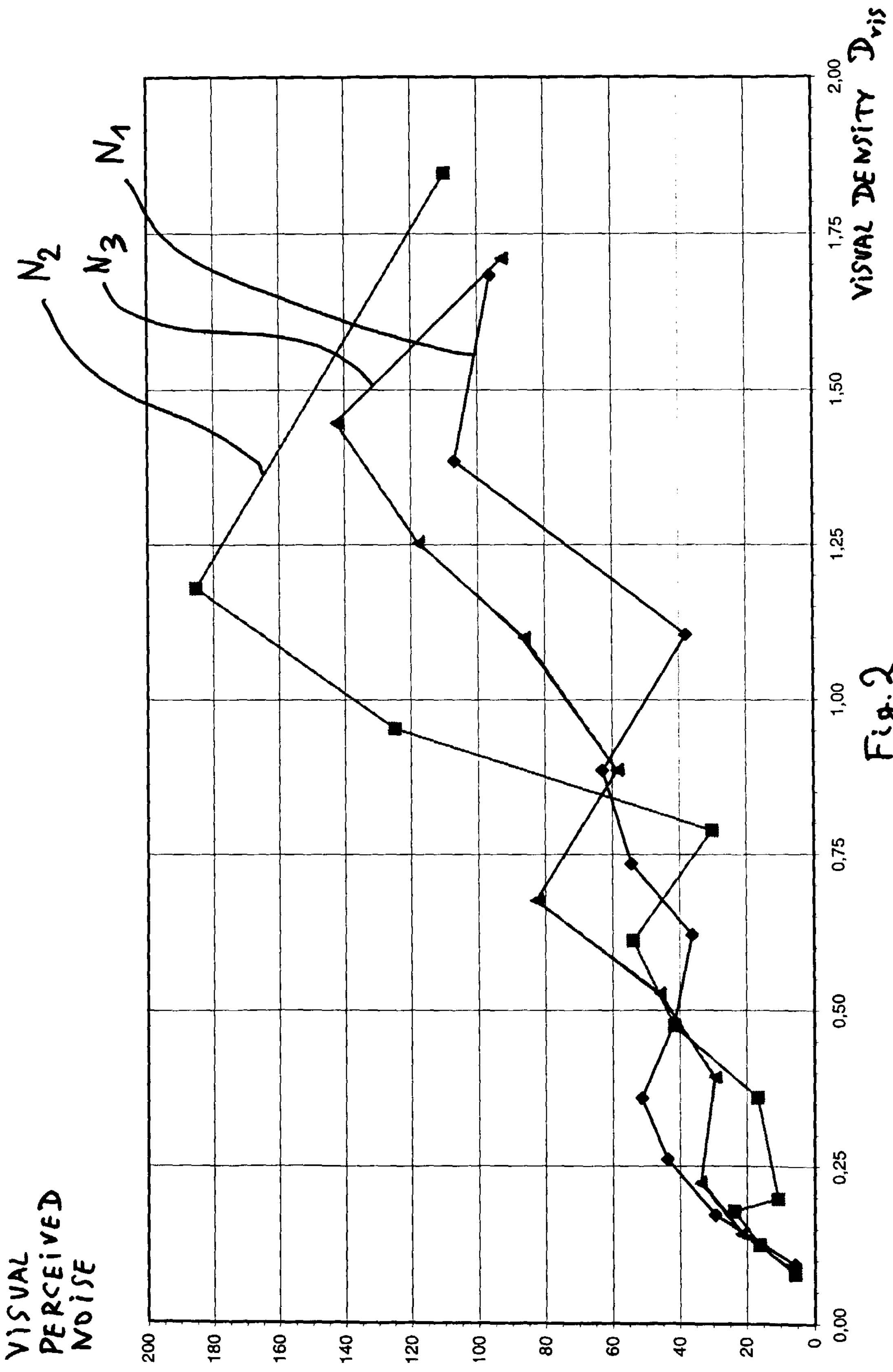
VISUAL PERCEIVED NOISE
200
180
160
140
120
100
80
60
40
20
0
0,00
0,25
0,50
0,75
1,00
1,25
1,50
1,75
2,00
VISUAL DENSITY D_{vis}
N_1
N_2
N_3

Fig. 2

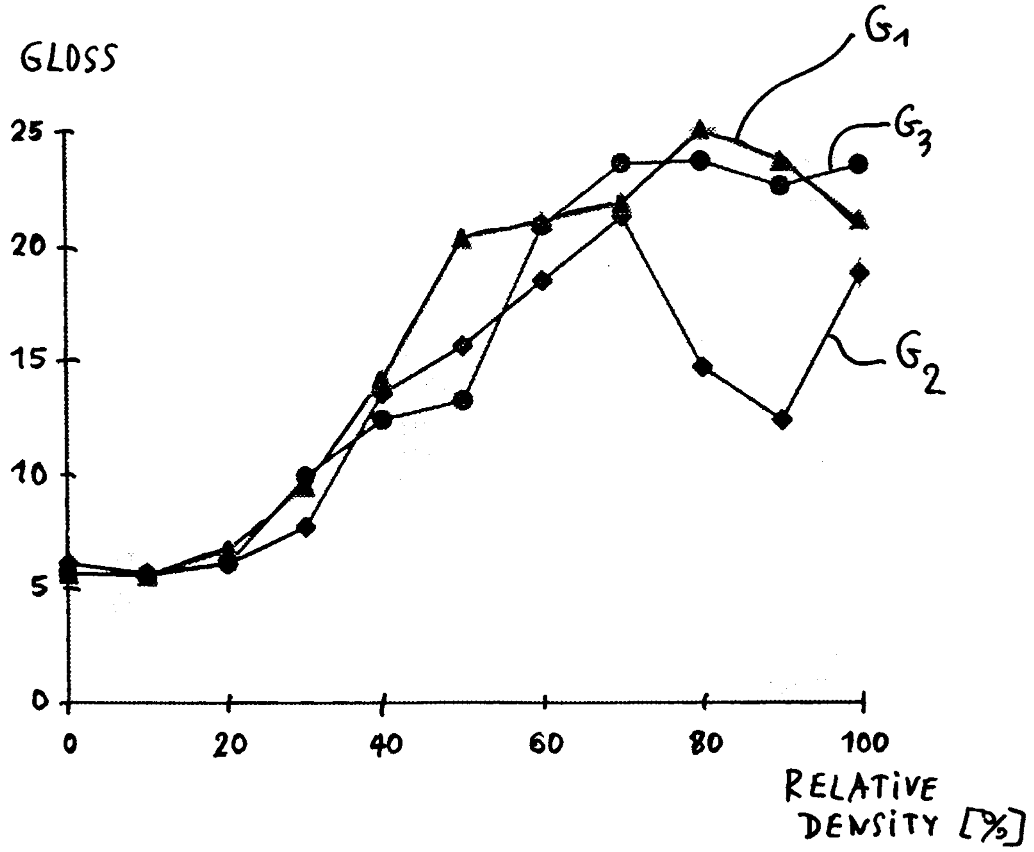

Fig. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 20 4392

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	9 June 1999	Lipp, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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