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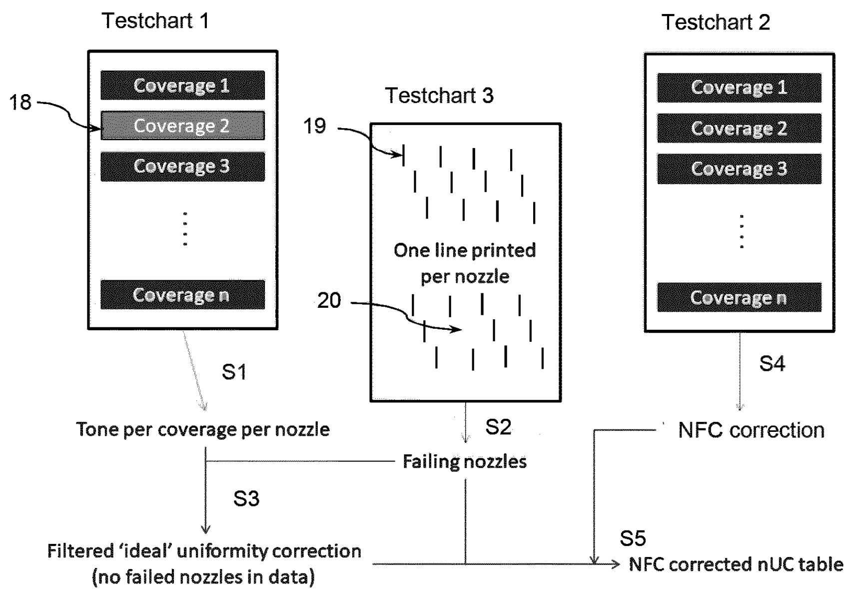
(54) STREAKINESS REDUCTION IN INKJET PRINTING

(57) A method for reducing streakiness in inkjet prints is disclosed. The printer comprises a page-wide array of ink jetting units, that apply ink drops on a receiving medium in accordance with an input image. The method comprises a number of steps, wherein a first optical density profile across the width of the array is determined for a first input image that comprises uniform test patterns of various density levels and a second optical density profile for a second input image wherein a number of jetting units are intentionally blocked. A comparison of two profiles yields an effect of a blocked ink jetting unit. Using this effect a correction table for the density associated with each jetting unit is composed and an input image is printed after processing an array of pixels associated with a particular ink jetting unit with the corresponding correction factor.

Fig. 4



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Description

BACKGROUND OF THE INVENTION

1. Field of the invention

[0001] The present invention relates to a method for reducing streakiness in inkjet prints from a printer having a page-wide array of ink jetting units, that apply ink drops on a receiving medium, transported in a transverse direction underneath the page-wide array, in accordance with an input image.

2. Description of the Related Art

[0002] Production inkjet printers are known to comprise a page-wide array of ink jetting units, wherein the page width ranges from A4 (21 cm) to A0 (84 cm), the array comprising one or more print heads, each print head consisting of several chips with individual jetting units, also referred to as nozzles. The term "print head", "print" and derivatives thereof are to be understood to include any device or technique that deposits or creates material on a surface in a controlled manner. Although the individual units are not positioned in a single line, they behave as such by appropriate timing of the ejection of the ink droplets from the nozzles, taking into account the velocity of the transportation of the medium. The arrangement of the page-wide array and the transported receiving medium is such that an individual jetting unit is controlled to apply ink drops for an array of pixels of the input image, e.g. a column of pixels in a raster image. Whereas the droplets of a single jetting unit are quite equal, the droplets of different jetting units are known to slightly vary in size, speed and direction. Without further precautions, this may show in a printed image as streak-like artefacts. This is solved for a great deal by adjusting the pixel values in an input image for each process color in the printer, usually cyan, magenta, yellow and black, in such a way that a jetting unit giving a lower ink density is compensated by making the associated pixel values higher and a jetting unit giving a higher ink density is compensated by making the associated pixel values lower. Such a compensation process is known as a shading correction. The necessary compensation factors are derived by measuring density profiles of uniform areas in printed images at various density levels.

[0003] There is, however, a remaining amount of streakiness, which is associated with more strongly deviating jetting units. This includes both jetting units that do not eject an ink drop, when controlled to do so, and jetting units that eject ink drops that come down on the receiving medium far from their intended position. These jetting units, also known as failing nozzles, are usually turned off and the missing ink density is provided by adjacent jetting units. Thus, the compensation factors of the adjacent or neighbouring jetting units are enhanced to compensate for the failing nozzle.

[0004] Within the framework of shading correction as indicated above, the crucial element is the method for obtaining the appropriate compensation factors. When using incorrect factors, over- and/or undercompensation may result, which enhances the streakiness, instead of reducing it. Also, the measurement of density profiles at various density levels is quite laborious and should not be executed very often. Furthermore, the optical resolution that is available for these measurements is usually less than the resolution of the ink jetting units in the page-wide array, making an individual jetting unit not very well discernable in a uniform background. In contrast, the measurement of individual jetting unit characteristics to determine which jetting units should be treated as deviating ones, is relatively simple and may be done in-between the printing of regular input images. Since during printing the characteristics of the jetting units may change, e.g. by drying ink in the nozzle or by air entrapment in the jetting unit, it is advantageous to regularly check the performance of the individual units. In short, there is a problem in deriving the compensation factors and maintaining their actuality. It is an object of the present invention to provide a method that comes forward to these issues.

SUMMARY OF THE INVENTION

[0005] The method according to the invention comprises the steps of: a) determining a first optical density profile across the width of the array for a first input image that comprises uniform test patterns of various density levels; b) repeating step a with a second input image wherein the test patterns of the first input image are modified by intentionally blocking a number of jetting units from applying an ink drop to obtain a second optical density profile; c) deriving an effect of a blocked ink jetting unit from a comparison of the first and second optical density profiles; d) determining a characteristic property of an individual jetting unit using a third input image; e) composing an ideal compensation table, which comprises for each ink jetting unit a density compensation factor that would make the first optical density profile uniform; f) deriving from the ideal compensation table a practical compensation table, wherein the density compensation factor is made zero for deviating ink jetting units, that have the characteristic property outside a predetermined range, and wherein the density compensation factors of ink jetting units adjacent to a deviating ink jetting unit are modified using the result from step c for obtaining a uniform density response, and g) printing an input image by processing for each ink jetting unit, an array of pixels associated with a particular ink jetting unit, using the corresponding compensation factor from the practical compensation table.

[0006] The use of intentionally blocked jetting units, which is done by not ejecting an ink drop from these units, although they might have been used, enables a determination of the effect of not using an ejection unit in a surrounding of other jetting units printing a uniform density of ink. Since the effect is usually not very large, the comparison of the two density profiles is needed to provide the necessary sensitivity for the optical effect of a missing ink jetting unit. Accidentally not jetting units will have the same effect in both profiles and the density profiles for the two input images will not be different around these units. A characteristic property of an individual jetting unit is determined by measuring the position of a dot that is associated with this unit. The third input image is built up in such a way that the dots of each jetting unit can be determined individually, which means that a number of jetting units on both sides adjacent to a drop ejecting jetting unit are kept silent. The ideal compensation table comprises a proper factor for all jetting units, even for the ones not working. The factors for these last ones may be approached by interpolation. Then a practical compensation table is composed from a second input image, wherein a number of individual jetting units are given a factor zero to prevent them from being controlled to eject an ink drop. This is decided based on a result from the determination of a characteristic property, such as the presence of a dot or the angle deviation of an ink drop from the jetting unit. The missing ink density for these jetting units is provided by adjacent jetting units by modifying the associated compensation factors from the ideal table. The advantage of this method is that a change in operability of a jetting unit, such as a blocked nozzle becoming working again, can be relatively fast accommodated in the table of compensation factors, without a necessity of keeping track which jetting units were previously operable, after determining the characteristic property of all jetting units once again. As noted earlier, this measurement is much faster than the uniform density measurements. It has been shown experimentally that this method reduces streakiness, in particular for page-wide arrays with a high integration density.

[0007] Useful details and preferred embodiments of the invention are indicated in the dependent claims.

[0008] In a further embodiment, the effect of a blocked ink jetting unit is determined by averaging the difference between the first and second density profile and fitting the average curve as a function of the ink jetting unit position. The best fitting function is found to be a Gaussian function, $f(n) = A \exp[-(n/S)^2]$, wherein n is the positional distance between a jetting unit for which a correction is applied and the blocked jetting unit and A and S parameters for respectively the amplitude and the width of the difference between the two profiles.

[0009] In a further embodiment, the parameters A and S for the Gaussian function depend on the characteristics of the adjacent jetting units, in particular the jetting angle in the direction of the page-wide array. For each blocked unit, a model may be used to find the optimal correction factors.

[0010] Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The present invention will become more fully understood from the detailed description given herein below and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

Figure 1	Overview of the application of shading correction to a uniform image;
Figure 2	Plot of a difference between optical densities measured around an intentionally blocked jetting unit;
Figure 3	Example of compensation factors applied around a blocked jetting unit;
Figure 4	Scheme of steps for deriving a practical compensation table, and
Figure 5	Sketch of the compensation being dependent on the position of adjacent ink dots.

DETAILED DESCRIPTION OF EMBODIMENTS

[0012] The present invention will now be described with reference to the accompanying drawings, wherein the same or similar elements are identified with the same reference numeral.

[0013] A page-wide array of ink jetting units is commonly controlled to eject ink droplets of discrete sizes. This may be only one size, or a small number of ink drop sizes. However, in order to reproduce contone images, in some part of the image processing sequence, the image is represented by a raster image, which comprises pixels, each pixel having a number of values, each value being representative for an amount of colorant that is to be printed. The pattern of dots, or ink drop sizes, that is to bring about this amount of colorant is generated by a halftone algorithm, such as stochastic dithering or error diffusion. This will not be discussed further, as the shading correction works on a raster image having contone values.

[0014] Figure 1A shows an example of a uniform raster image 1 with 9 pixels values in the page-wide array direction 2 and 7 values in the medium transport direction 3. All pixel values are equal and in this case indicate a value between 0 and 255, due to the 8-bit representation. During processing of the pixel values a 16-bit representation is used to diminish the effect of digital noise. 157 indicates a more than half fully covered medium. Figure 1B shows how this raster image will be printed if no shading correction is applied. The varying amount of ink ejected by the units of the array, results in a varying density of ink on the medium. Note that the shown variation in ink density cannot be measured as such and that the raster image 4 is a model situation. The compensation factors 5 are applied to compensate the variation in raster image 4, obtaining the compensated raster image 6 of Figure 1C. Each compensation factor is applied to a column of pixels associated with a single ejection unit. As this is the ideal compensation, the ink density is completely uniform and no streakiness will be visible in printing this image.

[0015] Figure 2 shows a graph 10 of the optical density 11 as measured from a uniform raster image with several of the ejection units intentionally turned off, as a function of the position 12 along the array, as measured in distance from the turned off unit. Individual measurements 13 show a variation around an average 14 that is used to derive compensation factors to provide the missing density. These factors are used for ejection units that are blocked or otherwise not functioning properly, either temporarily of permanent. The purpose of intentionally blocking is only to obtain a large number of measurements. The average difference between the optical density without and with intentionally turned off nozzles may be fitted by a Gaussian function,

$$f(n) = A \exp[-(n/S)^2],$$

wherein n is the positional distance between a jetting unit for which a correction is applied and the blocked jetting unit and A and S parameters for respectively the amplitude and the width of the difference between the two profiles. A takes typically a value of 0.2 and S a value of 2.1, wherein the value of A is strongly dependent on the process colour, as all measurements are performed for each process colour separately. An example of the derived factors is shown in Figure 3 as a number of additional factors 15 that are combined with the factors 5 in Figure 1 to practical compensation factors 17. The not functioning nozzle is associated with a compensation factor 0.0 as indicated by factor 16. Thus, it will not be controlled to eject ink.

[0016] Figure 4 shows the various elementary steps in their context. Testchart 1 comprises various uniform areas 18 with different coverages, indicating different tones of a process colour. In step S1 a measurement of these tones is made by an optical device, such as an in-line scanner. Testchart 3 comprises individual ejection unit testing elements in the form of single ejection unit lines 19 from which a characteristic property can be derived, such as the units that are not functioning, also known as failing nozzles, as indicated by a missing line 20, or a deviation angle of the individual droplets ejected by the unit. In step S2 an actual list of the ejection units that are to be discarded is made. This testchart may be made every time it is felt necessary to update this list. In step S3 the two results are combined to get an ideal compensation table, wherein the failing nozzles are approached by interpolation. Testchart 2 is printed in a similar way as testchart 1 with the addition of intentionally blocked ejection units. The difference in optical density between the measurements of these two testcharts, similar to Figure 2, is used to derive an individual nozzle failure correction (NFC) in step S4. Combining this correction with the ideal compensation table for the actual list of failing nozzles results in a practical compensation table, or NFC corrected nUC table, in step S5.

[0017] In a preferred embodiment, an individual measured optical density difference as indicated in graph 13, is correlated with a measured angle deviation in the direction of the page-wide array. Figure 5 indicates the effect that is reached. Again the vertical direction is associated with the transport direction of the receiving medium. In drawing 25 line 26 indicates positions on the receiving medium where no dots are printed due to a failing ejection unit. Line 27 is a line where the dots are ideally placed, in contrast to line 28, where the dots are printed with a large angle deviation, due to some misfunctioning of the associated ejection unit. In comparison drawing 30 is shown. Herein line 31 is the line where dots are absent and line 32 shows an ideal placement of dots. However, in this case the dots on lines 33 and 34, which are directly adjacent to line 31, are positioned such that they are close to line 31. It has been found that the compensation factors that are needed in the situation of drawing 30 are lower than the compensation factors as needed for the situation of drawing 25. The individual graphs 13 may be fitted by a Gaussian function and the parameters of this function may be correlated with the individual characteristic property of the ejection unit, such as in this case the angle of deviation from the ideal direction for the ink drop.

[0018] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the scope of the invention, and all such modifications are intended to be included within the scope of the following claims.

Claims

1. A method for reducing streakiness in inkjet prints from a printer having a page-wide array of ink jetting units, that apply ink drops on a receiving medium, transported in a transverse direction underneath the page-wide array, in accordance with an input image, the method comprising the steps of:

    a. determining a first optical density profile across the width of the array for a first input image that comprises uniform test patterns of various density levels (S1);
    b. repeating step a with a second input image wherein the test patterns of the first input image are modified by intentionally blocking a number

of jetting units from applying an ink drop to obtain a second optical density profile (S4);
c. deriving an effect of a blocked ink jetting unit from a comparison of the first and second optical density profiles (S4);
d. determining a characteristic property of an individual jetting unit using a third input image (S2);
e. composing an ideal compensation table, which comprises for each ink jetting unit a density compensation factor that would make the first optical density profile uniform (S3);
f. deriving from the ideal compensation table (5) a practical compensation table (17), wherein the density compensation factor is made zero for a deviating ink jetting unit, that has the characteristic property outside a predetermined range, and wherein the density compensation factors of ink jetting units adjacent to a deviating ink jetting unit are modified using the result from step c for obtaining a uniform density response (S5), and
g. printing an input image by processing for each ink jetting unit, an array of pixels associated with a particular ink jetting unit, using the corresponding compensation factor from the practical compensation table (17).

2. The method according to claim 1, wherein the characteristic property of an individual jetting unit is derived from a position of a dot on the receiving medium that is associated with said jetting unit.

3. The method according to claim 2, wherein the absence of a dot is interpreted as the characteristic property being outside the predetermined range as mentioned in step d.

4. The method according to claim 1, wherein in step b a series of jetting units is blocked and the effect of a blocked ink jetting unit in step c is derived by averaging the difference between the density profiles around the blocked jetting units.

5. The method according to claim 4, wherein the series of blocked jetting units comprises a number of equidistant jetting units.

6. The method according to claim 5, wherein the distance between the intentionally blocked jetting units is at least 10 units.

7. The method according to claim 4, wherein the averaged difference is fitted by a Gaussian curve, having two parameters A for the height of the curve and S for the width of the curve.

8. The method according to claim 7, wherein the density compensation factors of ink jetting units adjacent to a deviating ink jetting unit are obtained by modelling the difference between the optical density profiles using individual Gaussian curves having parameters A and S depending on the distance between dots associated with the adjacent jetting units.

9. A non-transitory computer readable medium storing computer executable instructions for executing a method according to claim 1.

10. A printer comprising an engine controller comprising a non-transitory computer readable medium according to claim 9.

Fig. 1

2

A.

3

1

157	157	157	157	157	157	157	157	157
157	157	157	157	157	157	157	157	157
157	157	157	157	157	157	157	157	157
157	157	157	157	157	157	157	157	157
157	157	157	157	157	157	157	157	157
157	157	157	157	157	157	157	157	157

B.

4

157	161	130	148	164	145	155	151	134
157	161	130	148	164	145	155	151	134
157	161	130	148	164	145	155	151	134
157	161	130	148	164	145	155	151	134
157	161	130	148	164	145	155	151	134
157	161	130	148	164	145	155	151	134

5

1.000	0.975	1.208	1.061	0.957	1.083	1.013	1.040	1.172

C.

6

157	157	157	157	157	157	157	157	157
157	157	157	157	157	157	157	157	157
157	157	157	157	157	157	157	157	157
157	157	157	157	157	157	157	157	157
157	157	157	157	157	157	157	157	157
157	157	157	157	157	157	157	157	157

Fig. 2

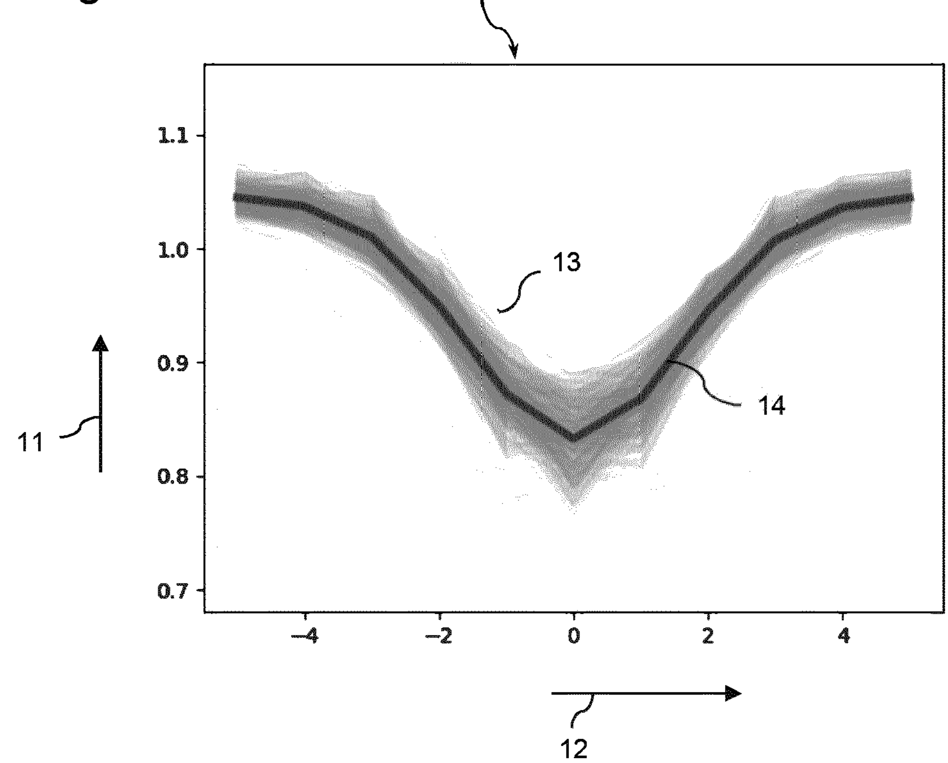

10
1.1
1.0
0.9
0.8
0.7
13
14
11
–4
–2
0
2
4
12

Fig. 3

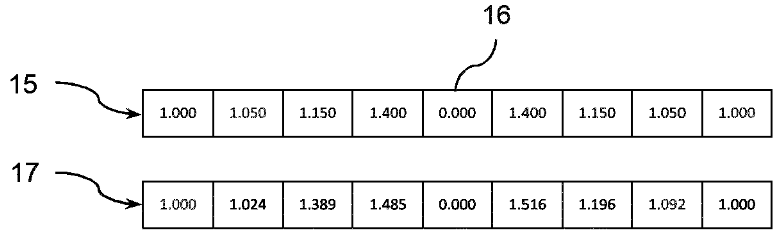

16
15
1.000
1.050
1.150
1.400
0.000
1.400
1.150
1.050
1.000
17
1.000
1.024
1.389
1.485
0.000
1.516
1.196
1.092
1.000

Fig. 4

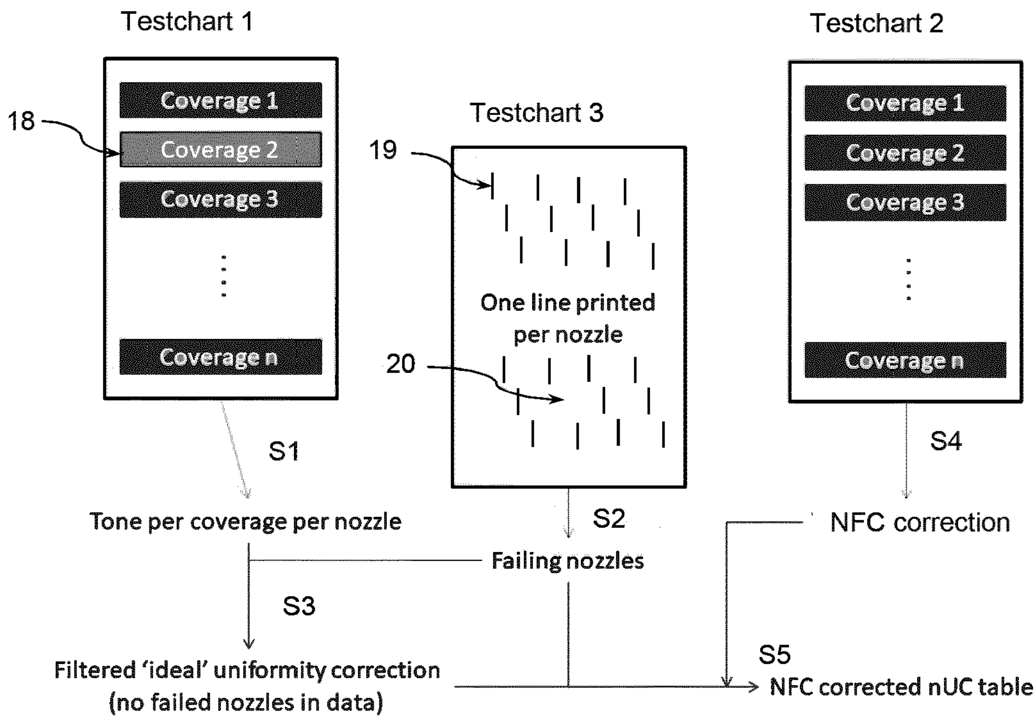
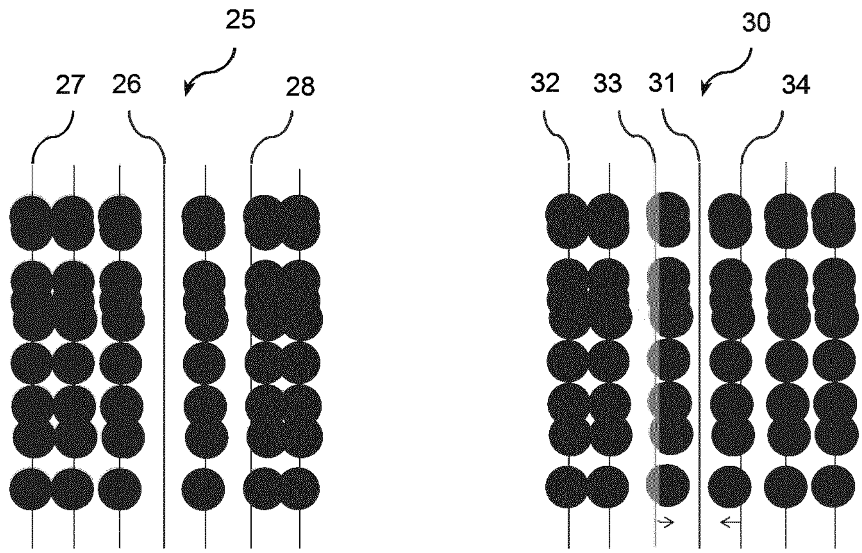

Testchart 1
Coverage 1
18
Coverage 2
Coverage 3
Coverage n
Testchart 3
19
One line printed per nozzle
20
Testchart 2
Coverage 1
Coverage 2
Coverage 3
Coverage n
S1
S4
Tone per coverage per nozzle
S2
NFC correction
Failing nozzles
S3
Filtered 'ideal' uniformity correction (no failed nozzles in data)
S5
NFC corrected nUC table

Fig. 5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EUROPEAN SEARCH REPORT

Application Number
EP 20 19 1708

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

B41J
H04N
G06K

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	4 February 2021	Hartmann, Mathias

CATEGORY OF CITED DOCUMENTS

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