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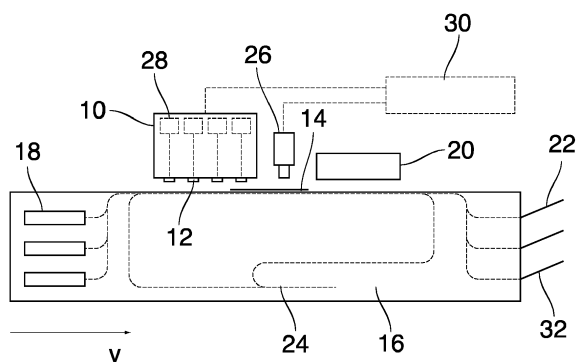
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(54) **METHOD OF DETECTING A FAILURE IN AN INK SUPPLY SYSTEM OF AN INK JET PRINTER**

(57) A method of detecting a failure in an ink supply system (28) of an ink jet printer, the printer comprising:
- a print head (10) having nozzles (12) arranged in an array that extends in a line direction, for printing onto a recording medium (14);
- a transport system (16) arranged to control a relative movement in a column direction (y), normal to the line direction, between the print head (10) and the recording medium (14); and
- said ink supply system (28), the ink supply system (28) having an ink source (34) and a connectivity pattern that describes connections between the ink source (34) and the nozzles (12),
the method comprising a step of capturing an image that

has been printed on the recording medium (14), the image having pixels arranged in pixel columns that extend in the column direction (y),
characterized in that the method comprises the further steps of:
- for each of a plurality of said pixel columns, averaging density values of a plurality of pixels in that column, thereby to obtain an averaged density value for each column, the averaged density values having a distribution in said line direction; and
- analyzing said distribution of the averaged density values and detecting at least one distribution pattern that correlates with the connectivity pattern of the ink supply system (28).

Fig. 1



Description

[0001] The invention relates to a method of detecting a failure in an ink supply system of an ink jet printer, the printer comprising:

- a print head having nozzles arranged in an array that extends in a line direction, for printing onto a recording medium;
- a transport system arranged to control a relative movement in a column direction, normal to the line direction, between the print head and the recording medium; and
- said ink supply system, the ink supply system having an ink source and a connectivity pattern that describes connections between the ink source and the nozzles,

the method comprising a step of capturing an image that has been printed on the recording medium, the image having pixels arranged in pixel columns that extend in the column direction.

[0002] A failure in the ink supply of an ink jet printer, caused for example by an ink supply line becoming clogged or by an ingress of ambient into parts of the ink supply system, may have the effect that some of the droplet ejection units of the print head become depleted with ink, so that no ink droplets can be expelled from their nozzles. The result is a visible artefact in the printed image, typically in the form of white streaks extending in the column direction or, in case of a multi-color printer, in the form of colored streaks.

[0003] In order to avoid a waste of recording media and ink, it is desired to detect such failures of the ink supply system as early as possible.

[0004] Known methods of detecting such failures comprise printing a test image that provides a background on which the artefacts can readily be discerned. An example of such a method has been disclosed in WO 2017/072760 A1.

[0005] However, printing a specific test image means that the regular production print process has to be interrupted, so that the productivity is compromised.

[0006] It is therefore an object of the invention to provide a method that permits to detect failures of the ink supply system even during a production print operation.

[0007] In order to achieve this object, the method according to the invention comprises the further steps of:

- for each of a plurality of said pixel columns, averaging density values of a plurality of pixels in that column, thereby to obtain an averaged density value for each column, the averaged density values having a distribution in said line direction; and
- analyzing said distribution of the averaged density values and detecting at least one distribution pattern that correlates with the connectivity pattern of the ink supply system.

[0008] The invention takes advantage of the fact that most ink jet print heads have a connectivity pattern that avoids a situation in which two neighboring nozzles are supplied with ink from a common supply line. A main reason for this is to avoid crosstalk between the neighboring nozzles due to pressure waves that are created in the ejection units for forming the ink droplets but also propagate in the ink supply system. When, in such a print head, a failure occurs in a particular ink supply line, the resulting streaks in the printed image will have a pattern that corresponds to the connectivity pattern in that the positions of the streaks in the line direction correspond to the nozzles that are commonly connected to the ink supply line in which the failure has occurred.

[0009] However, in a production print process, the distribution of pixel density values over a pixel line depends mainly on the image contents that have been printed, and a failure in the supply system leads only to a minor modification of that distribution. In principle, the failure can nevertheless be detected by comparing the captured image of the print on the recording medium to the target image that has been defined in the print job. However, such comparison is difficult to achieve because it requires that the pixels in the captured image can be identified with sufficient accuracy with the pixels in the image as defined in the print job.

[0010] In the invention, this problem is solved by averaging over a plurality of pixels that belong to the same pixel column. This averaging process smoothens-out the impact of the image contents on the density distribution, so that the specific distribution patterns caused by the artefacts stand out more clearly and can be detected with known pattern recognition methods.

[0011] More specific optional features of the invention are indicated in the dependent claims.

[0012] The detection of the characteristic pattern in the distribution of the averaged density values may involve for example, a filtering algorithm, a spatial Fourier analysis, or the use of a suitably trained neural network.

[0013] For capturing the image from the recording medium, a line camera may be used which is preferably arranged right downstream of the print head. In case of multi-color printing, the camera will of course be a color camera, and the method of the invention will be performed separately for each color channel and may possibly involve a coordinate transformation between the color space of the camera and the color space of the print head.

[0014] In an embodiment, the method of the present invention is also used to analyze the bitmap that is sent to the printer. The result of the analysis of the bitmap may be compared with the result of the analysis performed on the captured image printed on a print substrate based on that bitmap in order to avoid that a detected pattern in the captured printed image was already present in the bitmap and hence not a result of failing nozzles.

[0015] Embodiment examples will now be described in conjunction with the drawings, wherein:

- Fig. 1 is a schematic view of an ink jet printer to which the invention is applicable;
- Fig. 2 is a schematic view of a print head of the printer, showing an example of a connectivity pattern of an ink supply system;
- Fig. 3 shows a failure condition of the ink supply system;
- Fig. 4 shows a bitmap illustrating artefacts that result from a failure in the ink supply system shown in Fig. 3;
- Fig. 5 shows a distribution of averaged density values in the bitmap shown in Fig. 4;
- Fig. 6 is a diagram illustrating essential steps of a filtering algorithm for recognizing a characteristic pattern in the density distribution shown in Fig. 5; and
- Fig. 7 is a flow diagram illustrating essential steps of an example of a method according to the invention.

[0016] As is shown in Fig. 1, an ink jet printer has a print head 10 with nozzles 12 arranged to face a recording medium 14 so as to print an image by ejecting ink droplets onto the recording medium. In the example shown, the nozzles 12 are arranged in four parallel arrays that extend in a line direction x (Fig. 2) normal to the plane of the drawing in Fig. 1. Each array is provided for printing in one of four basic colors.

[0017] A sheet transport system 16 of the printer is arranged to convey media sheets from a selected one of a plurality of supply trays 18 past the print head 10 and a curing station 20, where the printed image is cured, to an output section where the sheets are directed to a selected one of a number of output trays 22. The transport system 16 further comprises a duplex loop 24 arranged to recirculate sheets on which an image has been printed on a first side back to the entry side of the print head 10 in reverse orientation so as to print another image on the back side of the sheet.

[0018] A line camera 26 is provided downstream of the print head 10 for capturing an image of the recording medium 14 on which a printed image has just been formed by the print head. The printed image on the recording medium 14 can be considered as a matrix of pixels that are arranged in lines (extending in the line direction x) and in columns that extend in a column direction y which is normal to the line direction and is also the transport direction of the media sheets. The line camera 26 captures an image of one pixel line at a time and is capable of capturing the entire printed image while the media sheet moves past the camera.

[0019] The print head 10 has four ink supply systems

28 each of which is associated with one of the arrays of nozzles 12 and serves for supplying ink to all the nozzles of the array, as will be described in greater detail below.

[0020] An electronic controller 30 is provided for controlling the operations of the printer, including the operations of the print head 10. The controller 30 is also configured to analyze the image data captured by the line camera 26 in order to detect a possible failure in one or more of the ink supply systems 28, as will be described below.

[0021] Since the line camera 26 is arranged closely behind the print head 10, upstream of the curing station 20 in this embodiment, the controller 30 has time to process the captured image data while the media sheet 14 from which the data are taken is still travelling towards the output section. Thus, if a failure in the ink supply system occurs and the printed image is found to be defective, it is still possible to actuate a switch in the output section and to divert the defective sheet into a specific discharge tray 32 rather than sending it to one of the trays 22 or into the duplex loop 24. The printer may then be shut down, or at least the print process may be interrupted so that the production of waste is reduced to a minimum. Optionally, the controller 30 may initiate a known maintenance process for removing the failure in the ink supply system, so that the print process can be resumed.

[0022] Fig. 2 shows the print head 10 in a front view, so that the column direction y is now the direction normal to the plane of the drawing, and the nozzles 12 visible in Fig. 2 constitute one of the arrays that extend in the line direction x.

[0023] The ink supply system 28 for the nozzle array shown in Fig. 2 comprises an ink source 34 for ink in one of the four print colors, and a network of ink supply lines 36 that connect the ink source 34 to the nozzles 12 (or more precisely to droplet ejection units associated with these nozzles) in accordance with a specific connectivity pattern. In the example shown, the connectivity pattern has been designed such that, for any pair of two neighboring nozzles 12, the ink is supplied via different ink supply lines. More specifically, only four main supply lines 38 are connected to the ink source 34 directly, and each of these main supply lines branches into a number of branch lines 40 that connect to every fourth nozzle. Thus, two nozzles, that are connected to the same branch line 40 are separated from one another by at least four nozzle positions.

[0024] Fig. 2 also illustrates an example of a failure condition of the ink supply system 28. In this example, one of the branch lines 40 is blocked by an obstruction 42. As a consequence, the nozzles 12 that are connected to that branch line downstream of the obstruction 42 become depleted with ink and will fail, so that no ink droplets can be deposited in the pixel columns that correspond to these nozzles. The failing nozzles have been designated by dashed lines in Fig. 2.

[0025] A typical cause for a failure of the ink supply system is the entry of ambient air through one of the

nozzles 12. Initially, only that particular nozzle will be affected, but since a certain underpressure is maintained in the ink supply system in order to prevent the ink from flowing out through the nozzles, more and more air will be drawn in, and a slug of air will grow and propagate upstream into the ink supply system, so that in the course of time more and more nozzles that are connected to the same branch line 40 will also fail.

[0026] Fig. 3 illustrates a situation where an obstruction 44 has reached one of the main supply lines 38, with the result that all nozzles 12 connected to that main supply line will fail.

[0027] Fig. 4 is a bitmap showing a printed image that has been formed with the print head 10 in the failure condition shown in Fig. 3. It can be seen that the image contents (a part of a face) are not rendered completely because the failing nozzles leave white streaks in the corresponding pixel columns.

[0028] It will be understood that, in a practical embodiment, the number of nozzles 12 per array will be significantly larger than in the simplified example shown here, so that the bitmap in Fig. 4 is unrealistically coarse.

[0029] Fig. 5 is a histogram obtained by averaging the density values of the pixel values in each column shown in Fig. 4, so that the height of each vertical bar in Fig. 5 designates an averaged density value D for each column. Thus, the histogram shows the distribution of the averaged density values D in the line direction. As has been indicated by a dashed curve in Fig. 5, the distribution is approximately periodic with a spatial frequency of four pixels and with the minima in the distribution coinciding with the positions of the failing nozzles. This periodicity reflects the periodicity of the connectivity pattern in the print head and can be detected for example by means of a Fourier analysis of the density distribution. For example, it is possible to form the scalar product of the density distribution with the sine wave shown by the dashed curve in Fig. 5, and then the scalar product may be normalized to the overall density of the printed image shown in Fig. 4. Then, it can be decided with high reliability that a failure in the ink supply system 28 has occurred by comparing the normalized scalar product to a suitable threshold value.

[0030] The validity of this detection method may be improved by increasing the length of the pixel columns over which the pixel densities are averaged.

[0031] As an alternative, the distribution of the averaged density values D may be subjected to a filtering procedure as has been illustrated in Fig. 6. The top line (A) in Fig. 6 shows the same histogram of the averaged density values as Fig. 5. This histogram can be divided into two parts that have been shown separately in the lines (B) and (C) in Fig. 6. To that end, the bitmap shown in Fig. 4 is divided into seven bins each of which as a width of four pixel, and each bin is then bisected. Line (B) in Fig. 6 shows only the averaged optical densities for the first and second pixel of each bin, and line (C) shows only the averaged optical densities for the third

and fourth pixel of each bin.

[0032] It will be observed that the number (4) of pixels per bin is determined by the connectivity pattern wherein the nozzles connected to the same branch line are separated from one another by four pixels.

[0033] The diagram in the bottom part of Fig. 6 consists of two vertical bars 46, 48. The first bar 46 has been obtained by stacking all the bars shown in the line (B) one upon the other, i.e. by summing up all the averaged density values of the first and second pixels of each bin. Analogously, the right bar 48 is obtained by summing up all the average optical densities of the third and fourth pixel of each bin. It can be seen that the right bar is significantly higher than the left bar. The reason is that the sub-bin used for forming the left bar included also the second pixel of each bin which, in this example, are the pixels that correspond to the failing nozzles so that the density values are zero.

[0034] Due to the connectivity pattern of the print head, regardless of which of the branch lines 40 is affected by the failure, the failing nozzles will either correspond to the first or second pixel of each bin or to the third or fourth pixel of each bin. In any case, only one of the two partial histograms shown in lines (B) and (C) will be affected, so that either the bar 46 is shorter than the bar 48 or, conversely, the bar 48 is shorter than the bar 46. In any case, a significant difference between the two bars will indicate the presence of a failure condition.

[0035] Again, the absolute value of the difference between the two bars will depend also upon the overall density of the image. This effect can be compensated for by normalizing the bars 46 and 48 in proportion to the difference between the maximum and the minimum of the pixel densities in the histogram in line (A). Then, if the absolute value of the difference between the length of the two normalized bars is above a certain threshold value, it can be inferred that a failure condition exists.

[0036] The validity of this method can be improved by capturing a larger part of the printed image, i.e. by capturing a plurality of bitmaps of the type shown in Fig. 4, but for different parts of the image, and then averaging over the results obtained for the different bitmaps.

[0037] An example of a more generalized version of this method will now be explained by reference to the flow diagram shown in Fig. 7.

[0038] In step S1, the printed image formed on the recording medium 14 is scanned with the line camera 26 (Fig. 1). It is possible to scan the entire image or only selected parts thereof. Preferably, the scan resolution should be equal to the print resolution, e.g. 600 x 600 dpi.

[0039] Then, in step S2, the vertical resolution of the image is reduced by a certain factor, e.g. a factor of 20, by averaging the pixel density values over pixel columns (which have a length of 20 pixel in case of the reduction factor 20). The result would be a reduced bitmap with a resolution of 600 x 30 dpi.

[0040] In step S3, a pixel area with a size of $n \times 1$ pixel is selected from that reduced bitmap. Here, n is the width

of the pixel area in the line direction x, and "1" is the height of the reduced bitmap in the column direction y (i. e. one pixel in the reduced bitmap, equivalent to 20 pixels in the original bitmap).

[0041] The histogram shown in Fig. 5 can be considered as a histogram for such a pixel area as selected in step S3. The number n would be 28 in that example. The number n may be selected as desired and may for example be 32 in a modified example. Preferably, the number n should be a multiple of a number m that characterizes the periodicity of the connectivity pattern (m = 4 in this example).

[0042] In step S4, the pixel area is divided into n/m (28/4 = 7) bins.

[0043] It will be observed that the density value of an individual pixel in the pixel area selected in step S3 is the averaged density value D. In step S5, a quantity "a" is calculated by averaging the averaged density values D over first m/2 pixels of all bins. This step is equivalent to averaging over all the bars shown in Fig. 6, line (B), equivalent to calculating the length of the bar 46.

[0044] Similarly, in step S6, a quantity "b" is calculated by averaging the averaged density values D over the second m/2 pixels of all bins, equivalent to averaging over all the bars in line (C) in Fig. 6 and calculating the height of the bar 48.

[0045] Step S7 is a step of searching the largest averaged density value among all pixel in the selected pixel area and storing this maximum as a quantity "top". Similarly, a quantity "bottom" obtained in step S8 is the minimum of the averaged density values of all pixel in the pixel area.

[0046] The quantities "top" and "bottom" are used for calculating a normalization factor (designated as "factor") in step S9. This factor is proportional to the difference between the quantities top and bottom, i. e. the dynamical range of the averaged density values, divided by a suitable scaling factor k which is selected in view of the available range of pixel density values in the original bitmap (Fig. 4). If the factor should turn out to be larger than 1, it is clipped to 1.

[0047] Step S10 is a step of calculating a quantity "dif" which indicates the height difference between the bars 46 and 48 in Fig. 6 after normalization with "factor".

[0048] Step S11 in Fig. 7 represents a loop in which the steps S3 - S10 are repeated several times, each time with a different pixel area selected in step S3. For example, the selected pixel areas may correspond to successive bitmaps taken at the same x position of the captured image and each having a height of 20 pixel in column direction y. Each repetition of the steps S3 - S10 will provide a new value "dif", and step S11 includes averaging over all these values "dif". The number of repetitions is suitably selected to suppress statistical fluctuations.

[0049] Then it is checked in step S12 whether the average of the values "dif" is larger than a certain threshold which, in this example, is given by $(m - 1)/m$ ($= 0,75$ if m

= 4).

[0050] If the average is larger than the threshold (Y), an error signal is sent in step S13, which means that a failure of the ink supply system has been detected. Otherwise (N), a new scan and detection cycle can start with step S1.

[0051] In this way, it is possible to quasi constantly monitor the print head for possible failures of the ink supply system.

Claims

1. A method of detecting a failure in an ink supply system (28) of an ink jet printer, the printer comprising:

- a print head (10) having nozzles (12) arranged in an array that extends in a line direction (x), for printing onto a recording medium (14);
- a transport system (16) arranged to control a relative movement in a column direction (y), normal to the line direction (x), between the print head (10) and the recording medium (14); and
- said ink supply system (28), the ink supply system (28) having an ink source (34) and a connectivity pattern that describes connections between the ink source (34) and the nozzles (12),

the method comprising a step of capturing an image that has been printed on the recording medium (14), the image having pixels arranged in pixel columns that extend in the column direction (y),

characterized in that the method comprises the further steps of:

- for each of a plurality of said pixel columns, averaging density values of a plurality of pixels **in that** column, thereby to obtain an averaged density value (D) for each column, the averaged density values (D) having a distribution in said line direction (x); and
- analyzing said distribution of the averaged density values (D) and detecting at least one distribution pattern that correlates with the connectivity pattern of the ink supply system (28).

2. The method according to claim 1, wherein the step of detecting at least one distribution pattern comprises a step of calculating a measure (dif) that indicates a likelihood of a failure, by applying a filter algorithm to the distribution of the averaged density values (D).

3. The method according to claim 2, wherein the steps of averaging pixel density values for each of a plurality of the pixel columns and analyzing said distribution are repeated for a number of successive areas of the captured image, the measure (dif) is averaged over said number of repetitions, and the av-

eraged measure is compared to a threshold value.

4. The method according to claim 1, wherein the step of analyzing the distribution of the averaged density values comprises a spatial Fourier analysis of the distribution. 5

5. An ink jet printer comprising:

- a print head (10) having nozzles (12) arranged in an array that extends in a line direction (x), for printing onto a recording medium (14); 10

- a transport system (16) arranged to control a relative movement in a column direction (y), normal to the line direction (x), between the print head (10) and the recording medium (14); and 15

- an ink supply system (28) having an ink source (34) and a connectivity pattern that describes connections between the ink source (34) and the nozzles (12), 20

- a camera (26) arranged for capturing an image that has been printed on the recording medium (14) by the print head (10); and 25

- a controller (30) arranged to control the print head (10) and to process image data provided by the camera (26), 30

characterized in that the controller (30) is configured to perform the method according to any of the claims 1 to 4.

6. The printer according to claim 5, wherein the camera (26) is a line camera. 35

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Fig. 1

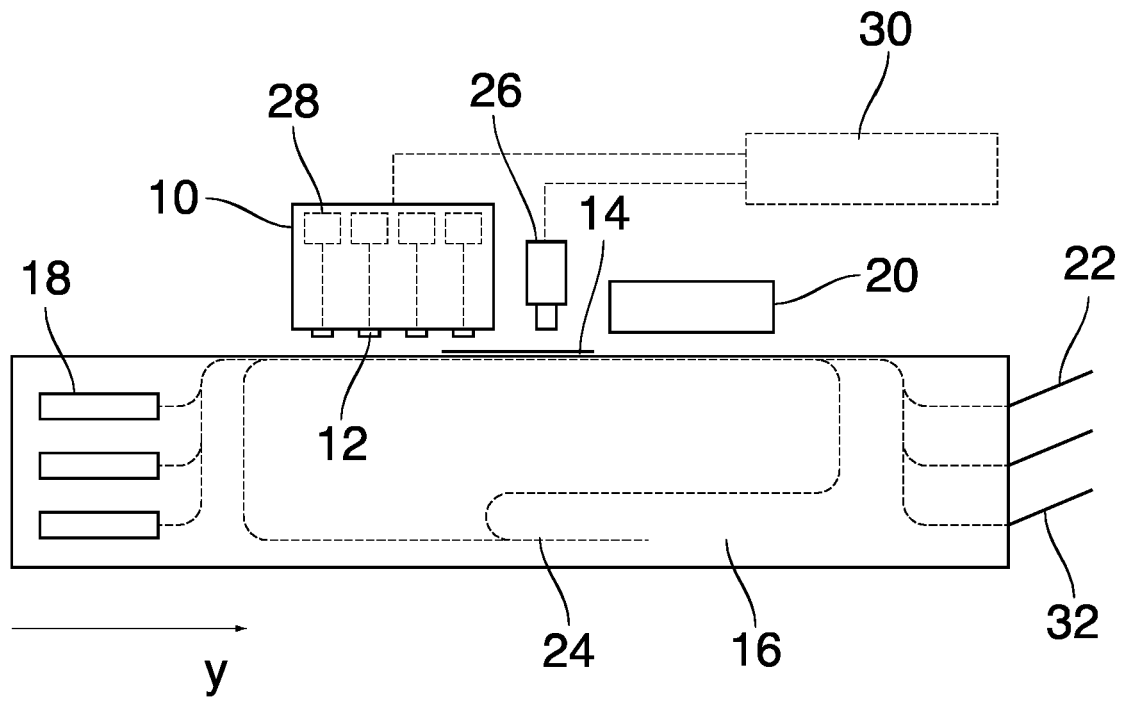


Fig. 2

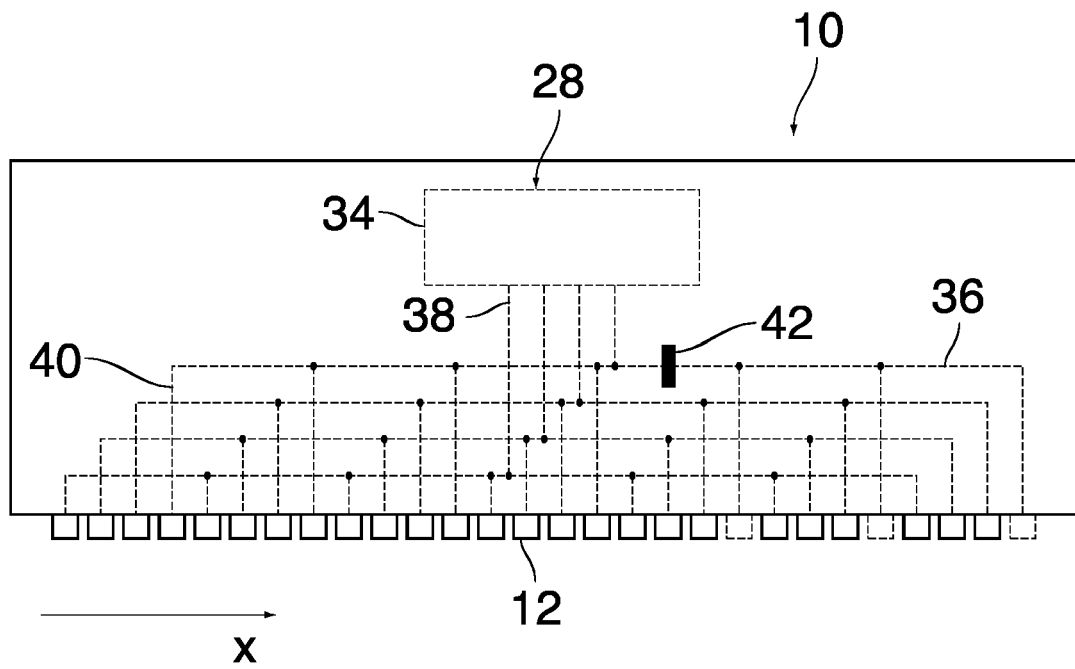


Fig. 3

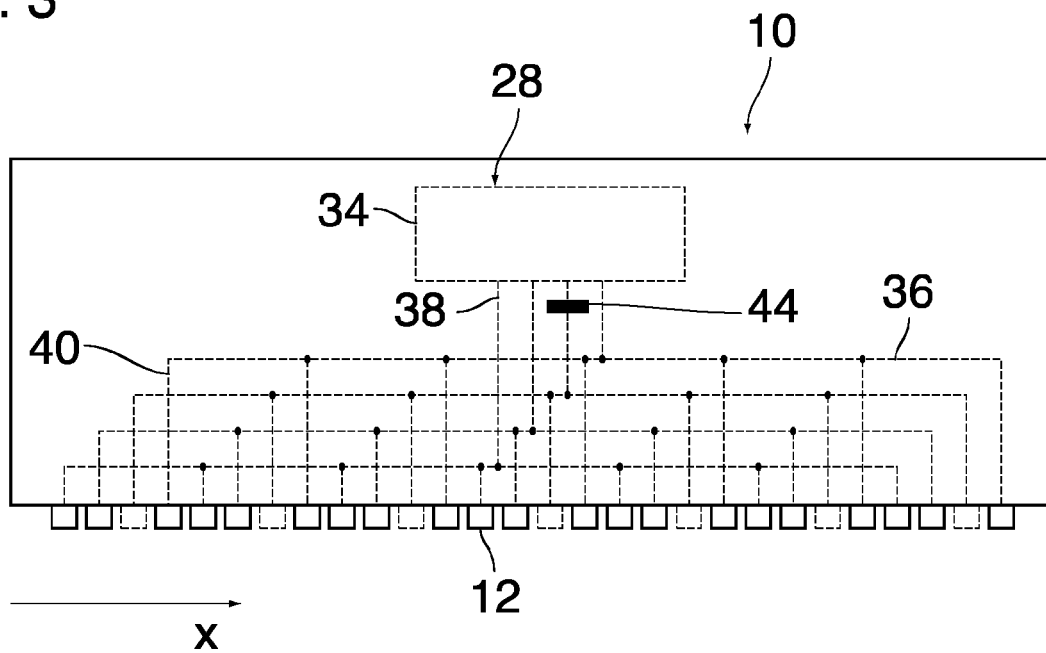


Fig. 4

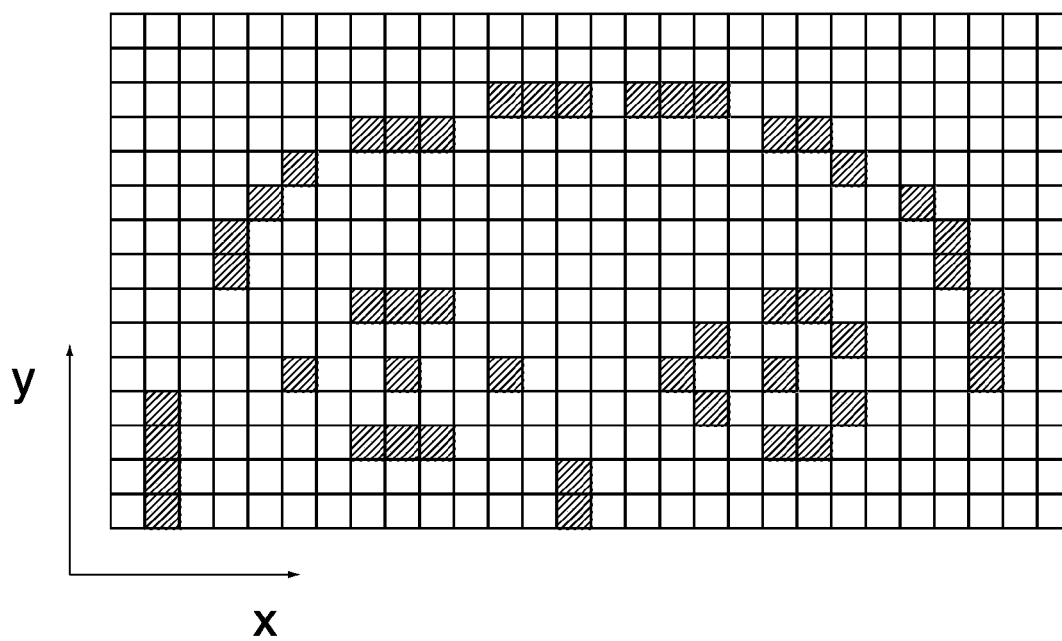


Fig. 5

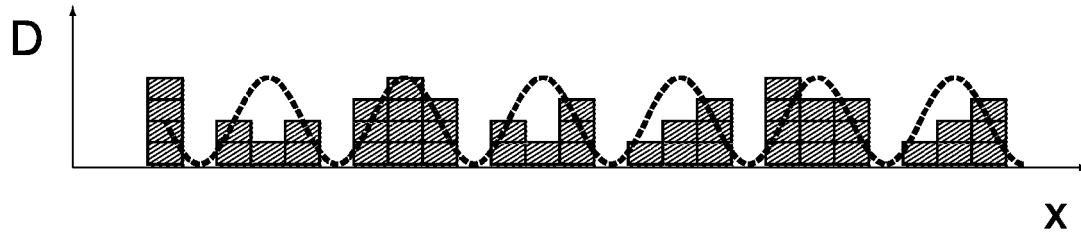


Fig. 6

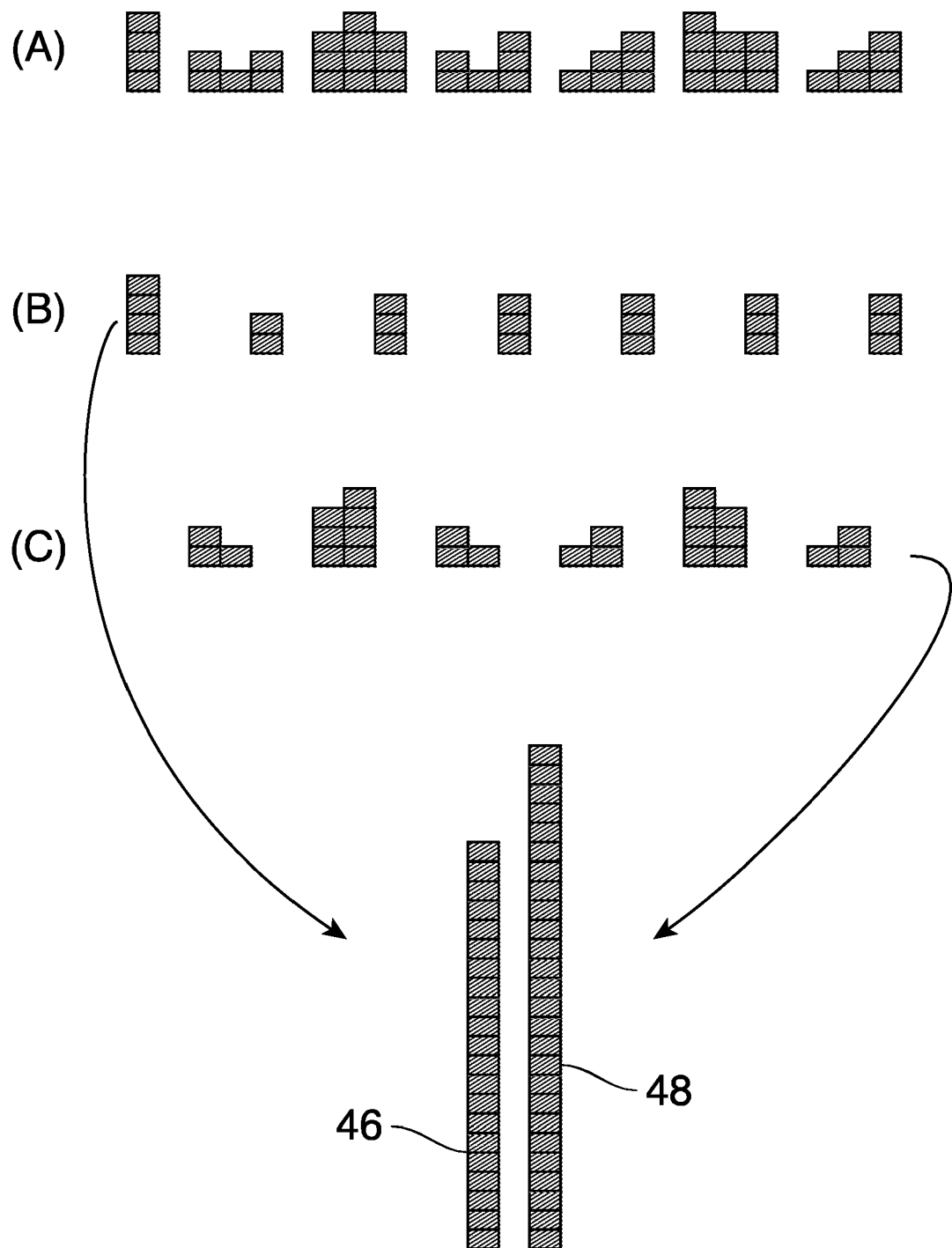
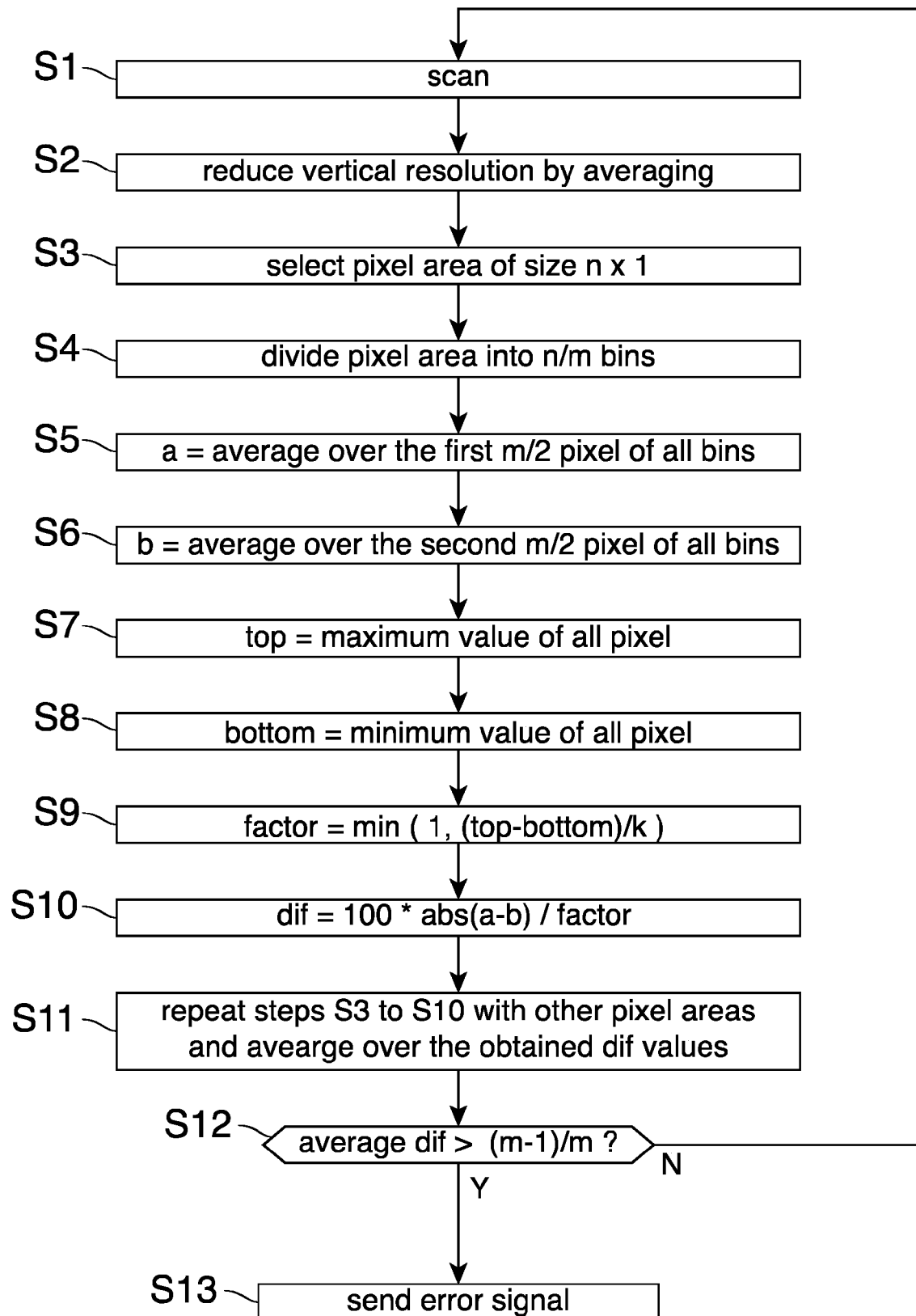


Fig. 7





EUROPEAN SEARCH REPORT

 Application Number
 EP 18 17 1267

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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Patent documents cited in the description

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