

(19)



(11)

EP 3 705 299 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
09.09.2020 Bulletin 2020/37

(51) Int Cl.:
B41J 2/21 ^(2006.01)
D06P 5/30 ^(2006.01)
B41J 3/407 ^(2006.01)

(21) Application number: **20155757.6**

(22) Date of filing: **06.02.2020**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicant: **KONICA MINOLTA, INC.**
Tokyo
100-7015 (JP)

(72) Inventor: **SASAKI, Keita**
Tokyo, 100-7015 (JP)

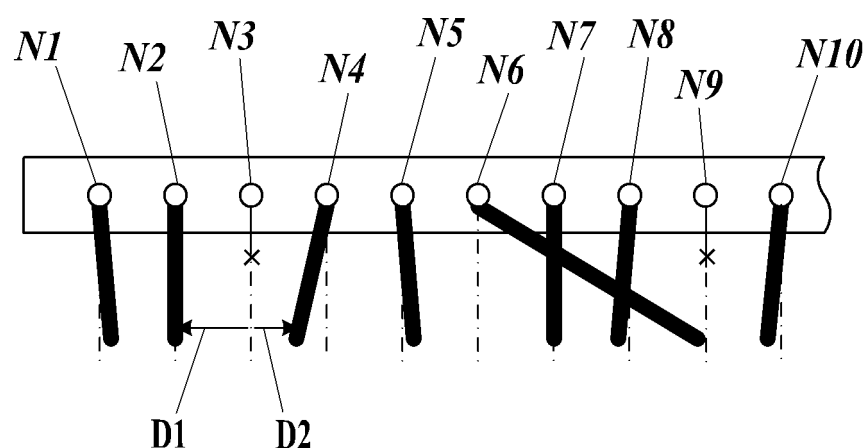
(74) Representative: **Gille Hrabal**
Brucknerstrasse 20
40593 Düsseldorf (DE)

(30) Priority: **05.03.2019 JP 2019039200**

(54) **INKJET RECORDING APPARATUS AND METHOD OF SETTING FOR SUPPLEMENTING DEFECTIVE NOZZLE**

(57) An inkjet recording apparatus (100) includes a recorder (20) and a controller (50). The recorder includes nozzles to eject ink. The controller controls operation of the recorder. The controller determines, for a defective nozzle having a defect in ink ejection, a first nozzle having

an actual ink landing position, where the ink lands, closest to a reference ink landing position of the defective nozzle as a supplementing nozzle that supplements the defect of the defective nozzle.

FIG. 4A**EP 3 705 299 A1**

Description

BACKGROUND

Technological Field

[0001] The present disclosure relates to an inkjet recording apparatus and a method of setting for supplementing a defective nozzle.

Description of the Related Art

[0002] There is an ink jet recording apparatus that records/forms an image, a thin film, a three-dimensional structure, and/or the like by ejecting ink from nozzles. A recent inkjet recording apparatus has a large number of nozzles some of which may have ejection defects. Examples of the ejection defects include a lack of ink ejection, an abnormal ink ejection volume, and an abnormal ejection direction. There is known a conventional technique of, when a defective nozzle is present, supplementing ink ejection of the defective nozzle with its nearby nozzle(s).

[0003] Ink droplets having landed on a recording medium may move, before fixing to the recording medium, in a way peculiar to the liquid, such as liquid gathering or permeation. JP 2014-43076A discloses a technique of changing a reference as to whether or not to supplement a nozzle having an abnormal ejection direction in consideration of liquid gathering that varies depending on the ejection timing.

SUMMARY

[0004] However, there are various factors that cause the abnormal ink ejection direction, and many nozzles may have a deviation in the ejection direction inconsiderable in normal image recording. Hence, when a nozzle used for supplementing a defective nozzle has a slight deviation in the ink ejection direction, a simple supplementing process disclosed in JP 2014-43076A or the like may not maintain quality of recording appropriately.

[0005] Objects of the present disclosure include providing an inkjet recording apparatus and a method of setting for supplementing a defective nozzle that maintain quality of recording more securely.

[0006] In order to achieve at least one of the above-mentioned objects, according to an aspect of the present invention, the following is provided.

1. An inkjet recording apparatus including a recorder that includes nozzles to eject ink; and a controller that controls operation of the recorder, wherein the controller determines, for a defective nozzle having a defect in ink ejection, a first nozzle having an actual ink landing position, where the ink lands, closest to a reference ink landing position of the defective nozzle as a supplementing nozzle that supplements the

defect of the defective nozzle.

2. Preferably, the inkjet recording apparatus according to item 1, further includes a storage that stores ejection information on actual ink landing positions of the nozzles, wherein the controller determines a distance between each of the actual ink landing positions and the reference ink landing position based on the ejection information.

3. Preferably, in the inkjet recording apparatus according to item 1 or 2, the recorder can eject the ink with multiple ink droplet volumes from each of the nozzles, and the controller adds a defective-nozzle set value corresponding to an ink droplet volume to be ejected from the defective nozzle to a first set value corresponding to an ink droplet volume to be ejected from the first nozzle, and causes the recorder to eject ink from the first nozzle with an ink droplet volume corresponding to the first set value after the addition.

4. Preferably, in the inkjet recording apparatus according to item 3, in response to the first set value after the addition exceeding a predetermined maximum set value, the controller transfers a first difference between the first set value after the addition and the maximum set value to a set value corresponding to an ink droplet volume to be ejected from a nozzle different from the first nozzle.

5. Preferably, in the inkjet recording apparatus according to item 4, the controller adds the first difference to a second set value corresponding to an ink droplet volume to be ejected from, as the nozzle different from the first nozzle, a second nozzle having an actual ink landing position second closest to the reference ink landing position of the defective nozzle, and adjusts the first set value to the maximum set value.

6. Preferably, in the inkjet recording apparatus according to item 5, in response to (i) the second set value after the addition exceeding the maximum set value and (ii) the defect of the defective nozzle being an abnormal ink landing position, the controller causes the recorder to eject the ink from the defective nozzle with an ink droplet volume corresponding to a second difference between the second set value after the addition and the maximum set value, and adjusts the second set value to the maximum set value.

7. Preferably, in the inkjet recording apparatus according to any one of items 1 to 6, the controller determines the first nozzle from the nozzles including a landing-position defective nozzle having an abnormal ink landing position.

8. Preferably, in the inkjet recording apparatus according to any one of items 4 to 6, the controller determines the nozzle different from the first nozzle from the nozzles including a landing-position defective nozzle having an abnormal ink landing position.

9. Preferably, in the inkjet recording apparatus ac-

cording to item 7 or 8, in response to a set value corresponding to an ink droplet volume to be ejected from the determined nozzle being equal to or greater than a first reference value or not, the controller determines whether or not to cause the determined nozzle to supplement the defect of the defective nozzle.

10. Preferably, in the inkjet recording apparatus according to any one of items 1 to 9, in response to (i) a first set value corresponding to an ink droplet volume to be ejected from the first nozzle being smaller than a predetermined second reference value and (ii) a distance between a reference ink landing position and the actual ink landing position of the first nozzle being equal to or greater than a predetermined reference distance, the controller does not use the first nozzle as a first choice of the supplementing nozzle.

11. Preferably, in the inkjet recording apparatus according to any one of items 1 to 10, the recorder ejects the ink to a fabric.

12. Preferably, the inkjet recording apparatus according to any one of items 1 to 11, further includes a storage that stores ejection information on actual ink landing positions of the nozzles, wherein the controller causes the recorder to record a predetermined test pattern on a recording medium by causing the recorder to eject ink droplets of the ink from the respective nozzles so as to land on the recording medium in predetermined arrangement, and generates the ejection information based on the actual ink landing positions in the test pattern.

13. Preferably, the inkjet recording apparatus according to item 12, the recorder can eject the ink with multiple ink droplet volumes from each of the nozzles, and the controller causes the recorder to record the test pattern by causing the recorder to eject the ink from the respective nozzles with a second smallest ink droplet volume or greater among the multiple ink droplet volumes.

14. Preferably, the inkjet recording apparatus according to item 12 or 13, further includes a reader that reads a surface of the recording medium, wherein the controller causes the reader to read the test pattern and determines the actual ink landing positions of the nozzles.

15. Preferably, the inkjet recording apparatus according to any one of items 12 to 14, further includes a conveyer that conveys the recording medium, wherein the controller causes the recorder to eject the ink to the recording medium while causing the conveyer to move the recording medium in a predetermined conveyance direction, and in the test pattern, lines extending in the conveyance direction are formed with the ink droplets ejected from the respective nozzles and are arranged so as to be distinguishable from one another.

16. Preferably, in the inkjet recording apparatus ac-

cording to any one of items 1 to 15, the controller calculates the actual ink landing position based on a distance between a recording medium and openings of the nozzles.

17. Preferably, in the inkjet recording apparatus according to item 16, the controller calculates the actual ink landing position based on a distance between a recording medium and openings of the nozzles.

18. Preferably, in the inkjet recording apparatus according to any one of items 1 to 17, the recorder includes a recording head including the nozzles arranged two-dimensionally, and the actual ink landing position includes a systematical deviation corresponding to an error in mounting the recording head.

19. A method of setting for supplementing a defective nozzle of a recorder that includes nozzles to eject ink, including determining, for a defective nozzle having a defect in ink ejection, a first nozzle having an actual ink landing position closest to a reference ink landing position of the defective nozzle as a supplementing nozzle that supplements the defect of the defective nozzle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The advantages and features provided by one or more embodiments of the invention will become more fully understood from the detailed description given hereinafter and the appended drawings which are given by way of illustration only, and thus are not intended as a definition of the limits of the present invention, wherein:

FIG. 1 is a perspective view of an inkjet recording apparatus;

FIG. 2 is a bottom view of a head unit viewed from a surface thereof that faces a conveyance surface;

FIG. 3 is a block diagram showing components of the inkjet recording apparatus by function;

FIG. 4A is a diagram to explain how to select supplementing nozzles;

FIG. 4B is a diagram to explain how to select supplementing nozzles;

FIG. 5A shows a pattern of setting supplementing nozzles;

FIG. 5B shows a pattern of setting supplementing nozzles;

FIG. 5C shows a pattern of setting supplementing nozzles;

FIG. 5D shows a pattern of setting supplementing nozzles;

FIG. 6A shows an example of a test image to obtain information on ink landing positions and defects in ink ejection;

FIG. 6B shows another example of the test image to obtain information on ink landing positions and defects in ink ejection;

FIG. 7 is a flowchart showing control steps of an ink ejection state determination process;

FIG. 8 is a flowchart showing control steps of an image data adjustment process;

FIG. 9 is a flowchart showing control steps of the image data adjustment process;

FIG. 10 is a flowchart showing control steps of a supplementing nozzle determination process that is called in the image data adjustment process;

FIG. 11A is a diagram to explain an incline of a recording head according to a modification; and

FIG. 11B is a diagram to explain the incline of the recording head according to the modification.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0008] Hereinafter, one or more embodiments of the present invention is described with reference to the drawings. However, the scope of the invention is not limited to the disclosed embodiments.

[0009] FIG. 1 is a perspective view of an inkjet recording apparatus 100 in an embodiment of the present disclosure.

[0010] The inkjet recording apparatus 100 has a plurality of, here eight, line heads, and is capable of recording a color image by ejecting ink with a single pass method. The inkjet recording apparatus 100 includes a conveyor 10, recorders 20, an ink supplier 30, and an imager 42 (reader).

[0011] The conveyor 10 includes a driving roller 11, a conveyance driver 12, and a conveyance belt 14. The conveyance driver 12 has a rotation motor that causes the driving roller 11 to rotate at a predetermined speed. The endless conveyance belt 14 is stretched around the driving roller 11 and a driven roller (not illustrated) to be a loop. Rotation of the driving roller 11 makes the conveyance belt 14 move circularly. The outer circumferential surface of the conveyance belt 14 serves as a conveyance surface. The conveyor 10 places a recording medium in a predetermined area on the conveyance surface and conveys the recording medium in the circular movement direction (movement direction of the recording medium being conveyed, namely the conveyance direction) according to the circular movement of the conveyance belt 14. In this embodiment, the type of recording medium is a continuous fabric or the like. The conveyor 10 keeps sending out, for example, a rolled fabric, places it on the conveyance surface, and conveys it.

[0012] Each of the recorders 20 includes a head unit 21 (see FIG. 2), a carriage 22, and a pair of carriage lifters 23. The number of recorders 20 corresponds to the number of colors of ink. Herein, eight recorders 20 are provided. The carriage 22 extends in a direction intersecting (in this embodiment, orthogonal to) the conveyance direction of the conveyor 10 on a plane parallel to the conveyance surface. The carriage 22 is provided above (in the height direction of) the conveyance surface of the conveyor 10 conveying the recording medium. The head unit 21 is fixed to the carriage 22 such that ink droplets can be ejected from openings of nozzles N (see FIG.

2) over the entire width of the recording medium being conveyed (recordable width in the width direction; some margin may be present at one end or both ends). Each of the eight head units 21 includes recording elements 26 (see FIG. 3) that include the nozzles N, ink flow paths (ink chambers), and elements for ejecting ink from the nozzles N (electromechanical conversion elements 252 to be described later, see FIG. 3). The number of recording elements 26 (at least two) is appropriately determined according to the recording resolution, the size of recording medium on which the inkjet recording apparatus 100 can record images, and the like. The carriages 22, namely the recorders 20, are provided at positions different from each other in the conveyance direction. Each of the carriages 22 is provided such that its position in the height direction can be changed by the pair of carriage lifters 23. As the carriage 22 moves, the distance between the head unit 21 and the conveyance surface changes. By recording operation performed by the recording elements 26, the recording elements 26 eject ink and thereby record (form) an image on the recording medium.

[0013] The pair of carriage lifters 23 changes the distance between the carriage 22 and the conveyance surface. The pair of carriage lifters 23 includes lifting motors 232, electromagnetic brakes 233, beam members 234, and supporters 235.

[0014] Two beam members 234 are provided above the conveyance belt 14 (conveyance surface for the recording medium) to be substantially parallel to each other in the direction intersecting the conveyance direction (herein, in the direction orthogonal to the conveyance direction, namely in the width direction). The supporters 235 are fixed to the respective ends of each beam member 234. The lifting motors 232, the electromagnetic brakes 233, and the carriage 22 are fixed to the supporters 235.

[0015] The position of the carriage 22 is changed upwards/downwards and fixed by operation of the lifting motors 232 and the electromagnetic brakes 233 driven in accordance with control signals from a controller 50 (see FIG. 3).

[0016] The lifting motors 232 move the carriage 22 at a predetermined ascending/descending speed. As the lifting motors 232, servomotors or stepping motors are used, for example.

[0017] The electromagnetic brakes 233 maintain the fixed state of the carriage 22. When the electromagnetic brakes 233 release the fixed state in accordance with drive signals, the carriage 22 is temporarily movable by the lifting motors 232. In a normal state including a state at the time when the power supply is off, the electromagnetic brakes 233 fix the carriage 22. As the electromagnetic brakes 233, disc brakes are used, for example.

[0018] The ink supplier 30 stores ink of various colors to be used in image recording, and supplies the ink to the head units 21. In this embodiment, ink tanks 31 for the ink of the respective colors are placed in a dedicated rack 32 and connected to the corresponding head units

21 that eject the ink of the respective colors through pipes or tubes. The colors of the ink are not specifically limited. In this embodiment, ink of eight different colors including C (cyan), M (magenta), Y (yellow), K (black), and, for example, P (pink), S (sky), G (gray), and O (orange) is supplied. Ink of all these colors may not be supplied. The head units 21 eject the ink of the respective colors as fine dots from the nozzles, so that the fine dots land on the recording medium, thereby recording a mixed color image. The mixed color image is expressed with an ink density corresponding to the number and size of ink droplets of each color, and combination of densities of the respective colors. The ink colors that are stored in the ink storing tanks 31 and supplied to the head units 21 may be changed with other colors.

[0019] The imager 42 is provided downstream from the recorders 20 in the conveyance direction. The imager 42 images and reads a surface(s) of the recording medium on which an image has been recorded by the recorders 20 (or the recording medium that has passed through the recorders 20 with no image recorded thereon). The imager 42 may include an illuminator (not illustrated). The illuminator approximately uniformly illuminates the surface of the recording medium to be imaged by the imager 42.

[0020] The imager 42 includes, for example, a one-dimensional imaging sensor. In this embodiment, the one-dimensional imaging sensor has a plurality of imaging elements arranged at least in the width direction over the width of the conveyance belt 14. The conveyer 10 operates to move the recording medium in the conveyance direction, thereby allowing the imager 42 to image the surface of the recording medium two-dimensionally. As the imaging sensor, a CCD (Charge Coupled Device) sensor, a CMOS (Complementary Metal Oxide Semiconductor) sensor, or the like is used. Each imaging element in the imaging sensor performs imaging operation of outputting an amount of electric charges and a voltage that correspond to the amount of light input to a light receiving element from the surface of the recording medium via an optical system (lens). In this embodiment, the imaging sensor can perform imaging at each of R, G, and B wavelength bands (multiple wavelength bands). Thus, the imager 42 can obtain and read a color image. The distance between the imager 42 and the conveyance surface may be changeable, as with the distance between the carriage 22 and the conveyance surface.

[0021] FIG. 2 is a bottom view of the head unit 21 viewed from the surface thereof that faces the conveyance surface.

[0022] Because the head units 21 for the respective colors of ink have the same shape and configuration, the description made herein refers to any one of the head units 21.

[0023] In this embodiment, the head unit 21 includes eight recording heads 211 fixed thereto. On the bottom surface of each recording head 211, openings of the nozzles N are arranged at a predetermined nozzle pitch in

the width direction. The positions of the openings of the nozzles N in the conveyance direction may be different from each other as long as the openings are arranged at predetermined intervals in the width direction. In this embodiment, the openings of the nozzles N of the recording head 211 are arranged to be staggered. The number and size of the openings of the nozzles N shown in FIG. 2 are for explanation. The actual number of the nozzles N is larger, and the actual size of the openings is sufficiently smaller than the width of the arrangement area of the nozzles N in the width direction.

[0024] The eight recording heads 211 included in one head unit 21 are arranged at different positions to be staggered, thereby having different arrangement areas of the openings of the nozzles N in the width direction. Thus, the recording heads 211 perform image recording on different recording areas. The arrangement areas in the width direction of the nozzles N of the adjacent recording heads 211 slightly overlap on one another at the edges. By combining the recording areas in the width direction of the eight recording heads 211, the head unit 21 can eject ink over the entire width in the width direction of the recording medium from the nozzles of the respective recording heads 211 with the above-mentioned nozzle pitch. The recording medium may have some margin at both ends thereof in the width direction.

[0025] FIG. 3 is a block diagram showing components of the inkjet recording apparatus 100 by function.

[0026] The inkjet recording apparatus 100 includes the conveyer 10, the recorders 20, a detector 40, the controller 50, a storage 60, a communication unit 70, a display 81, an operation receiver 82, and a bus 90. The conveyer 10 has the conveyance driver 12 described above. The detector 40 includes the imager 42 described above.

[0027] The recorders 20 include a carriage driver 24 and a head driver 25 as well as the above-described components. The carriage driver 24 outputs drive signals to the above-described lifting motors 232, the electromagnetic brakes 233, and so forth to operate or fix them. As described above, the recording elements 26 include the electromechanical conversion elements 252 and the nozzles N.

[0028] The head driver 25 includes a recording controller 251. Under the control of the controller 50, the recording controller 251 outputs a drive signal(s) to change a pressure applied to ink in the ink flow paths communicating with the nozzles N of the recording heads 211. As components to change the pressure, for example, the electromechanical conversion elements 252 (in this embodiment, piezoelectric elements) are used. When the electromechanical conversion elements 252 deform with the voltage applied thereto (i.e., output voltage in accordance with the drive signal), the ink flow paths, especially pressure chambers formed to have the size and shape for appropriately changing the pressure, deform. For the drive signals, predetermined voltage waveform patterns are prepared. Whether or not to output the drive signals

having the voltage waveform patterns to the electromechanical conversion elements 252 of the respective nozzles is determined in accordance with control signals from the controller 50 and data for driving the head driver 25 (halftone image data). By the deformation of the electromechanical conversion elements 252 (recording operation of the recording elements 26) in accordance with the drive signals, ink is pushed out from the nozzles N, separated from ink in the ink flow paths by an appropriate volume, and ejected as ink droplets. Herein, ink ejection volume (ink droplet volume) can be set to multiple levels, for example, three levels. The voltage waveform patterns correspond to the set ink ejection volumes.

[0029] The detector 40 includes an encoder 43 as well as the above-described imager 42. The encoder 43 detects rotation of the rotation motor or the driving roller 11 of the conveyance driver 12, and outputs a signal at every predetermined angle of rotation in the rotation direction.

[0030] The controller 50 integrally controls the entire operation of the inkjet recording apparatus 100. The controller 50 includes a CPU (Central Processing Unit) 51 and a RAM (Random Access Memory) 52. The controller 50 performs various processes for image recording based on image data, status signals or clock signals of components, and the like. The controller 50 also performs processes for: adjusting operation related to ink ejection from the nozzles N; detecting defects in ink ejection operation and dealing with the defects; detecting deterioration in image quality and adjusting the image quality; and so forth.

[0031] The CPU 51 performs various arithmetic processes, and controls conveyance of recording media, supply and ejection of ink, reading operation of recorded images, and so forth in the inkjet recording apparatus 100. The CPU 51 performs calculation and control for the various processes described above in accordance with programs read out from the storage 60.

[0032] The RAM 52 provides a working memory space for the CPU 51 and stores temporary data. Some of the temporary data may be appropriately stored in a DRAM area in the storage 60.

[0033] The storage 60 stores programs 61, various types of setting data, job data 64 related to image recording instructions, and so forth. The job data 64 includes image data as a recording target, processed data of the image data, and information on operation settings. The programs 61 include a program for determining defective nozzles that have a defect(s) in ejecting ink, programs for various types of image processing, and a program for supplementing the defective nozzles, and the like. The setting data includes a defective nozzle list 62 that shows positions of the defective nozzles and ejection position information 63 (ejection information) on the ink ejection directions of the nozzles N.

[0034] The storage 60 in this embodiment includes a volatile memory, such as a DRAM, and a nonvolatile memory. The temporary data, such as job data and processing data, is stored in the volatile memory, proc-

essed at a high speed, and may be deleted after the image recording finishes. The programs, setting data, and the like are stored in the nonvolatile memory and retained even while the electric power being not supplied to the inkjet recording apparatus 100. Some of the programs and setting data, for example, initial data and a basic program, may be stored in the ROM or the like that is not erasable or rewritable instead of in the nonvolatile memory.

[0035] The communication unit 70 is a communication interface that controls communications with external apparatuses. The communication interface includes, for example, one or more network cards, such as a LAN card, for various communication protocols. The communication unit 70 can obtain image data as the recording target and job data including settings for image recording from the external apparatuses, and send status information and so forth to the external apparatuses under the control of the controller 50.

[0036] The display 81 displays the status of the inkjet recording apparatus 100, an operation menu, and so forth on the display screen in response to control signals from the controller 50. As the display screen, a liquid crystal screen is used, for example. The display 81 may include an LED lamp or the like that notifies presence/absence of power supply, errors, and/or the like.

[0037] The operation receiver 82 receives operations made by a user and outputs them to the controller 50. The operation receiver 82 includes, for example, a touch sensor. The touch sensor may be superposed on the display screen of the display 81 and used as a touchscreen. The controller 50 outputs, to the controller 50, information on the position and type of a touch detected by the touch sensor. The operation receiver 82 may have a push-button switch and/or a numeric keypad.

[0038] The bus 90 is a channel that electrically connects the controller 50 and the components exchanging signals with the controller 50, and transmits the signals.

[0039] Next, control of ink ejecting operation in this embodiment is described.

[0040] The inkjet recording apparatus 100 records a two-dimensional image by ejecting ink from the nozzles N while conveying a recording medium. The inkjet recording apparatus 100 determines, on the basis of the halftone image data, presence/absence of ink ejection and the volume of ink to be ejected at each pixel position. The pixel positions are determined by combinations of ejection timings during the conveyance and positions of the nozzles N.

[0041] As described above, some of the nozzles N may have defects in ejecting ink (ejection defects). The ejection defects include: lack of ink ejection (i.e. no ink is ejected); an abnormal ejection volume (mostly, reduction in the volume); an abnormal ejection speed; and an abnormal ejection direction. The ejection defects are caused by abnormality in driving circuits including the electromechanical conversion elements, clogging of nozzles, adhesion of foreign substances to around openings

of nozzles, and so forth. The clogging of nozzles and adhesion of foreign substances often occur over time during use of an inkjet recording apparatus.

[0042] The ejection direction gradually changes according to the degree of clogging of nozzles N and the amount and position of foreign substances adhering to around the openings of the nozzles N with respect to an abnormal ejection direction as an ejection defect. Whether or not a nozzle N has an abnormal ejection direction is determined, for example, by comparing (i) a distance between an actual landing position of ejected ink and a reference ink landing position (hereinafter called ink-landing-position distance) of the nozzle N and (ii) a predetermined reference distance (e.g. two or three times a nozzle interval). The ink-landing-position distance depends on the ejection direction of the nozzle N and a distance between the opening of the nozzle N and the recording medium. Because the inkjet recording apparatus 100 can change the position of the carriage 22, the inkjet recording apparatus 100 can change the distance between the openings of the nozzles N and the recording medium according to characteristics of the surface of the recording medium, for example, the magnitude of fluffiness thereof. Whether or not the ejection direction of the nozzle N is abnormal may be determined on the basis of the type of recording medium and the distance between the openings of the nozzles N and the recording medium calculated for each type of recording medium. Alternatively, whether or not the ejection direction is abnormal may be determined on the basis of the angle of the ink ejection direction. Information on defective nozzles is stored in the defective nozzle list 62. Information on the type of recording medium may be obtained from an input operation received by the operation receiver 82 or the job data 64 obtained through the communication unit 70. The operation receiver 82 and the communication unit 70 constitute an input receiver of the inkjet recording apparatus 100 in this embodiment.

[0043] When the ink-landing-position distance is equal to or shorter than the reference distance (or a difference between the actual ink ejection angle of the nozzle N and a reference angle is equal to or smaller than a reference difference), the ejection is regarded as normal even if the ink landing position slightly deviates (differs) from its reference ink landing position. Information on ink landing positions (or ink ejection angles) of the nozzles N is stored in the ejection position information 63.

[0044] When a defective nozzle is present, a normal nearby nozzle(s) takes over the ink ejection setting of the defective nozzle, thereby supplementing the defective nozzle. As the nearby nozzle, a nozzle adjacent to the defective nozzle in the width direction (nozzle on either side of the defective nozzle in the width direction) is normally selected. Because the width of coverage by an ink droplet having been ejected from a nozzle and landed on a recording medium is wider than a nozzle interval by, for example, two to three times, ejecting ink from its adjacent nozzle is unlikely to cause severe deterioration in

image quality. However, in an image having a uniform density or the like, a line having a low ink density (white streak) tends to occur at the original ink landing position of a defective nozzle. Such a non-uniformity in density is conspicuous.

[0045] In performing settings for supplementary ejection for a defective nozzle, the inkjet recording apparatus 100 in this embodiment preferentially selects, from its two adjacent nozzles in the width direction, a nozzle (first nozzle) ink of which lands at a position closer to the original ink landing position (reference ink landing position) of the defective nozzle as a supplementing nozzle that supplements (complements) the defective nozzle. That is, a nozzle having an actual ink landing position closest to the reference ink landing position of the defective nozzle is preferentially selected. The ink having been supplementarily ejected from the supplementing nozzle and landed on the recording medium tends to spread towards the original ink landing position of the defective nozzle. This restrains occurrence of white streaks. Also, the ink ejected from the supplementing nozzle is less likely to overlap with ink ejected from a normal nozzle adjacent to the supplementing nozzle on the opposite side of the defective nozzle. This restrains occurrence of black streaks due to locally increase in ink density as a result of ink overlapping.

[0046] FIGS. 4A and 4B are diagrams to explain how to select a supplementing nozzle(s). In practice, amounts of deviation (deviation amounts) between actual ink landing positions and their reference ink landing positions are each sufficiently smaller (shorter) than the flying distance (dropping distance) of ink. However, for explanation's sake, the flying distance of ink is shortened in FIG. 4A in relation to the deviation amounts.

[0047] As shown in FIG. 4A, among nozzles N1 to N10 arranged in the width direction, nozzles N3 and N9 do not eject ink. As shown in FIGS. 4A and 4B, a nozzle N6 has an actual ink ejection direction that inclines from a direction perpendicular to the nozzle opening surface (vertically downward in this embodiment) by some angle, namely has an actual ink landing position that deviates from its original (reference) ink landing position by +2.8 nozzle intervals, when the ink flies a predetermined flying distance (distance perpendicular to the nozzle opening surface). Hence, the nozzle N6 is set as a defective nozzle having an abnormal ink ejection direction (ejection-direction defective nozzle).

[0048] Nozzles N2 and N4 adjacent to the defective nozzle N3, which does not eject ink, have actual ink landing positions of ± 0.0 and -0.4 from their respective reference ink landing positions. That is, ink ejected from the nozzle N2 lands at its correct ink landing position, whereas ink ejected from the nozzle N4 lands at an ink landing position a little far towards the original ink landing position of the nozzle N3. Hence, the nozzle N4 is preferentially set as a supplementing nozzle for the nozzle N3. Similarly, the nozzle N5 is preferentially set as a supplementing nozzle for the nozzle N6, and the nozzle N10 is pref-

erentially set as a supplementing nozzle for the nozzle N9. Even when nozzles adjacent to a defective nozzle have the deviation amounts in ink landing position of a reference distance or less, preference between the adjacent nozzles as supplementing nozzles may be reversed depending on a relationship between the actual ink landing positions of the adjacent nozzles and the reference ink landing position of the defective nozzle.

[0049] FIGS. 5A to 5D show patterns of setting supplementing nozzles. In each pattern, numerical values in the upper row are set values (four levels) corresponding to ink ejection volumes (three levels of volumes as described above, and a level of no ink ejection) originally set in the halftone image data, and numerical values in the lower row are set values in the halftone image data after settings for supplementing defective nozzles are done.

[0050] As shown in FIG. 5A, when the nozzles N4, N5, and N10, which are preferentially set as supplementing nozzles for the defective nozzles N3, N6, and N9, respectively, are originally set not to eject ink (set values thereof are "0"), the nozzles N4, N5, and N10 simply take over the ink ejection settings of the nozzles N3, N6, and N9, respectively. This mainly applies to images that have a low gradation, require a small ink ejection volume, and have high brightness.

[0051] As shown in FIG. 5B, when the nozzles N4 and N10 are originally set to eject ink (herein, original set values of the nozzles N4 and N10 are "1"), whereas the nozzle N5 is originally set not to eject ink, the original set values of the nozzles N3, N6, and N9 (defective-nozzle set values) are added to the original set values of the nozzles N4, N5, and N10 (first set values), respectively, so that the set values of the nozzles N4 and N10 become "2". This mainly applies to images that have a low to medium gradation and require a medium ink ejection volume.

[0052] As shown in FIG. 5C, when the total of the original set value of a defective nozzle and the original set value of its corresponding supplementing nozzle as the first nozzle exceeds "3" being the maximum value that can be set (predetermined maximum set value), the excess (difference between the original set value after the addition and the maximum set value) is transferred to a nozzle on the opposite side, namely a nozzle (second nozzle) having an ink landing position second closest to the reference ink landing position of the defective nozzle. In this pattern, the total of the original set value "2" of the defective nozzle N3 and the original set value "2" of the nozzle N4 is "4", which exceeds the maximum set value. To deal with this, the nozzle N4 is set to have the maximum set value "3", and the excess "1" is added to the original set value of the nozzle N2 (second set value) on the opposite side. Further, the original set value "2" of the nozzle N9 is transferred to the nozzle N8 because the value "2" cannot be transferred to the nozzle N10 having the original set value "3". This mainly applies to images that have a medium to high gradation, require a

large ink ejection volume, and have low brightness.

[0053] Herein, the nozzle N6 has an actual ink landing position closest to the original ink landing position of the nozzle N9. Hence, as shown in FIG. 5D, the nozzle N6 may be used as a supplementing nozzle for the nozzle N9. That is, when a nozzle other than the nozzles next to the defective nozzle has an abnormal ejection direction but has a normal ink ejection volume and ejection speed (landing-position defective nozzle), the landing-position defective nozzle may supplement ink ejection of the defective nozzle. The supplementary ink ejection by such landing-position defective nozzles may be limited to a case where the ink density of an image (ejection frequency and ejection volume of each nozzle) is equal to or greater than a predetermined reference value. An ink droplet having a smaller volume tends to deviate more from its reference landing position, and an ink droplet having a longer flying distance tends to fly less stably. Hence, determination on whether or not to include a landing-position defective nozzle in supplementing nozzles may depend on whether or not the set value of the landing-position defective nozzle is equal to or greater than a predetermined reference value (first reference value), for example, "2".

[0054] FIGS. 6A and 6B show examples of a test image to obtain information on ink landing positions and ink ejection defects.

[0055] Detection of ink landing positions and ink ejection defects, and generation and update of the ejection position information 63 and the defective nozzle list 62 are performed on the basis of results of reading the test image (predetermined test pattern) with the imager 42. The test image is formed with ink ejected from each nozzle N to land at its predetermined position on the recording medium. As shown in FIG. 6A, the recorder 20 records, with the respective nozzles N, individual straight lines that extend in the conveyance direction on the recording medium so as to be distinguishable from each other. Because ink landing positions of the nozzles N could deviate from their respective reference ink landing positions by two or three times the nozzle interval, in order to identify individual straight lines recorded with the nozzles N, straight lines adjacent to each other in the width direction need to be separated by two or three times the result of two or three times the nozzle interval. That is, the straight lines need to be separated by a distance of about 4 to 9 times the nozzle interval. Between the above-described 4 to 9 nozzle intervals, straight lines are recorded at different positions in the conveyance direction. In this embodiment, eight consecutive nozzles N record eight straight lines L at different positions in the conveyance direction, so that the positions of straight lines L in the conveyance direction are determined in units of eight lines.

[0056] In FIG. 6B, nozzles N corresponding to regions V1 and V2 where straight lines are not drawn are determined as not ejecting ink. A nozzle N corresponding to a thinner straight line T1 is determined as having an in-

sufficient ink ejection volume. A nozzle N corresponding to a straight line F1 that greatly differs in its drawing position as compared with nearby straight lines is determined as having an incorrect ejection direction.

[0057] Straight lines recorded with the nozzles N other than the defective nozzles described above may also have a slight positional deviation. By identifying positions of the straight lines, deviation amounts in ejection direction of the respective nozzles N are obtained. However, it is noted that, in this embodiment, the overall amount of deviation in ejection position of the recording head 211 due to, for example, deviation in position thereof is not determined with these straight lines only. In this embodiment, a reference drawing position where a straight line is assumed to be drawn with a target nozzle N is determined by, for example, averaging positions in the width direction of a predetermined number of straight lines on each side of the straight line of the target nozzle N. Alternatively, reference drawing positions where straight lines are assumed to be drawn with target nozzles N may be determined by (i) averaging positions in the width direction of a predetermined part of (or all of) straight lines and (ii) obtaining positions at multiples of the nozzle interval multiplied by a constant (determined by a positional relationship of the target nozzles) away from the average position.

[0058] The test image may be recorded, and the defective nozzle list 62 and the ejection position information 63 may be updated at one or more timings: (i) when the inkjet recording apparatus 100 initially starts up, (ii) when power supply to the inkjet recording apparatus 100 restarts, (iii) when the inkjet recording apparatus 100 finishes image recording operation for all image recording instructions and shifts to a standby state, and (iv) before the apparatus 100 starts image recording operation in response to a new image recording instruction received.

[0059] FIG. 7 is a flowchart showing control steps of an ink ejection state determination process that is performed by the controller 50. When the ink ejection state determination process starts, the controller 50 (CPU 51) causes each recorder 20 (head driver 25) to operate and record the above-described test image on a recording medium (Step S101). The controller 50 may set the ink droplet volume of each nozzle N to the secondly smaller level or greater among the three levels (volumes). As described above, when a nozzle having an abnormal ejection direction ejects an ink droplet having a small volume, the droplet may fly unstably and land on a further deviated position. Even a normal nozzle may have a slight deviation in its ink landing position. Next, the controller 50 causes the imager 42 to read the recorded test image (Step S102).

[0060] On the basis of the read test image, for each nozzle N, the controller 50 determines whether or not a straight line has been recorded, and determines where in the width direction the straight line has been recorded and what the ink density the straight line has. The controller 50 stores the determined position of the straight

line recorded with each nozzle in and thereby updates the ejection position information 63 (Step S103).

[0061] The controller 50 determines defective nozzles. The controller 50 determines, as defective nozzles, a nozzle (i) that has not recorded a straight line, (ii) that has recorded a straight line with an insufficient ink density, and (iii) that has recorded a straight line at a position deviating from its reference position by a reference distance or more, and records information on the defective nozzles in the defective nozzle list 62 (Step S104). The controller 50 then ends the ink ejection state determination process.

[0062] FIGS. 8 and 9 show flowcharts of control steps of an image data adjustment process that is performed by the controller 50. The image data adjustment process includes a method of setting for supplementing defective nozzles in this embodiment, and is a process to convert image data as the recording target into image data for driving the head driver 25 (driving image data) and output the driving image data to the head driver 25 in accordance with an image recording instruction. The image data adjustment process starts when the image recording instruction is obtained. The following cases are not assumed in the following process: (i) two defective nozzles except landing-position defective nozzles are adjacent to each other, and (ii) two or more defective nozzles except landing-position defective nozzles are included in nozzles as supplementing nozzles (i.e., the number of defective nozzles except landing-position defective nozzles is three or more, including a target defective nozzle). Such cases require cleaning of the nozzles N, replacement of the recording head 211, or the like, and are handled separately from the image data adjustment process.

[0063] When the image data adjusting process starts, the controller 50 (CPU 51) generates halftone image data for driving the head driver 25 on the basis of image data as the recording target (Step S151). Pixels of the generated halftone image data correspond to respective nozzles N and are shown by set values (i.e., pixel values) with multiple levels (four levels, namely "0" to "3", in this embodiment) that correspond to steps (three levels except a level of no ink ejection) of ink droplet volumes that can be ejected from the nozzles N. The controller 50 determines, as a target pixel, the first pixel in the first row of the generated halftone image data (pixel at an end of the first row) (Step S152).

[0064] The controller 50 determines whether or not a nozzle N (target nozzle N) corresponding to the target pixel is a defective nozzle on the basis of the defective nozzle list 62 (Step S153). If the controller 50 determines that the target nozzle N is not a defective nozzle (Step S153: NO), the controller 50 proceeds to Step S175 (A).

[0065] If the controller 50 determines that the target nozzle N is a defective nozzle (Step S153: YES), the controller 50 calls and performs a supplementing nozzle determination process (Step S154). In the supplementing nozzle determination process, the controller 50 determines supplementing nozzles for the defective nozzle

on the basis of the ejection position information 63 in ascending order of distances between the reference ink landing position of the defective nozzle and actual ink landing positions of respective nozzles. The controller 50 determines the first, second, third, and forth supplementing nozzles in ascending order of distances between the reference ink landing position of the defective nozzle and actual ink landing positions of the respective nozzles. Next, the controller 50 determines whether the first supplementing nozzle is a landing-position defective nozzle that has an abnormal ejection direction, or has a distance between its reference ink landing position and its actual ink landing position being equal to or greater than a certain distance (Step S 155). If the controller 50 determines that the first supplementing nozzle is not a landing-position defective nozzle and also does not have the distance being equal to or greater than the certain distance (Step S155: NO), the controller 50 proceeds to Step S158.

[0066] If the controller 50 determines that the first supplementing nozzle is a landing-position defective nozzle or has a distance between its reference ink landing position and its actual ink landing position being equal to or greater than the certain distance (Step S155: YES), the controller 50 determines whether or not "first set value + defective-nozzle set value ≥ 2 " holds (i.e., the ink droplet volume is the middle level in three levels) (Step S156). The first set value is a set value for the ink droplet volume of the first supplementing nozzle. If the first supplementing nozzle is a defective nozzle, the first set value is normally set to "0". The defective-nozzle set value is a set value for the ink droplet volume of the defective nozzle, which is to be supplemented, corresponding to the target pixel. If the controller 50 determines that "first set value + defective-nozzle set value ≥ 2 " holds (Step S156: YES), the controller 50 proceeds to Step S158. If the controller 50 determines that "first set value + defective-nozzle set value ≥ 2 " does not hold (Step S156: NO), the controller 50 exchanges the first supplementing nozzle with the second supplementing nozzle (Step S157), and proceeds to Step S158.

[0067] After proceeding to Step S158 from any of Steps S155 to S 157, the controller 50 adds the defective-nozzle set value to the first set value (Step S158: setting step). The controller 50 determines whether or not "first set value + defective-nozzle set value $>$ maximum set value" holds (Step S159), the maximum set value corresponding to a predetermined maximum ink droplet volume ejectable by each nozzle. If the controller 50 determines that "first set value + defective-nozzle set value $>$ maximum set value" does not hold (Step S159: NO), the controller 50 proceeds to Step S175 (A). If the controller 50 determines that "first set value + defective-nozzle set value $>$ maximum set value" holds (Step S159: YES), the controller 50 adjusts the set value of the first supplementing nozzle to the maximum set value (Step S160).

[0068] The controller 50 determines whether or not the total of (i) a excess (first excess) of the total of the first set value and the defective-nozzle set value over the

maximum set value and (ii) a second set value corresponding to the ink droplet volume of the second supplementing nozzle exceeds the maximum set value (Step S161). If the controller 50 determines that "first excess + second set value $>$ maximum set value" does not hold (Step S161: NO), the controller 50 determines whether or not the second supplementing nozzle is a landing-position defective nozzle (Step S162). If the controller 50 determines that the second supplementing nozzle is not a landing-position defective nozzle (Step S162: NO), the controller 50 proceeds to Step S165. If the controller 50 determines that the second supplementing nozzle is a landing-position defective nozzle (Step S162: YES), the controller 50 determines whether or not "first excess + second set value ≥ 2 " holds (Step S163). If the controller 50 determines that "first excess + second set value ≥ 2 " holds (Step S163: YES), the controller 50 proceeds to Step S165. If the controller 50 determines that "first excess + second set value ≥ 2 " does not hold (Step S163: NO), the controller 50 exchanges the second supplementing nozzle with the third supplementing nozzle (Step S164), and proceeds to Step S165.

[0069] After proceeding to Step S165 from any of Steps S162 to S164, the controller 50 adds the first excess to the second set value (Step S165), and proceeds to Step S175 (A).

[0070] If the controller 50 determines in Step S161 that "first excess + second set value $>$ maximum set value" holds (Step S161: YES), the controller 50 adjusts the second set value to the maximum set value (Step S166), and proceeds to Step S167 (B).

[0071] The controller 50 determines whether or not the defective nozzle corresponding to the target pixel is a landing-position defective nozzle (Step S167). If the controller 50 determines that the defective nozzle corresponding to the target pixel is a landing-position defective nozzle (Step S167: YES), the controller 50 adjusts the defective-nozzle set value to an excess (second excess) of the total of the second set value and the first excess over the maximum set value (Step S168). The controller 50 then proceeds to Step S175.

[0072] If the controller 50 determines that the defective nozzle corresponding to the target pixel is not a landing-position defective nozzle (i.e., the defective nozzle has a defect other than an abnormal ejection direction) (Step S167: NO), the controller 50 determines whether or not the third supplementing nozzle is in the next row in the conveyance direction (Step S169). If the controller 50 determines that the third supplementing nozzle is in the next row (Step S169: YES), the controller 50 transfers the second excess to the next row (i.e., to a set value of the defective nozzle corresponding to a pixel in the next row) (Step S170), and proceeds to Step S175.

[0073] If the controller 50 determines that the third supplementing nozzle is not in the next row (i.e., the third supplementing nozzle is in the same row as the defective nozzle) (Step S169: NO), the controller 50 determines whether or not the third supplementing nozzle is a land-

ing-position defective nozzle (Step S171). If the controller 50 determines that the third supplementing nozzle is not a landing-position defective nozzle (Step S171: NO), the controller 50 proceeds to Step S174. If the controller 50 determines that the third supplementing nozzle (having a third set value) is a landing-position defective nozzle (Step S171: YES), the controller 50 determines whether or not "second excess + third set value ≥ 2 " holds (Step S172). If the controller 50 determines that "second excess + third set value ≥ 2 " holds (Step S172: YES), the controller 50 proceeds to Step S174. If the controller 50 determines that "second excess + third set value ≥ 2 " does not hold (i.e., second excess + third set value = 1) (Step S172: NO), the controller 50 exchanges the third supplementing nozzle with the fourth supplementing nozzle (Step S173), and proceeds to Step S174.

[0074] After proceeding to Step S174 from any of Steps S171 to S173, the controller 50 adds the second excess to the third set value (Step S174), and proceeds to Step S175.

[0075] After proceeding to Step S175 from any of Steps S153, S159, S165, S168, S170, and S174, the controller 50 determines whether or not all the pixels in the current row of the halftone image data have been set as the target pixel (Step S 175). If the controller 50 determines that not all the pixels in the current row of the halftone image data have been set as the target pixel (Step S175: NO), the controller 50 sets a pixel next to the current target pixel in the same row as the next target pixel (Step S176). The controller 50 then returns to Step S153 (C).

[0076] If the controller 50 determines that all the pixels in the current row have been set as the target pixel (Step S175: YES), the controller 50 outputs, to the head driver 25, the row data as data with ink ejection settings done for driving the head driver 25 (Step S177). The image recording operation based on the output row data may be controlled separately according to the conveyance state of the recording medium and synchronization signals in accordance with signals of the encoder 43.

[0077] The controller 50 determines whether or not all the pixels in all the rows in the halftone image data have been set as the target pixel (Step S178). If the controller 50 determines that all the pixels in all the rows in the halftone image data have not been set as the target pixel yet (Step S178: NO), the controller 50 sets the first pixel in the next row as the next target pixel (Step S179), and returns to Step S153 (C). If the controller 50 determines that all the pixels in all the rows in the halftone image data have been set as the target pixel (Step S178: YES), the controller 50 ends the image data adjustment process.

[0078] The controller 50 may output the adjusted image data to the head driver 25 as a whole, instead of on a row basis, after all the pixels in all the rows have been set (adjusted).

[0079] FIG. 10 is a flowchart showing control steps of the supplementing nozzle determination process that is called in the image data adjustment process.

[0080] When the supplementing nozzle determination process is called, the controller 50 obtains, from the ejection position information 63, information on the ink landing positions of nozzles N that correspond to a predetermined number (e.g. three) of pixels on each of the right and left sides of the target defective pixel (Step S201). The controller 50 calculates (determines) the distance between the reference ink landing position of the target defective nozzle (nozzle corresponding to the target pixel) and the actual ink landing position of each of the nozzles N (nozzles corresponding to the pixels on the right and left sides of the target pixel). The controller 50 ranks/sorts the nozzles N in ascending order of the calculated distances (Step S202). Because only the top four nozzles in the ascending order are needed as supplementing nozzles in this embodiment, the controller 50 may determine the top four nozzles only.

[0081] The controller 50 associates and stores information on the sorted/ranked supplementing nozzles with information on whether or not the respective supplementing nozzles are any of defective nozzles (Step S203). The controller 50 then ends the supplementing nozzle determination process and returns to the image data adjustment process.

[Modification]

[0082] FIGS. 11A and 11B are diagrams to explain an incline of a recording head 211 in a modification.

[0083] As shown in FIG. 11A, the recording head 211 has nozzles N the openings of which are arranged two-dimensionally, or more specifically, arranged so as to form two rows that extend in the width direction and are arranged at different positions in the conveyance direction. The openings are arranged at equal intervals such that the openings of one row alternate with those of the other row in the width direction. Because of the limit of mounting accuracy or the like, when the recording head 211 is mounted with a slight deviation in the angle of rotation (mounting error) in a plane including the width and conveyance directions, the positions of the openings of the nozzles N deviate in the width direction according to the deviation in the angle of rotation. The amounts of deviation in the positions of the openings belonging to one row differ from those of the openings belonging to the other row. Hence, as shown in FIG. 11B, an interval (distance) D11 between nozzles N11 and N12 in the width direction differs from an interval D12 between nozzles N12 and N13 in the width direction. That is, even though ink is ejected in the correct direction from the nozzles N, intervals between their ink landing positions systematically differ in the width direction such that the short interval alternates with the long interval.

[0084] Even though slight deviations each being smaller than an average nozzle interval occur in all the ink landing positions, the deviations do not seriously affect image quality. However, when non-uniformity in density occurs at a certain point in the width direction by the ab-

normal ejection and supplement thereof, the point becomes conspicuous, especially when the point is in an image having a uniform density.

[0085] When such a recording head 211 has a defective nozzle, a supplementing nozzle is mechanically selected from nozzles on the left and right sides of the defective nozzle on the basis of the row to which the defective nozzle belongs and the direction of the inclination, as long as the ink ejection directions of nozzles N other than the defective nozzle are accurately perpendicular to the nozzle opening surface. In this modification, the interval D11 is shorter than the interval D12. When the nozzle N12 is determined as a defective nozzle and the nozzles N11 and N13 eject ink in the correct direction, the nozzle N11 is selected as a supplementing nozzle. When the nozzles N11 and N13 eject ink in the incorrect direction, the supplementing nozzle may be determined on the basis of the sum of (i) influence of the deviation in the rotation angle and (ii) influence of the deviation in the ink ejection direction. That is, a supplementing nozzle may be determined on the basis of the actual ink landing positions of the nozzles N11 and N13.

[0086] As described above, the inkjet recording apparatus 100 in this embodiment includes the recorder 20 that includes nozzles N to eject ink and the controller 50 that controls operation of the recorder 20. The controller 50 determines, for a defective nozzle having a defect in ink ejection, a first nozzle having an actual ink landing position closest to a reference ink landing position of the defective nozzle as a supplementing nozzle that supplements the defect of the defective nozzle.

[0087] The inkjet recording apparatus 100 takes account of slight deviations of the ink landing positions of the nozzles N, and preferentially selects, as a supplementing nozzle, a nozzle having an actual ink landing position closest to the reference ink landing position of the defective nozzle, instead of simply selecting a nozzle adjacent to the defective nozzle (i.e., nozzle closest to the defective nozzle). Thus, the inkjet recording apparatus 100 can restrain occurrence of white and black streaks as compared with conventional apparatuses, and maintain quality of image to be recorded more securely.

[0088] Furthermore, the inkjet recording apparatus 100 includes the storage 60 that stores the ejection position information 63 on actual ink landing positions of the nozzles N. The controller 50 determines a distance between each of the actual ink landing positions and the reference ink landing position on the basis of the ejection position information 63. By determining the actual ink landing position of each of the nozzles N and storing the information thereof beforehand, the inkjet recording apparatus 100 can quickly and easily determine, when a new defective nozzle occurs, an optimum nozzle(s) for supplementing ink ejection of the defective nozzle.

[0089] Furthermore, the recorders 20 can eject the ink with multiple volumes from each of the nozzles N. The controller 50 adds a defective-nozzle set value corresponding to an ink droplet volume to be ejected from the

defective nozzle to a first set value corresponding to an ink droplet volume to be ejected from the first nozzle, and causes the first nozzle to eject ink with an ink droplet volume corresponding to the first set value after the addition.

[0090] Thus, the inkjet recording apparatus 100 can appropriately supplement the ink ejection volume of the defective nozzle with another nozzle.

[0091] Furthermore, in response to the first set value after the addition exceeding the predetermined maximum set value, the controller 50 transfers a first difference between the first set value after the addition and the maximum set value to a set value corresponding to an ink droplet volume to be ejected from a nozzle different from the first nozzle.

[0092] Because each nozzle N has a limit in an ink droplet volume to eject, another nozzle(s) may also supplement the defective nozzle when a supplementing nozzle cannot fully supplement the defective nozzle. Because a greater ink ejection volume less generates white streaks and makes black streaks less conspicuous, deterioration in image quality is sufficiently restrained.

[0093] More specifically, the controller 50 adds the first difference to a second set value corresponding to an ink droplet volume to be ejected from, as the nozzle different from the first nozzle, a second nozzle having an actual ink landing position second closest to the reference ink landing position of the defective nozzle, and adjusts the first set value to the maximum set value. Naturally, the closer the ink landing position of a supplementing nozzle to the reference ink landing position of the defective nozzle is, the more faithful the recorded image is to the image data. Hence, when a nozzle N having an ink landing position closest to the reference ink landing position of the defective nozzle cannot fully supplement the defective nozzle, a nozzle N having an ink landing position second closest to the reference ink landing position of the defective nozzle also supplements the remaining ink ejection. Thus, the image quality is maintained more appropriately and securely.

[0094] Furthermore, in response to (i) the second set value after the addition exceeding the maximum set value and (ii) the defect of the defective nozzle being an abnormal ink landing position, the controller 50 causes the recorder 20 to eject ink from the defective nozzle with an ink droplet volume corresponding to a second difference between the second set value after the addition and the maximum set value, and adjusts the second set value to the maximum set value. When the nozzles having closest and second closest ink landing positions to the reference ink landing position of the defective nozzle (normally the nozzles on both sides of the defective nozzle) cannot fully supplement the ink ejection volume of the defective nozzle, the region around the reference ink landing position is supposed to be in a region having a high ink density, and hence a small deviation in ink landing position does not reduce image quality. Thus, when the defective nozzle is a landing-position defective nozzle hav-

ing an abnormal ejection direction, the inkjet recording apparatus 100 can cause the defective nozzle to eject ink with a remaining volume to keep the overall ink ejection volume. Thus, the image quality can be maintained.

[0095] Furthermore, the controller 50 determines the first nozzle from the nozzles including a landing-position defective nozzle having an abnormal ink landing position. That is, the landing-position defective nozzle can be a supplementing nozzle when the landing-position defective nozzle has an actual ink landing position close to the reference ink landing position of the defective nozzle. By utilizing nozzles that are normally stopped from being used, the inkjet recording apparatus 100 can keep the overall ink ejection volume and maintain more appropriate image quality as compared with conventional apparatuses.

[0096] Furthermore, the controller 50 determines the nozzle different from the first nozzle from the nozzles N including a landing-position defective nozzle having an abnormal ink landing position. As with the first nozzle, the controller 50 may determine a landing-position defective nozzle as the second nozzle (second supplementing nozzle in the above embodiment) or as a supplementing nozzle having a lower rank.

[0097] Furthermore, in response to a set value corresponding to an ink droplet volume to be ejected from the determined nozzle being equal to or greater than a predetermined first reference value or not, the controller 50 determines whether or not to cause the determined nozzle to supplement the defect of the defective nozzle. When a landing-position defective nozzle ejects ink with a small volume, its ink landing position tends to deviate. In consideration of this, the landing-position defective nozzle may be used as a supplementing nozzle only when its set value after addition is equal to or greater than a first reference value (in the above embodiment, "2"). Thus, the inkjet recording apparatus 100 can maintain image quality more stably.

[0098] Furthermore, in response to (i) a first set value corresponding to an ink droplet volume to be ejected from the first nozzle being smaller than a predetermined second reference value (in the above embodiment, same as the first reference value) and (ii) a distance between a reference ink landing position and the actual ink landing position of the first nozzle being equal to or greater than a predetermined reference distance, the controller 50 does not use the first nozzle as a first choice of the supplementing nozzle. When a normal nozzle has a deviation in ink landing position by a distance shorter than a reference distance, the flying distance of ink becomes longer and its ink landing position could further deviate. When such a nozzle is the first nozzle that is supposed to eject ink with a small volume, the nozzle may not be used as a first choice of the supplementing nozzle, because a slight deviation in ink landing position may affect image quality. Thus, stability in image quality can be maintained.

[0099] Furthermore, each recorder 20 ejects the ink to

a fabric. The technique described above can maintain image quality on a recording medium more effectively, especially when the recording medium is a fabric that absorbs ink and is less likely to have an uneven surface after the absorption.

[0100] Furthermore, the controller 50 causes the recorder 20 to record a predetermined test pattern on the recording medium by causing the recorder 20 to eject ink droplets from the respective nozzles so as to land on the recording medium in which the ink ejected from each of the nozzles N lands in a predetermined arrangement, and generates the ejection position information 63 based on the actual ink landing positions in the test pattern.

[0101] By generating the ejection position information 63 on the basis of the actual ink landing positions, the inkjet recording apparatus 100 can determine supplementing nozzles highly precisely.

[0102] Furthermore, the controller 50 causes the recorder 20 to record the test pattern by causing the recorder 20 to eject the ink from the respective nozzles N with a second smallest volume or greater among the multiple volumes.

[0103] As described above, when ink with a small volume flies long, its ink landing position is more likely to deviate. By recording the test pattern with a certain volume of ink, the inkjet recording apparatus 100 can determine the ink landing positions precisely.

[0104] Furthermore, the inkjet recording apparatus 100 includes the imager 42 that reads a surface of the recording medium, and the controller 50 causes the imager 42 to read the test pattern and determines the actual ink landing position of each of the nozzles N. Thus, the inkjet recording apparatus 100 can save times and efforts by performing inline processing, and obtain nearly real-time data on deviations in ink landing positions, which change with time, by quickly reflecting the read test pattern image on the data. Still further, because the imager 42 may be also used as an imager for checking recorded images of the inkjet recording apparatus 100, the inkjet recording apparatus 100 can utilize the imager 42 more effectively.

[0105] Furthermore, the inkjet recording apparatus 100 includes the conveyer 10 that conveys the recording medium, and the controller 50 causes the recorder 20 to eject the ink to the recording medium while causing the conveyer 10 to move the recording medium in a predetermined conveyance direction. In the test pattern, lines extending in the conveyance direction are formed with the ink droplets ejected from the respective nozzles N and are arranged so as to be distinguishable from one another.

[0106] That is, the inkjet recording apparatus 100 may utilize the test pattern for determining ink landing positions, as well as for determining defective nozzles. Thus, the inkjet recording apparatus 100 minimizes increase of time and efforts for processes.

[0107] Furthermore, the controller 50 calculates the actual ink landing positions on the basis of a distance

between the recording medium and the openings of the nozzles N. The distance between the recording medium and the openings of the nozzles N can be changed depending on the type of recording medium or the like. According to the change of the above-described distance, the ink landing positions in a certain ejection angle change. By calculating the ink landing positions on the basis of the distance, the inkjet recording apparatus 100 can select supplementing nozzles appropriately and flexibly.

[0108] Furthermore, the inkjet recording apparatus 100 includes the input receiver (operation receiver 70 and communication unit 82) that receives an input for setting a type of recording medium, and the controller 50 sets the distance between the recording medium and the openings of the nozzles N based on the type. By determining beforehand the appropriate distance between the recording medium and the openings of the nozzles N for each type of recording medium, the inkjet recording apparatus 100 can select supplementing nozzles only by setting the type of recording medium, without much time and efforts.

[0109] Furthermore, the recorder 20 includes the recording heads 211 each of which includes the nozzles arranged two-dimensionally, and the actual ink landing positions include a systematical deviation corresponding to an error in mounting the recording head 211. That is, contents of the selection of supplementing nozzles described above is effective not only in supplementing individual defective nozzles but also in dealing with deviations in ink landing positions caused by the level of mechanical accuracy.

[0110] Furthermore, the method of setting for supplementing defective nozzles in the embodiment described above includes determining, for a defective nozzle having a defect in ink ejection, a first nozzle having an actual ink landing position closest to a reference ink landing position of the defective nozzle as a supplementing nozzle that supplements the defect of the defective nozzle.

[0111] Thus, the inkjet recording apparatus 100 can record images having higher uniformity in density, restrain occurrence of white and black streaks as compared with conventional apparatuses, and accordingly maintain quality of image to be recorded more securely.

[0112] The present invention is not limited to the above-described embodiment, and can be variously modified.

[0113] For example, in the above embodiment, the inkjet recording apparatus 100 can adjust the ink ejection volume with three levels. However, the inkjet recording apparatus 100 may be an apparatus that cannot adjust the ink ejection volume but only set whether or not to eject ink. In such a case, the maximum set value is "1".

[0114] Further, in the above embodiment, nozzles having an abnormal ink landing position (landing-position defective nozzles) may be used as supplementing nozzles. However, the landing-position defective nozzles may not be used as supplementing nozzles in any case. Alternatively,

landing-position defective nozzles may be used as supplementing nozzles without the condition on the ink ejection volume. Still alternatively, a landing-position defective nozzle may not be set as the first nozzle, but may be set as the second nozzle or a supplementing nozzle having a lower rank.

[0115] Further, although the level of the ink ejection volumes of normal nozzles is not taken into account in the above embodiment, it may be taken into account when normal nozzles are set/determined as a complementing nozzle.

[0116] Further, although it is assumed that ink landing positions could deviate in the width direction in the above embodiment, ink landing positions could deviate in the conveyance direction. When an ink landing position of a defective nozzle deviates in the conveyance direction and cannot be corrected by finely adjusting the ink ejection timing, the deviation may be or may not be taken into account to determine the distance between the reference ink landing position of the defective nozzle and actual ink landing positions of its nearby supplementing nozzles. When the deviation is not considered, the defective nozzle the ink landing position of which deviates in the conveyance direction is treated as a defective nozzle that does not eject ink.

[0117] The ink is not limited to color ink. Further, even when a protective film is formed, unevenness in film thickness can be reduced. Still further, the recording medium is not limited to fabrics, but may be paper, film, or the like.

[0118] The test image is not limited to the one described above. Further, the test image may be recorded section by section depending on the margin of the recording medium.

[0119] Regardless of whether or not the inkjet recording apparatus 100 includes the imager 42, the test image may be read by an external apparatus. Further, operation of determining the ink landing position on the basis of the reading result may also be performed by an external apparatus. In such cases, the controller 50 may obtain the test image or the result of reading the test image from an external apparatus.

[0120] Furthermore, in the above embodiment, the distance between the recording medium and the openings of the nozzles N is set depending on the type of the recording medium. However, the distance may be set by a user directly and appropriately. When the distance cannot be changed, the ink landing positions are fixed.

[0121] Furthermore, although the inkjet recording apparatus 100 in the above embodiment has the line heads as an example, the inkjet recording apparatus 100 may be an apparatus that utilizes a scan printing system.

[0122] The detailed configuration, control, procedure, and so forth described in the above embodiment can be appropriately modified within the scope of the present invention. The scope of the present invention is not limited to the embodiment described above but includes the scope of the present invention described in the scope of claims and the scope of their equivalents.

[0123] Although embodiments of the present invention have been described and illustrated in detail, the disclosed embodiments are made for purposes of illustration and example only and not limitation. The scope of the present invention should be interpreted by terms of the appended claims.

Claims

1. An inkjet recording apparatus (100) comprising:

a recorder (20) that includes nozzles to eject ink; and
a controller (50) that controls operation of the recorder, wherein
the controller determines, for a defective nozzle having a defect in ink ejection, a first nozzle having an actual ink landing position, where the ink lands, closest to a reference ink landing position of the defective nozzle as a supplementing nozzle that supplements the defect of the defective nozzle.

2. The inkjet recording apparatus according to claim 1, further comprising a storage (60) that stores ejection information (63) on actual ink landing positions of the nozzles, wherein the controller determines a distance between each of the actual ink landing positions and the reference ink landing position based on the ejection information.

3. The inkjet recording apparatus according to claim 1 or 2, wherein the recorder can eject the ink with multiple ink droplet volumes from each of the nozzles, and the controller adds a defective-nozzle set value corresponding to an ink droplet volume to be ejected from the defective nozzle to a first set value corresponding to an ink droplet volume to be ejected from the first nozzle, and causes the recorder to eject ink from the first nozzle with an ink droplet volume corresponding to the first set value after the addition.

4. The inkjet recording apparatus according to claim 3, wherein in response to the first set value after the addition exceeding a predetermined maximum set value, the controller transfers a first difference between the first set value after the addition and the maximum set value to a set value corresponding to an ink droplet volume to be ejected from a nozzle different from the first nozzle.

5. The inkjet recording apparatus according to claim 4, wherein the controller adds the first difference to a second set value cor-

responding to an ink droplet volume to be ejected from, as the nozzle different from the first nozzle, a second nozzle having an actual ink landing position second closest to the reference ink landing position of the defective nozzle, and
adjusts the first set value to the maximum set value.

6. The inkjet recording apparatus according to claim 5, wherein in response to (i) the second set value after the addition exceeding the maximum set value and (ii) the defect of the defective nozzle being an abnormal ink landing position, the controller causes the recorder to eject the ink from the defective nozzle with an ink droplet volume corresponding to a second difference between the second set value after the addition and the maximum set value, and adjusts the second set value to the maximum set value.

7. The inkjet recording apparatus according to any one of claims 1 to 6, wherein the controller determines the first nozzle from the nozzles including a landing-position defective nozzle having an abnormal ink landing position.

8. The inkjet recording apparatus according to any one of claims 4 to 6, wherein the controller determines the nozzle different from the first nozzle from the nozzles including a landing-position defective nozzle having an abnormal ink landing position.

9. The inkjet recording apparatus according to claim 7 or 8, wherein in response to a set value corresponding to an ink droplet volume to be ejected from the determined nozzle being equal to or greater than a first reference value or not, the controller determines whether or not to cause the determined nozzle to supplement the defect of the defective nozzle.

10. The inkjet recording apparatus according to any one of claims 1 to 9, wherein in response to (i) a first set value corresponding to an ink droplet volume to be ejected from the first nozzle being smaller than a predetermined second reference value and (ii) a distance between a reference ink landing position and the actual ink landing position of the first nozzle being equal to or greater than a predetermined reference distance, the controller does not use the first nozzle as a first choice of the supplementing nozzle.

11. The inkjet recording apparatus according to any one of claims 1 to 10, wherein the recorder ejects the ink to a fabric.

12. The inkjet recording apparatus according to any one of claims 1 to 11, further comprising a storage (60) that stores ejection information (63) on actual ink landing positions of the nozzles, wherein the control-

- ler
causes the recorder to record a predetermined test pattern on a recording medium by causing the recorder to eject ink droplets of the ink from the respective nozzles so as to land on the recording medium in predetermined arrangement, and generates the ejection information based on the actual ink landing positions in the test pattern. 5
13. The inkjet recording apparatus according to claim 12, wherein
the recorder can eject the ink with multiple ink droplet volumes from each of the nozzles, and
the controller causes the recorder to record the test pattern by causing the recorder to eject the ink droplets of the ink from the respective nozzles with a second smallest ink droplet volume or greater among the multiple ink droplet volumes. 10 15
14. The inkjet recording apparatus according to claim 12 or 13, further comprising a reader (42) that reads a surface of the recording medium, wherein
the controller causes the reader to read the test pattern and determines the actual ink landing positions of the nozzles. 20 25
15. The inkjet recording apparatus according to any one of claims 12 to 14, further comprising a conveyer (10) that conveys the recording medium, wherein
the controller causes the recorder to eject the ink to the recording medium while causing the conveyer to move the recording medium in a predetermined conveyance direction, and
in the test pattern, lines extending in the conveyance direction are formed with the ink droplets ejected from the respective nozzles and are arranged so as to be distinguishable from one another. 30 35
16. The inkjet recording apparatus according to any one of claims 1 to 15, wherein the controller calculates the actual ink landing position based on a distance between a recording medium and openings of the nozzles. 40
17. The inkjet recording apparatus according to claim 16, further comprising an input receiver (70, 82) that receives an input for setting a type of the recording medium, wherein the controller sets the distance between the recording medium and the openings of the nozzles based on the type. 45 50
18. The inkjet recording apparatus according to any one of claims 1 to 17, wherein
the recorder includes a recording head (211) including the nozzles arranged two-dimensionally, and
the actual ink landing position includes a systematic deviation corresponding to an error in mounting the recording head. 55
19. A method of setting for supplementing a defective nozzle of a recorder (20) that includes nozzles to eject ink, comprising determining (S158), for a defective nozzle having a defect in ink ejection, a first nozzle having an actual ink landing position closest to a reference ink landing position of the defective nozzle as a supplementing nozzle that supplements the defect of the defective nozzle.

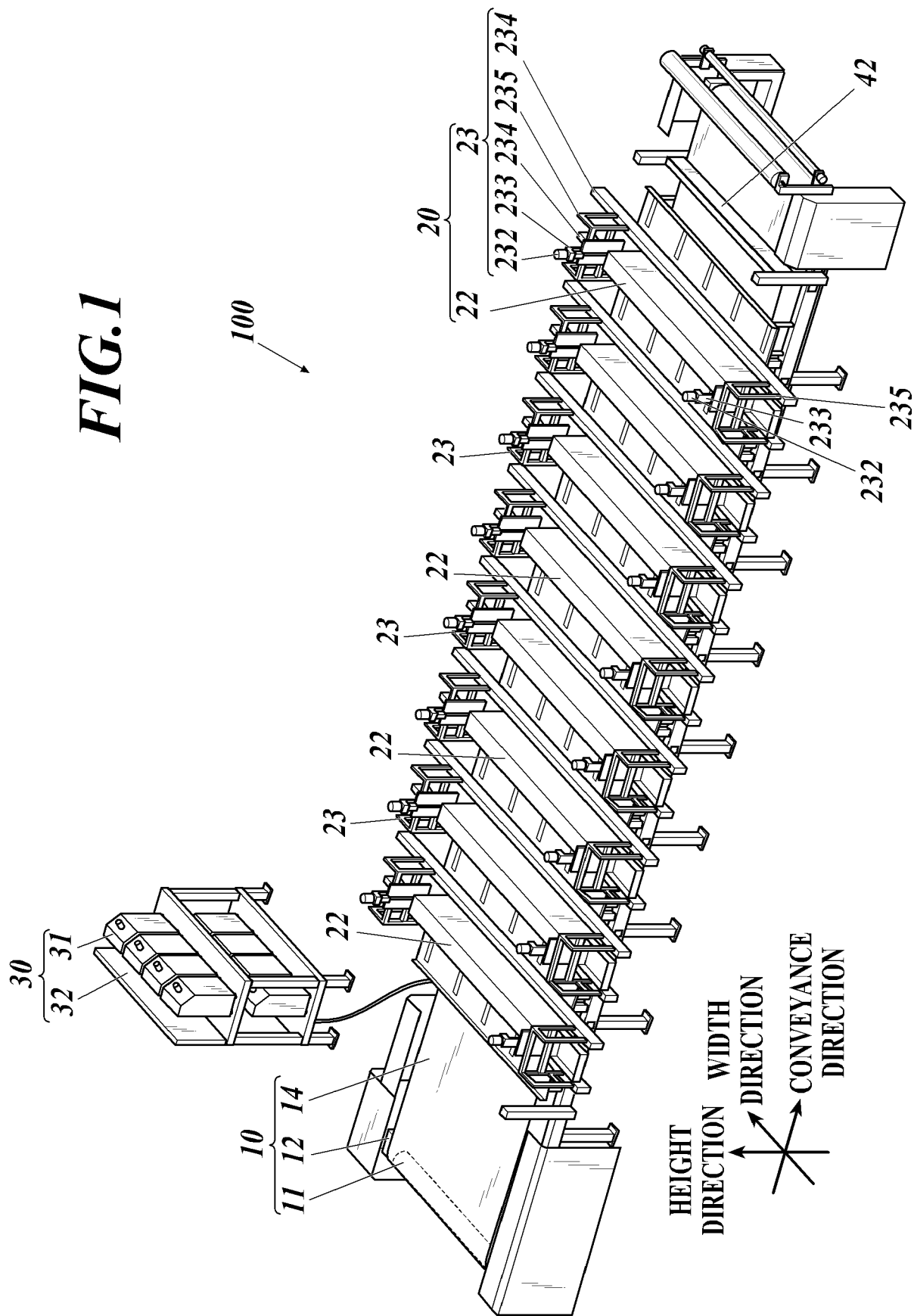


FIG.2

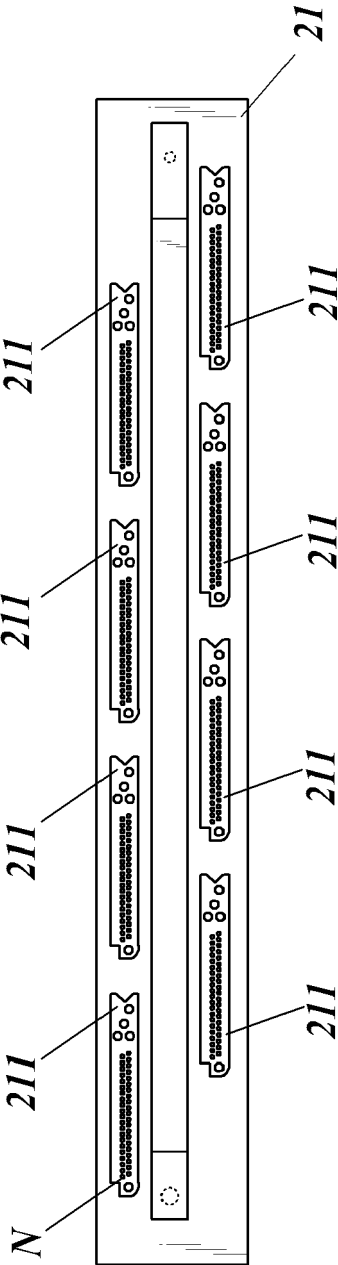


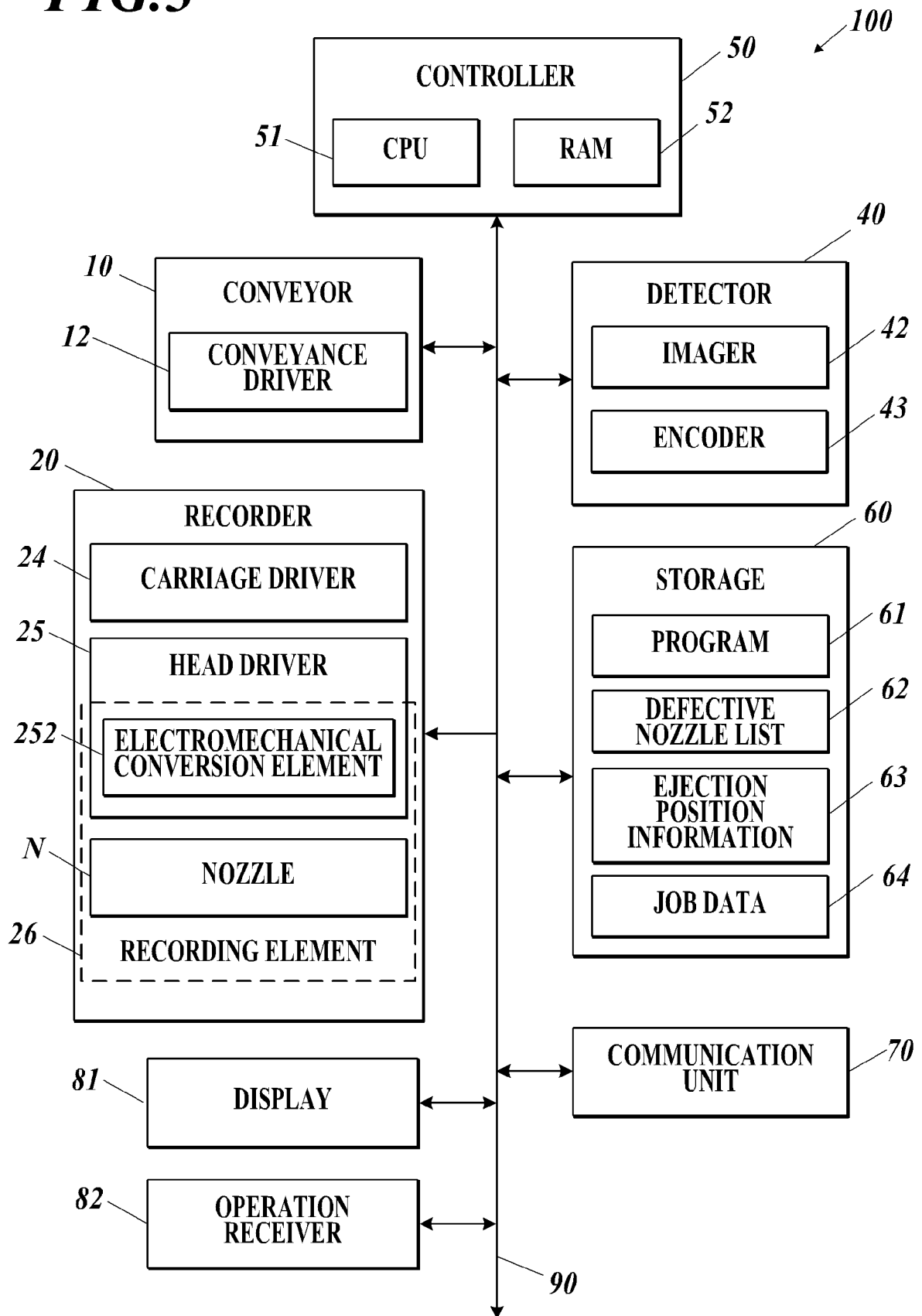
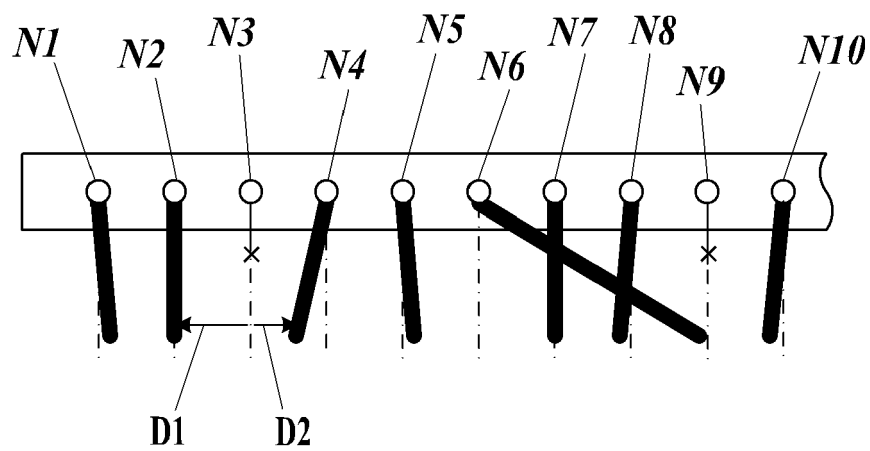
FIG.3

FIG.4A**FIG.4B**

N1	N2	N3	N4	N5	N6	N7	N8	N9	N10
+0.2	±0.0	-	-0.4	+0.2	+2.8	±0.0	-0.2	-	-0.3
		x			x			x	

FIG.5A

N1	N2	N3	N4	N5	N6	N7	N8	N9	N10
1	0	1	0	0	1	0	0	1	0
1	0	0	1	1	0	0	0	0	1

FIG.5B

N1	N2	N3	N4	N5	N6	N7	N8	N9	N10
1	0	1	1	0	1	1	0	1	1
1	0	0	2	1	0	1	0	0	2

FIG.5C

N1	N2	N3	N4	N5	N6	N7	N8	N9	N10
3	0	2	2	0	2	3	0	2	3
3	1	0	3	2	0	3	2	0	3

FIG.5D

N1	N2	N3	N4	N5	N6	N7	N8	N9	N10
3	0	2	2	0	2	3	0	2	3
3	1	0	3	2	2	3	0	0	3

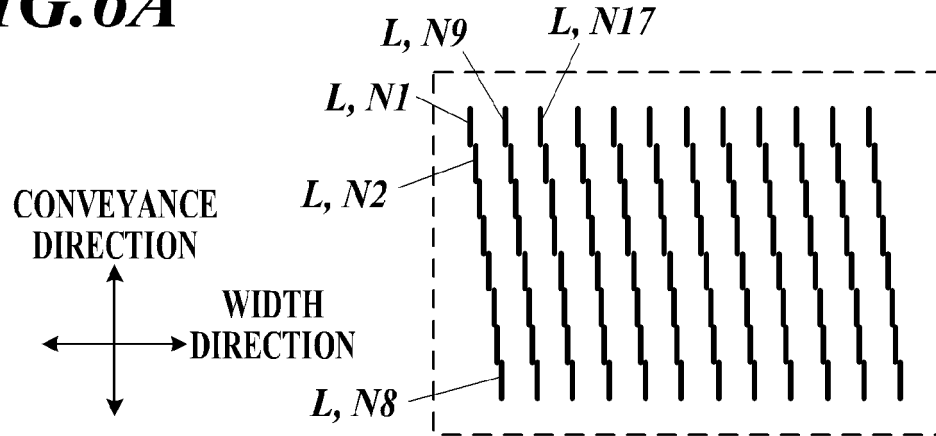
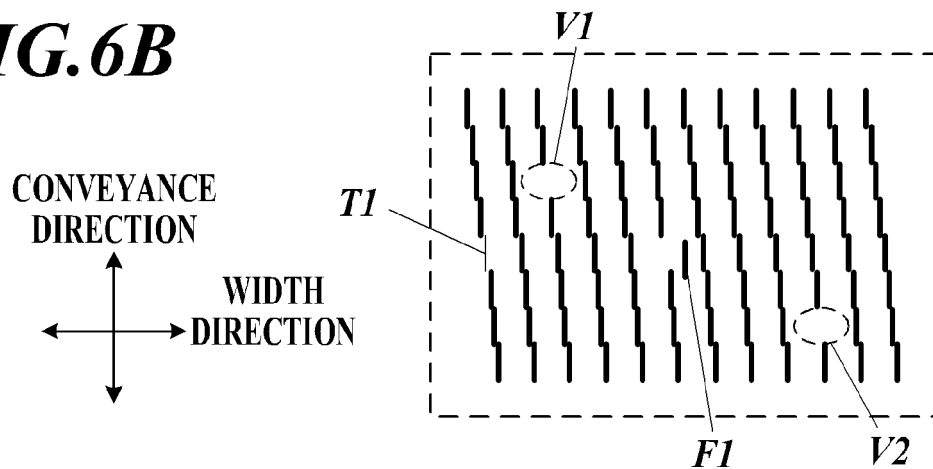
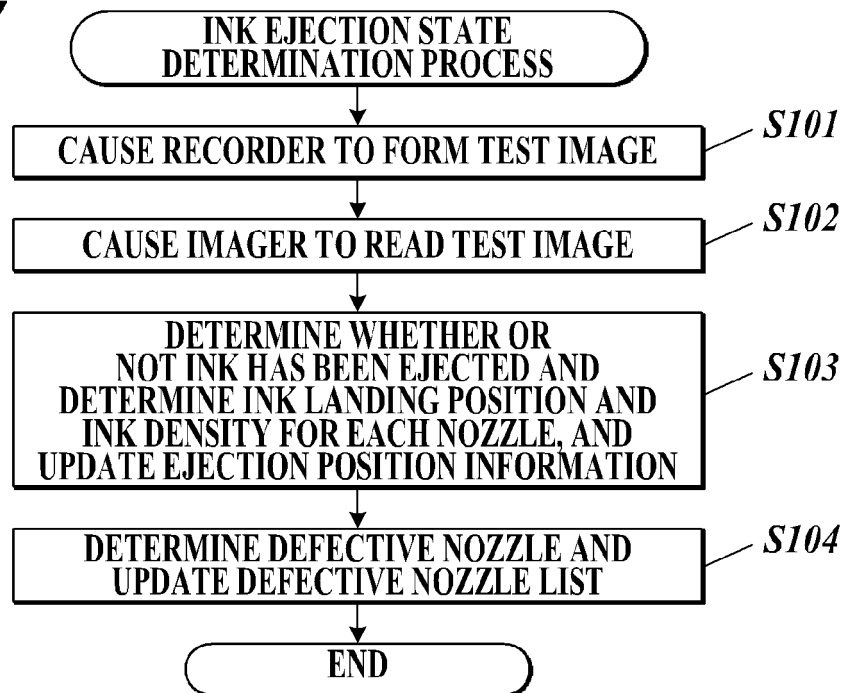
FIG. 6A**FIG. 6B****FIG. 7**

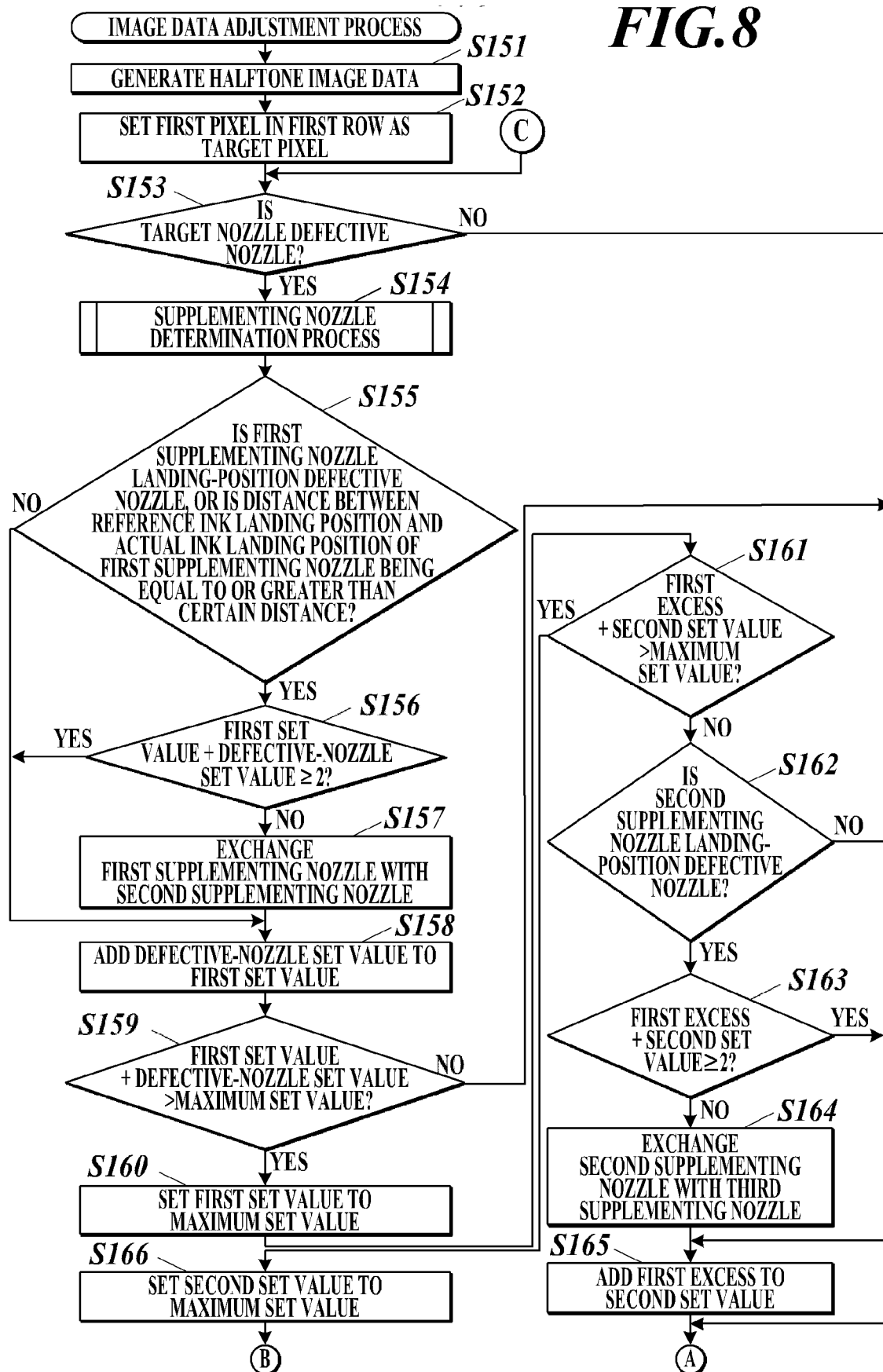
FIG. 8

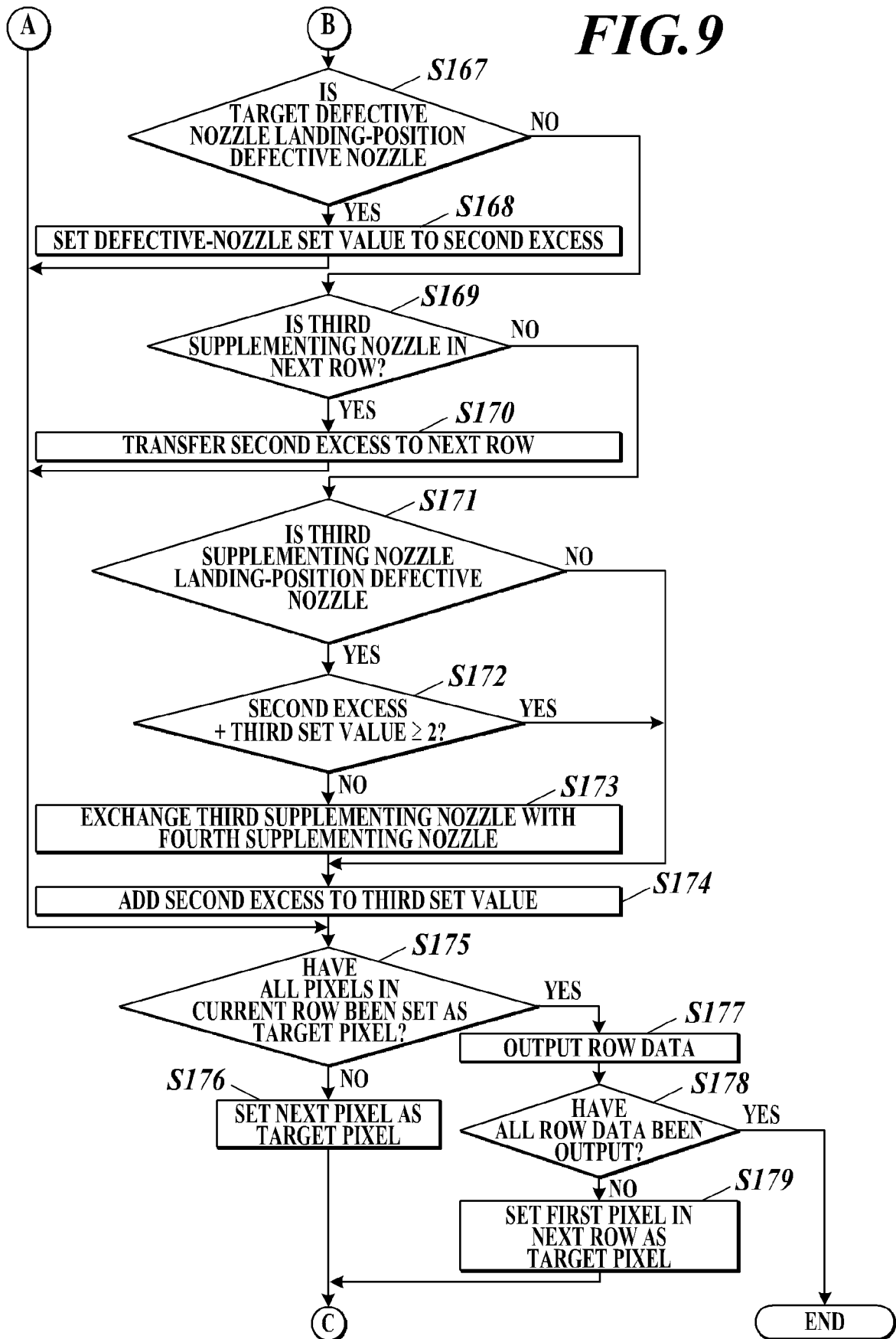
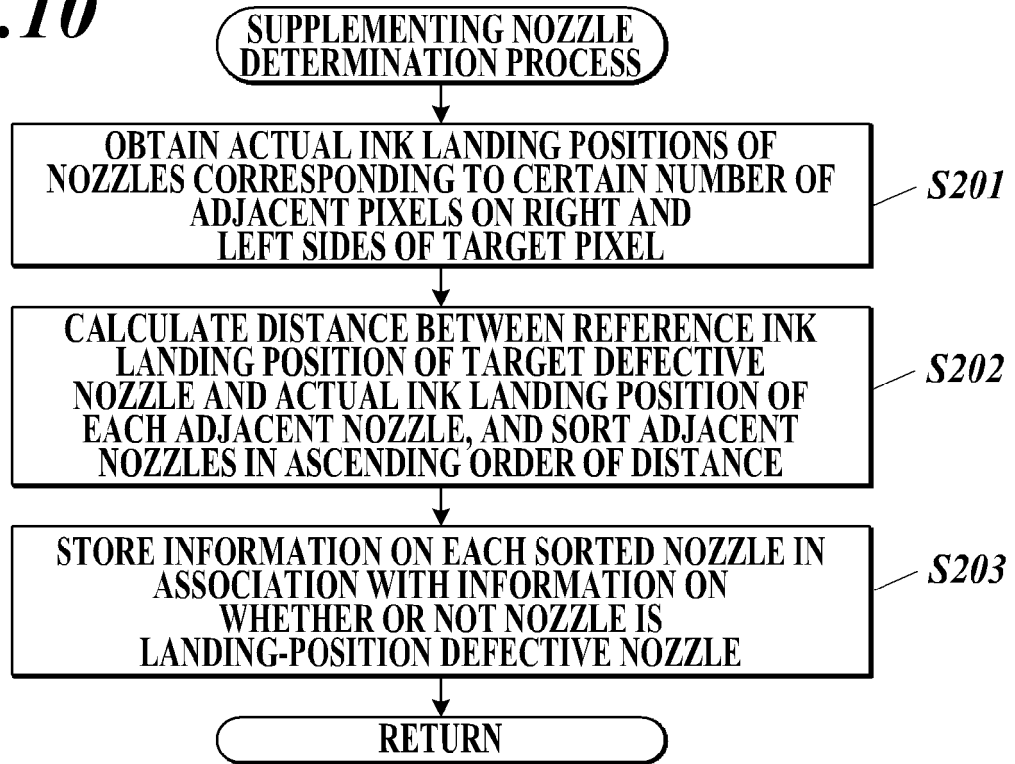
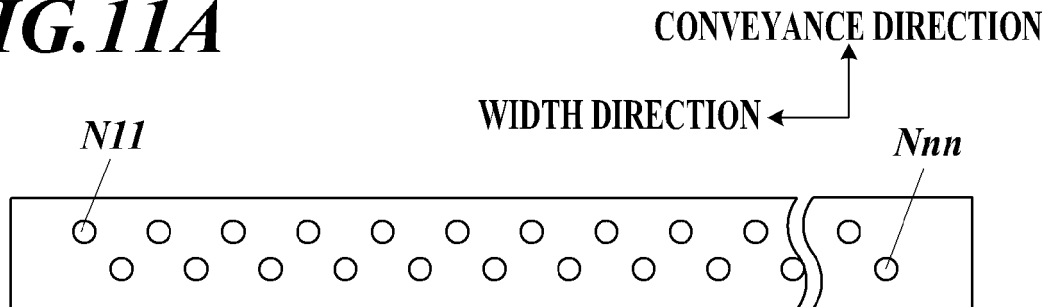
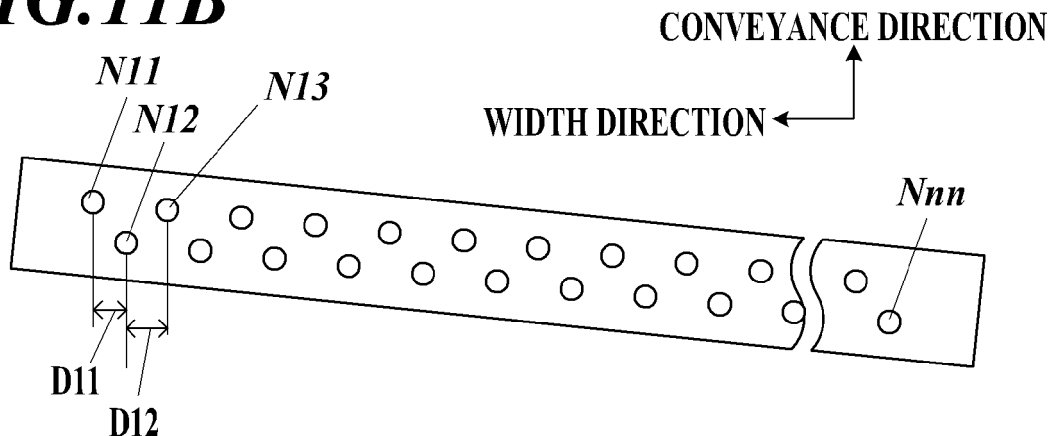
FIG.9

FIG.10**FIG.11A****FIG.11B**



EUROPEAN SEARCH REPORT

 Application Number
 EP 20 15 5757

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2004/119766 A1 (SHIBATA TSUYOSHI [JP] ET AL) 24 June 2004 (2004-06-24)	1,2,7,9, 11-17,19	INV. B41J2/21
Y	* figures 1-4 * * paragraph [0082] - paragraph [0083] * * paragraph [0004] * * paragraph [0049] *	3-6,8, 10,18	B41J3/407 D06P5/30
X	US 5 581 284 A (HERMANSON HERMAN A [US]) 3 December 1996 (1996-12-03) * figures 1-4 * * column 6, line 1 - line 5 *	1,19	
Y	US 9 573 382 B1 (METCALFE DAVID J [US]) 21 February 2017 (2017-02-21) * figure 3 *	3-5	
Y	US 2014/300656 A1 (UESHIMA MASASHI [JP]) 9 October 2014 (2014-10-09) * figure 8 * * paragraph [0084] *	6,8	
Y	US 2018/104962 A1 (MAEDA KOTARO [JP] ET AL) 19 April 2018 (2018-04-19) * figures 3, 4, 6 * * paragraphs [0055], [0069] *	10	TECHNICAL FIELDS SEARCHED (IPC) B41J D06Q D06P
Y	US 2016/288555 A1 (EBISAWA TAKASHI [JP]) 6 October 2016 (2016-10-06) * figure 5 * * paragraph [0084] *	18	
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 26 June 2020	Examiner João, César
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 20 15 5757

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

26-06-2020

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2004119766	A1	24-06-2004	CN 1490165 A	21-04-2004
			EP 1384592 A1	28-01-2004
			JP 4164305 B2	15-10-2008
			JP 2004058284 A	26-02-2004
			US 2004119766 A1	24-06-2004

US 5581284	A	03-12-1996	JP H08207321 A	13-08-1996
			US 5581284 A	03-12-1996

US 9573382	B1	21-02-2017	CN 107150503 A	12-09-2017
			DE 102017203247 A1	07-09-2017
			JP 2017154496 A	07-09-2017
			KR 20170102807 A	12-09-2017
			US 9573382 B1	21-02-2017

US 2014300656	A1	09-10-2014	EP 2789468 A1	15-10-2014
			JP 5826787 B2	02-12-2015
			JP 2014200970 A	27-10-2014
			US 2014300656 A1	09-10-2014

US 2018104962	A1	19-04-2018	JP 2018065287 A	26-04-2018
			US 2018104962 A1	19-04-2018

US 2016288555	A1	06-10-2016	EP 3075548 A2	05-10-2016
			EP 3243665 A1	15-11-2017
			JP 6567312 B2	28-08-2019
			JP 2016190386 A	10-11-2016
			US 2016288555 A1	06-10-2016

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2014043076 A [0003] [0004]