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Image processing apparatus, printing apparatus, and image processing method for converting image data into dot data

Abstract

A total sum obtained by multiplying a distribution ratio set for each of distribution destination pixels by a relative position in a first direction is a first direction total sum, a total sum obtained by multiplying the distribution ratio set for each of the distribution destination pixels by a relative position in a second direction is a second direction total sum, a ratio of the second direction total sum to the first direction total sum is a total sum ratio, a ratio of a second direction resolution to a first direction resolution is a resolution ratio, the total sum ratio when the resolution ratio is a first resolution ratio is a first total sum ratio, when the resolution ratio is a second resolution ratio greater than the first resolution ratio is a second total sum ratio, and the second total sum ratio is greater than the first total sum ratio.

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Background/Summary

(1) The present application is based on, and claims priority from JP Application Serial Number 2022-180842, filed Nov. 11, 2022, the disclosure of which is hereby incorporated by reference herein in its entirety.
BACKGROUND
1. Technical Field
(2) The present disclosure relates to an image processing apparatus capable of performing halftone processing by an error diffusion method, a printing apparatus and an image processing method.
2. Related Art
(3) There is known an image processing apparatus that performs halftone processing for generating dot data representing a dot formation state by reducing the number of tones of multi-tone image data in order to form a print image. Halftone processing by an error diffusion method is known as a technique for obtaining high-quality output. JP 2005-137019 A discloses an image processing apparatus that performs the halftone processing by the error diffusion method.
(4) In a print image, a resolution in a horizontal direction may be different from a resolution in a vertical direction. In this case, when the halftone processing by the error diffusion method is performed, a dot arrangement may be biased, and in particular, the bias may appear as a decrease in

granularity in a low-tone portion in the image. Thus, in the halftone processing by the error diffusion method, there is room for improvement in terms of granularity.

SUMMARY

(5) An image processing apparatus of the present disclosure is an image processing apparatus configured to convert image data in which a first direction resolution in a first direction and a second direction resolution in a second direction intersecting the first direction are set into dot data representing a dot formation state by an error diffusion method, the image processing apparatus including an aspect including a conversion unit configured to determine the dot formation state based on a pixel value and a distributed error in a conversion target pixel included in a plurality of pixels constituting the image data, and a diffusion unit configured to diffuse an error generated in the conversion target pixel, in accordance with a distribution ratio set for each of a plurality of distribution destination pixels that are not converted, to the plurality of distribution destination pixels wherein a total sum obtained by multiplying the distribution ratio set for each of the distribution destination pixels by a relative position of the distribution destination pixel in the first direction with respect to the conversion target pixel is a first direction total sum, and the first direction total sum is not 0, a total sum obtained by multiplying the distribution ratio set for each of the distribution destination pixels by a relative position of the distribution destination pixel in the second direction with respect to the conversion target pixel is a second direction total sum, and the second direction total sum is not 0, a ratio of the second direction total sum to the first direction total sum is a total sum ratio, a ratio of the second direction resolution to the first direction resolution is a resolution ratio, the total sum ratio when the resolution ratio is a first resolution ratio is a first total sum ratio, the total sum ratio when the resolution ratio is a second resolution ratio greater than the first resolution ratio is a second total sum ratio, and each of the distribution ratios is set for the distribution destination pixel so that the second total sum ratio is greater than the first total sum ratio.

(6) Further, a printing apparatus of the present disclosure includes an aspect including the image processing apparatus, and a printing unit configured to form a print image having the first direction resolution in the first direction and the second direction resolution in the second direction on a medium in accordance with the dot data.

(7) Further, an image processing method of the present disclosure is an image processing method of converting image data in which a first direction resolution in a first direction and a second direction resolution in a second direction intersecting the first direction are set into dot data representing a dot formation state by an error diffusion method, the image processing method including an aspect including a conversion step for determining the dot formation state based on a pixel value and a distributed error in a conversion target pixel included in a plurality of pixels constituting the image data, and a diffusion step for diffusing an error generated in the conversion target pixel, in accordance with a distribution ratio set for each of a plurality of distribution destination pixels that are not converted, to the plurality of distribution destination pixels wherein a total sum obtained by multiplying the distribution ratio set for each of the distribution destination pixels by a relative position of the distribution destination pixel in the first direction with respect to the conversion target pixel is a first direction total sum, and the first direction total sum is not 0, a total sum obtained by multiplying the distribution ratio set for each of the distribution destination pixels by a relative position of the distribution destination pixel in the second direction with respect to the conversion target pixel is a second direction total sum, and the second direction total sum is not 0, a ratio of the second direction total sum to the first direction total sum is a total sum ratio, a ratio of the second direction resolution to the first direction resolution is a resolution ratio, the total sum ratio when the resolution ratio is a first resolution ratio is a first total sum ratio, the total sum ratio when the resolution ratio is a second resolution ratio greater than the first resolution ratio is a second total sum ratio, and each the distribution ratios is set for the distribution destination pixel so that the second total sum ratio is greater than the first total sum ratio.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a diagram schematically illustrating an example of an image processing apparatus.
(2) FIG. **2** is a diagram schematically illustrating an example of a nozzle surface of a printing head and a dot pattern on a medium.
(3) FIG. **3** is a diagram schematically illustrating an example of halftone processing by an error diffusion method.
(4) FIG. **4** is a diagram schematically illustrating an example of resolutions of a print image.
(5) FIG. **5** is a diagram schematically illustrating an example of distribution ratio tables in accordance with resolution ratios.
(6) FIG. **6** is a diagram schematically illustrating an example in which an angle θs calculated from the distribution ratio table is matched with an angle θr based on a resolution ratio Ry/Rx.
(7) FIG. **7** is a diagram schematically illustrating an example in which the angle θs calculated from the distribution ratio table is matched with the angle θr based on the resolution ratio Ry/Rx.
(8) FIG. **8** is a flowchart schematically illustrating an example of print control processing.
(9) FIG. **9** is a flowchart schematically illustrating an example of halftone processing.
(10) FIG. **10** is a diagram schematically illustrating an example in which dots are arranged so as to be evenly dispersed by bringing a total sum ratio calculated from a distribution ratio close to a resolution ratio.
(11) FIG. **11** is a flowchart schematically illustrating another example of the print control processing.

DESCRIPTION OF EMBODIMENTS

(12) Embodiments of the present disclosure will be described. Of course, the following embodiments only illustrate the present disclosure, and not all features illustrated in the embodiments are indispensable for the solution of the disclosure.

(1) Overview of Technology Included in Present Disclosure

(13) First of all, an overview of technique included in the present disclosure will be described with reference to examples illustrated in FIG. **1** to FIG. **11**. Note that the drawings of the present application schematically illustrate the examples, that an enlargement factor in each direction illustrated in each drawing may vary among the drawings, and that the drawings may not be consistent with one another. Of course, the elements of the technology are not limited to specific examples illustrated with reference numerals. Note that in the section “Overview of technology included in present disclosure”, a word included in parentheses is for supplementary description of the immediately preceding word.

(14) Aspect 1

(15) As illustrated in FIGS. **1**, **3** and **9**, an image processing apparatus U**0** according to an aspect of the present technology is the image processing apparatus U**0** capable of converting image data (for example, ink amount data DA**2**) in which a first direction resolution (for example, a resolution Rx) in a first direction (for example, an X direction) and a second direction resolution (for example, a resolution Ry) in a second direction (for example, a Y direction) intersecting the first direction into dot data DA**3** representing a formation state of a dot **38** by an error diffusion method, and includes a conversion unit U**1** and a diffusion unit U**2**. The conversion unit U**1** determines the formation state of the dot **38** based on a pixel value MP**0** and a distributed error EP**0** in a conversion target pixel P**0** included in a plurality of pixels PX**0** constituting the image data (DA**2**). The diffusion unit U**2** diffuses an error E**0** generated in the conversion target pixel P**0**, in accordance with a distribution ratio Ri set for each of a plurality of distribution destination pixels Qi that are not converted, to the plurality of distribution destination pixels Qi. Here, as illustrated in FIGS. **4** and **5**, a total sum obtained by multiplying the distribution ratio Ri set for each of the distribution

destination pixels Qi by a relative position (for example, Δxi) of the distribution destination pixel Qi in the first direction with respect to the conversion target pixel P**0** is a first direction total sum (for example, a total sum Sx) that is not 0, a total sum obtained by multiplying the distribution ratio Ri set for each of the distribution destination pixels Qi by a relative position (for example, Δyi) of the distribution destination pixel Qi in the second direction with respect to the conversion target pixel P**0** is a second direction total sum (for example, a total sum Sy) that is not 0, a ratio of the second direction total sum (Sy) to the first direction total sum (Sx) is a total sum ratio (for example Sy/Sx), a ratio of the second direction resolution (Ry) to the first direction resolution (Rx) is a resolution ratio (for example Ry/Rx), the total sum ratio (Sy/Sx) when the resolution ratio (Ry/Rx) is a first resolution ratio RR**1** is a first total sum ratio SR**1**, and the total sum ratio (Sy/Sx) when the resolution ratio (Ry/Rx) is a second resolution ratio RR**2** greater than the first resolution ratio RR**1** is a second total sum ratio SR**2**. Each of the distribution ratios Ri is set for the distribution destination pixel Qi so that the second total sum ratio SR**2** is greater than the first total sum ratio SR**1**.
(16) As described above, the dot data DA**3** in which the dots **38** are arranged so as to be more evenly dispersed in accordance with the resolution ratio (Ry/Rx) of an image is generated. Therefore, the above aspect can provide an image processing apparatus that contributes to improvement in granularity in accordance with a resolution ratio of an image.
(17) In the present application, “first”, “second”, . . . are terms for distinguishing components included in a plurality of components having similarities, and do not indicate an order. Which components among the plurality of components “first”, “second”, . . . are applied to is relatively determined. For example, when a plurality of pixels of image data are arranged in the X direction and the Y direction, the Y direction corresponds to the second direction when the X direction corresponds to the first direction, and the X direction corresponds to the second direction when the Y direction corresponds to the first direction.
(18) The dot data may be binary data indicating whether a dot is formed, or may be data indicating three values or more including a size of the dot.
(19) Note that the description above also applies to the following aspects.
(20) Aspect 2
(21) As illustrated in FIGS. **5** to **7**, each of the distribution ratio Ri may be set for the distribution destination pixel Qi such that the total sum ratio (Sy/Sx) matches the resolution ratio (Ry/Rx).
(22) In the above case, the dots **38** are arranged so as to be more evenly dispersed in accordance with the resolution ratio (Ry/Rx) of an image. Thus, the aspect described above can provide a suitable example that improves image quality in terms of granularity.
(23) Aspect 3
(24) As illustrated in FIG. **3**, the image data (DA**2**) may have the pixel value for at least cyan, magenta and yellow for each of the pixels PX**0**. As illustrated in FIG. **11**, the present image processing apparatus may convert the image data (DA**2**) into the dot data DA**3** by the error diffusion method when the dots **38** of at least one of the cyan and the magenta are formed with the yellow as a background.
(25) When the dots **38** of at least one of cyan and magenta are sparsely formed with yellow as a background, and an arrangement of the dots **38** is biased, uncomfortable feeling may occur. In the above-described aspect, when the dots **38** of at least one of cyan and magenta are formed with yellow as a background, the dots **38** are arranged so as to be more evenly dispersed according to the resolution ratio (Ry/Rx) of an image, and thus it is possible to improve image quality of an output image.
(26) Aspect 4
(27) As illustrated in FIG. **5**, when the first direction resolution (Rx) is greater than the second direction resolution (Ry), a range in which the plurality of distribution destination pixels Qi are arranged in the first direction may be wider than a range in which the plurality of distribution

destination pixels Qi are arranged in the second direction. When the second direction resolution (Ry) is greater than the first direction resolution (Rx), the range in which the plurality of distribution destination pixels Qi are arranged in the second direction may be wider than the range in which the plurality of distribution destination pixels Qi are arranged in the first direction.
(28) When the first direction resolution (Rx) is greater than the second direction resolution (Ry), the range in which the plurality of distribution destination pixels Qi are arranged in the first direction is wider than the range in which the plurality of distribution destination pixels Qi are arranged in the second direction, and thus a range in which an error is diffused is wider in the first direction than in the second direction. As a result, the dots **38** are arranged so as to be more evenly dispersed in accordance with the resolution ratio (Ry/Rx) of the image. On the other hand, when the second direction resolution (Ry) is greater than the first direction resolution (Rx), the range in which the plurality of distribution destination pixels Qi are arranged in the second direction is wider than the range in which the plurality of distribution destination pixels Qi are arranged in the first direction, so that the range in which an error is diffused is wider in the second direction than in the first direction. As a result, the dots **38** are arranged so as to be more evenly dispersed in accordance with the resolution ratio (Ry/Rx) of the image. Thus, the aspect described above can provide a suitable example that improves image quality in terms of granularity.
(29) Aspect 5
(30) Incidentally, as illustrated in FIG. **1**, the printing apparatus **1** according to an aspect of the present technology includes the image processing apparatus U**0** described above and a printing unit U**3** that forms a print image IM**0** having the first direction resolution (Rx) in the first direction and the second direction resolution (Ry) in the second direction on a medium ME**0** in accordance with the dot data DA**3**.
(31) As described above, the dots **38** are arranged so as to be more evenly dispersed in accordance with the resolution ratio (Ry/Rx) of the print image IM**0**. Therefore, the aspect described above can provide a printing apparatus that contributes to improvement of granularity in accordance with a resolution ratio of a print image.
(32) Aspect 6
(33) In addition, an image processing method according to an aspect of the present technology is an image processing method of converting image data (DA**2**) in which a first direction resolution (Rx) in a first direction and a second direction resolution (Ry) in a second direction intersecting the first direction are set into dot data DA**3** representing a formation state of the dot **38** by an error diffusion method, and includes the following steps. (A1) A conversion step ST**1** of determining a formation state of the dot **38** based on the pixel value MP**0** and the distributed error EP**0** in the conversion target pixel P**0** included in the plurality of pixels PX**0** constituting the image data (DA**2**). (A2) A diffusion step ST**2** of diffusing the error E**0** generated in the conversion target pixel P**0** to the plurality of distribution destination pixels Qi in accordance with the distribution ratio Ri set for each of the plurality of distribution destination pixels Qi that are not converted.
(34) Here, as illustrated in FIGS. **4** and **5**, a total sum obtained by multiplying the distribution ratio Ri set for each of the distribution destination pixels Qi by a relative position (Δxi) of the distribution destination pixel Qi in the first direction with respect to the conversion target pixel P**0** is a first direction total sum (Sx) that is not 0, a total sum obtained by multiplying the distribution ratio Ri set for each of the distribution destination pixels Qi by a relative position (Δyi) of the distribution destination pixel Qi in the second direction with respect to the conversion target pixel P**0** is a second direction total sum (Sy) that is not 0, a ratio of the second direction total sum (Sy) to the first direction total sum (Sx) is a total sum ratio (Sy/Sx), a ratio of the second direction resolution (Ry) to the first direction resolution (Rx) is a resolution ratio (Ry/Rx), the total sum ratio (Sy/Sx) when the resolution ratio (Ry/Rx) is a first resolution ratio RR**1** is a first total sum ratio SR**1**, and the total sum ratio (Sy/Sx) when the resolution ratio (Ry/Rx) is a second resolution ratio RR**2** greater than the first resolution ratio RR**1** is a second total sum ratio SR**2**. Each of the

distribution ratios Ri is set for the distribution destination pixel Qi so that the second total sum ratio SR**2** is greater than the first total sum ratio SR**1**.
(35) As described above, the dot data DA**3** in which the dots **38** are arranged so as to be more evenly dispersed in accordance with the resolution ratio (Ry/Rx) of an image is generated. Therefore, the above aspect can provide an image processing method that contributes to improvement in granularity in accordance with a resolution ratio of an image.
(36) Further, the present technique can be applied to a printing system including the image processing apparatus described above, a method of controlling the image processing apparatus described above, a control program for the image processing apparatus described above, a control program for the printing system described above, a computer-readable recording medium in which any of the control programs described above is recorded, and the like. Further, the above-described image processing apparatus may include a plurality of separate units.
(2) Specific Example of Printing Apparatus Including Image Processing Apparatus
(37) FIG. **1** schematically illustrates the printing apparatus **1** including the image processing apparatus U**0**. Although the printing apparatus **1** of the specific example is a printer **2** itself, the printing apparatus **1** may be a combination of the printer **2** and a host device HO**1**. Note that the printer **2** may include additional elements not illustrated in FIG. **1**. FIG. **2** schematically illustrates a nozzle surface **30***a* of a printing head **30** and a dot pattern on the medium ME**0**.
(38) The printer **2** illustrated in FIG. **1** is a serial printer which is a type of ink jet printer. Of course, a printer to which the present technology can be applied may be a line printer having a nozzle row in which nozzles are arranged over substantially an entire width direction of a medium, an electrophotographic printer such as a laser printer in which toner as a color material is used, or the like.
(39) The printer **2** which is an ink jet system includes a controller **10**, a RAM **21** which is a semiconductor memory, a communication I/F **22**, a storage unit **23**, an operating panel **24**, the printing head **30**, a drive unit **50**, and the like. RAM is an abbreviation for Random Access Memory, and I/F is an abbreviation for interface. The controller **10**, the RAM **21**, the communication I/F **22**, the storage unit **23**, and the operating panel **24** are coupled to a bus and can input/output information to/from each other.
(40) The controller **10** includes a CPU **11** which is a processor, a color conversion unit **12**, a halftone processing unit **13**, a rasterization processing unit **14**, a drive signal transmission unit **15**, and the like. CPU is an abbreviation for Central Processing Unit. The halftone processing unit **13** is an example of the image processing apparatus U**0** including the conversion unit U**1** and the diffusion unit U**2**. The controller **10** controls main scanning and sub scanning by the drive unit **50** and discharging of ink droplets **37** by the printing head **30** based on original image data DA**1** acquired from the host device HO**1**, a memory card (not illustrated), or the like. The original image data DA**1** may be applied with, for example, RGB data having 2.sup.8-tone or 2.sup.16-tone integer values for R, G and B for each pixel. Here, R means red, G means green, and B means blue.
(41) The controller **10** can be configured by a SoC or the like. SoC is an abbreviation for System on a Chip.
(42) The CPU **11** serves as a core device in performing information processing and control in the printer **2**.
(43) The color conversion unit **12** refers to a color conversion LUT defining, for example, correspondence relationship between a tone value for R, G and B and a tone value for C, M, Y and K, and converts the RGB data into the ink amount data DA**2** having a 2.sup.8-tone or 2.sup.16-tone integer value for C, M, Y and K for each pixel. Here, C means cyan, M means magenta, Y means yellow, K means black, and LUT is an abbreviation for look-up table. The ink amount data DA**2** indicates used amounts of ink **36** of C, M, Y and K in units of pixels PX**0** (see FIG. **2**). Further, when resolutions of RGB data are different from output resolutions Rx and Ry (see FIG. **4**), the color conversion unit **12** first converts the resolutions of the RGB data into the output resolutions

Rx and Ry, or converts resolutions of the ink amount data DA**2** into the output resolutions Rx and Ry. The ink amount data DA**2** having the output resolutions Rx and Ry is an example of image data in which the output resolutions Rx and Ry are set.

(44) The halftone processing unit **13** performs halftone processing by an error diffusion method on a tone value of each pixel PX**0** constituting the ink amount data DA**2**, to reduce the number of tones of the tone value and generate the dot data DA**3**. The dot data DA**3** represents a formation state of the dot **38** in units of pixels PX**0**. The dot data DA**3** may be binary data indicating whether a dot is formed, or may be three-or-more-tone multivalued data that can support dots of different sizes such as small, medium, and large.

(45) The rasterization processing unit **14** generates raster data RA**0** by performing rasterization processing of rearranging the dot data DA**3** in an order in which the dots **38** are formed by the drive unit **50**.

(46) The drive signal transmission unit **15** uses the raster data RA**0** to generate a drive signal SG**1** corresponding to a voltage signal to be applied to a drive element **32** of the printing head **30**, and outputs the drive signal SG**1** to a drive circuit **31** of the printing head **30**. For example, when the raster data RAO corresponds to "dot formation", the drive signal transmission unit **15** outputs the drive signal SG**1** for discharging ink droplets for forming dots. When the raster data RA**0** is four-valued data, the drive signal transmission unit **15** outputs the drive signal SG**1** for discharging ink droplets for a large dot when the raster data RA**0** corresponds to "large dot formation", outputs the drive signal SG**1** for discharging ink droplets for a medium dot when the raster data RA**0** corresponds to "medium dot formation", and outputs the drive signal SG**1** for discharging ink droplets for a small dot when the raster data RA**0** corresponds to "small dot formation".

(47) Note that when the printer **2** is a line printer, the rasterization processing unit **14** need not be present at the controller **10**, and the drive signal transmission unit **15** may generate the drive signal SG**1** from the dot data DA**3**.

(48) The components **11** to **15** described above may each be formed by an ASIC that directly reads processing target data from the RAM **21** and directly writes the processed data to the RAM **21**. Here, the ASIC is an abbreviation for "Application Specific Integrated Circuit".

(49) The drive unit **50** controlled by the controller **10** includes a carriage drive unit **51** and a roller drive unit **55**. In the drive unit **50**, the carriage drive unit **51** drives a carriage **52** to move back and forth along a main scanning direction D**1**, and sends the medium ME**0** by driving of the roller drive unit **55** in a send direction D**3** along a transport path **59**. As illustrated in FIG. **2**, the main scanning direction D**1** is a direction intersecting an arrangement direction D**4** of nozzles **34**, and is a direction orthogonal to the arrangement direction D**4**, for example. The send direction D**3** is a direction intersecting the main scanning direction D**1**, and is a direction orthogonal to the main scanning direction D**1**, for example. In FIG. **1**, the send direction D**3** is a direction toward the right side. Thus, the left side and the right side thereof are respectively referred to as an upstream side and a downstream side. A sub scanning direction D**2** illustrated in FIG. **2** is a direction opposite to the send direction D**3**. The carriage drive unit **51** reciprocates the carriage **52** along the main scanning direction D**1** in accordance with the control of the controller **10**. It can be said that the carriage drive unit **51** performs the main scanning in which a relative positional relationship between the printing head **30** and the medium ME**0** is changed along the main scanning direction D**1**. The roller drive unit **55** includes a transport roller pair **56** and a discharge roller pair **57**. Under the control by the controller **10**, the roller drive unit **55** performs the sub scanning for sending the medium ME**0** in the send direction D**3**, by rotating a driving transport roller of the transport roller pair **56** and a driving discharge roller of the discharge roller pair **57**. It can be said that the roller drive unit **55** performs the sub scanning in which a relative positional relationship between the printing head **30** and the medium ME**0** is changed along the sub scanning direction D**2** intersecting the main scanning direction D**1**. The medium ME**0** is a material holding a print image thereon, and is formed of paper, resin, metal, or the like. The material of the medium ME**0** is not particularly

limited, and various materials such as resin, metal, and paper may be used. A shape of the medium ME**0** is also not particularly limited, and may be various shapes such as a rectangular shape and a roll shape, and may even be a three-dimensional shape.

(50) The carriage **52** is mounted with the printing head **30**. The carriage **52** may be mounted with an ink cartridge **35** from which the ink **36** to be discharged as the ink droplets **37** is supplied to the printing head **30**. Of course, the ink **36** may be supplied to the printing head **30** through a tube from the ink cartridge **35** installed outside the carriage **52**. The carriage **52** is fixed to an endless belt (not illustrated), and is capable of moving in the main scanning direction D**1** along a guide **53**. The guide **53** is an elongated member with a longitudinal direction extending along the main scanning direction D**1**. The carriage drive unit **51** is configured with a servomotor, and reciprocates the carriage **52** along the main scanning direction D**1** in accordance with an instruction from the controller **10**.

(51) The transport roller pair **56** upstream of the printing head **30** sends the medium ME**0** nipped therebetween toward the printing head **30** by rotation of the driving transport roller, during the sub scanning. The discharge roller pair **57** downstream of the printing head **30** transports the medium ME**0** nipped therebetween toward a medium discharge unit (not illustrated), by rotation of the driving discharge roller, during the sub scanning. The roller drive unit **55** is configured with a servomotor, and operates the transport roller pair **56** and the discharge roller pair **57** to send the medium ME**0** in the send direction D**3**, in accordance with an instruction from the controller **10**.

(52) A platen **58** is on a lower side of the transport path **59**, and supports the medium ME**0** on the transport path **59**, by being in contact with the medium ME**0**. The printing head **30** controlled by the controller **10** discharges the ink droplets **37** toward the medium ME**0** supported by the platen **58**. Thus, the ink **36** adheres to the medium ME**0**.

(53) The printing head **30** including the drive circuit **31**, the drive element **32**, and the like includes the nozzle surface **30***a* provided with the plurality of nozzles **34** that discharge the ink droplets **37**, and discharges the ink droplets **37** onto the medium ME**0** on the platen **58**, to perform printing. Here, the nozzle row is a row of a plurality of nozzles that are each a small hole through which the ink droplets are ejected. The nozzle surface **30***a* is a surface from which the ink droplets **37** are discharged. The drive circuit **31** applies a voltage signal to the drive element **32** in accordance with the drive signal SG**1** input from the drive signal transmission unit **15**. The drive element **32** may be a piezoelectric element that applies pressure to the ink **36** in a pressure chamber in communication with the nozzles **34**, a drive element that produces bubbles in the pressure chamber using heat to discharge the ink droplets **37** from the nozzles **34**, and the like. The pressure chamber of the printing head **30** is supplied with the ink **36** from the ink cartridge **35**. The drive element **32** makes the ink **36** in the pressure chamber discharged as the ink droplets **37** onto the medium ME**0**, from the nozzles **34**. As a result, the dot **38** of the ink droplets **37** is formed on the medium ME**0**. Formation of the dot **38** according to the raster data RA**0** while the printing head **30** moves in the main scanning direction D**1**, and sending the medium ME**0** in the send direction D**3** for the sub scanning performed once are repeated to form the print image IM**0** on the medium ME**0**.

(54) The controller **10** including the rasterization processing unit **14** and the drive signal transmission unit **15**, the printing head **30**, and the drive unit **50** are an example of the printing unit U**3** that forms the print image IM**0** with the output resolutions Rx and Ry on the medium ME**0** in accordance with the dot data DA**3**.

(55) The RAM **21** stores the original image data DA**1** and the like received from the host device HO**1**, a memory (not illustrated), or the like. The communication I/F **22** is coupled to the host device HO**1** wirelessly or using a wire, and inputs/outputs information from/to the host device HO**1**. The host device HO**1** includes a computer such as a personal computer and a tablet terminal, a mobile phone such as a smart phone, a digital camera, a digital video camera, and the like. The storage unit **23** may be a nonvolatile semiconductor memory such as a flash memory, a magnetic storage device such as a hard disk, or the like. The operating panel **24** includes an output unit **25**

such as a liquid crystal panel that displays information, an input unit **26** such as a touch panel that receives an operation on a display screen, and the like.

(56) The printing head **30** illustrated in FIG. **2** includes a plurality of nozzle rows **33** each including the plurality of nozzles **34** arranged in the arrangement direction D**4** at a predetermined interval, that is, a nozzle pitch, at the nozzle surface **30***a*. The plurality of nozzle rows **33** include a cyan nozzle row **33**C for discharging the ink droplets **37** corresponding to C, a magenta nozzle row **33**M for discharging the ink droplets **37** corresponding to M, a yellow nozzle row **33**Y for discharging the ink droplets **37** corresponding to Y, and a black nozzle row **33**K for discharging the ink droplets **37** corresponding to K. Each ink droplet **37** is discharged from the nozzle **34** targeting the pixel ME**0** of the medium PX**0**. Of course, the dot **38** corresponding to C is formed on the medium ME**0** from the ink droplets **37** corresponding to C, the dot **38** corresponding to M is formed on the medium ME**0** from the ink droplets **37** corresponding to M, the dot **38** corresponding to Y is formed on the medium ME**0** from the ink droplets **37** corresponding to Y, and the dot **38** corresponding to K is formed on the medium ME**0** from the ink droplets **37** corresponding to K. Each of the nozzle rows **33** discharges the ink droplets **37** toward the medium ME**0**. The plurality of nozzles **34** included in each nozzle row **33** may be arranged in a single row, or may be arranged in a staggered manner, that is, in two rows.

(57) FIG. **3** schematically illustrates the halftone processing performed by the halftone processing unit **13** that converts the ink amount data DA**2** into the dot data DA**3**. In FIG. **3**, each pixel PX**0** of the ink amount data DA**2** and the dot data DA**3** is indicated by a square, and the conversion target pixel P**0** is indicated by a thick line. When the ink amount data DA**2** is 256-tone, the ink amount data DA**2** has a tone value C.sub.256 for C, a tone value M.sub.256 for M, a tone value Y.sub.256 for Y, and a tone value K.sub.256 for K for each pixel PX**0**. The dot data DA**3** has a dot value C.sub.d for C, a dot value M.sub.d for M, a dot value Y.sub.d for Y, and a dot value K.sub.d for K for each pixel PX**0**. In the conversion target pixel P**0**, the pixel value MP**0** of the conversion target pixel P**0** is illustrated in an upper row, and the generated error E**0** is illustrated in a lower row. In a plurality of distribution destination pixels Q**1** to Q**6** to which the error E**0** is distributed in accordance with distribution ratios R**1** to R**6**, pixel values M**1** to M**6** of the distribution destination pixels Q**1** to Q**6** are illustrated in upper rows, and errors E**1** to E**6** distributed from the conversion target pixel P**0** are illustrated in lower rows. Here, the distribution destination pixels Q**1** to Q**6** are collectively referred to as a distribution destination pixel Qi, the distribution ratios R**1** to R**6** are collectively referred to as a distribution ratio Ri, the pixel values M**1** to M**6** are collectively referred to as a pixel value Mi (not illustrated), and the errors E**1** to E**6** are collectively referred to as an error Ei. In a converted pixel PX**2**, a tone value based on the 256-tone ink amount data DA**2** is illustrated as a tone value corresponding to a dot value, for convenience.

(58) The ink amount data DA**2** and the dot data DA**3** include the plurality of pixels PX**0** arranged orderly in the X direction, which is a horizontal direction in FIG. **3**, and in the Y direction, which is a vertical direction in FIG. **3**. Here, the X direction is an example of the first direction, and the Y direction is an example of the second direction. The X direction and the Y direction intersect each other, and are orthogonal to each other in FIG. **3**. In FIG. **3**, it is assumed that the origin of XY coordinates is located in the upper left, an X coordinate closer to a right side is larger, and a Y coordinate closer to a lower side is larger. As an arrow illustrated in an upper part of FIG. **3**, the conversion target pixel P**0** is first set at an origin pixel at an upper left corner and then set at pixels up to a pixel at an upper right corner in an ascending order of the X coordinates, then is moved downward by one row, set at a pixel at left end and then set at pixels up to a pixel at a right end in an ascending order of the X coordinates, this setting order is repeated and ends with a pixel at a lower right corner. According to this setting order, the converted pixels PX**2** are upper pixels each having a smaller Y coordinate than that of the conversion target pixel P**0**, and left pixels each having the same Y coordinate as that of the conversion target pixel P**0** and a smaller X coordinate than that of the conversion target pixel P**0**. Further, unconverted pixels PX**1** are right pixels each

having the same Y coordinate as the conversion target pixel P**0** and an X coordinate greater than that of the conversion target pixel P**0**, and lower pixels each having a Y coordinate greater than that of the conversion target pixel P**0**. The distribution destination pixel Qi is selected from the unconverted pixels PX**1** existing on either the right side or the lower side of the conversion target pixel P**0**.
(59) Note that since the ink amount data DA**2** is prepared for each color, the dot data DA**3** is generated for each color. For example, when the ink amount data DA**2** is prepared for C, M, Y and K, the dot data DA**3** is generated for C, M, Y and K.
(60) The conversion unit U**1** included in the halftone processing unit **13** determines a formation state of the dot **38** in the conversion target pixel P**0** based on the pixel value MP**0** and the distributed error EP**0**. For example, when the dot data DA**3** is binary data representing whether the dot **38** is formed, the conversion unit U**1** determines a dot value of the conversion target pixel P**0** to be 0 corresponding to "no dot" or 1 corresponding to "dot formation". In FIG. **3**, a 256-tone value 0 corresponding to the dot value 0, or a 256-tone value 255 corresponding to the dot value 1 is illustrated in each converted pixel PX**2**.
(61) The diffusion unit U**2** included in the halftone processing unit **13** calculates the error E**0** associated with the dot value determination in the conversion target pixel P**0**, and diffuses the generated error E**0** to the plurality of distribution destination pixels Qi in accordance with the distribution ratios Ri respectively set for the plurality of distribution destination pixels Qi that are not converted. The diffusion unit U**2** determines the error Ei to be distributed to each distribution destination pixel Qi by multiplying the error E**0** by the distribution ratio Ri determined from a distribution ratio table TA**0** illustrated in a lower part of FIG. **3**. For example, in the distribution ratio table TA**0** illustrated in FIG. **3**, based on the conversion target pixel P**0**, a weight of 4 is assigned to each of the distribution destination pixels Q**1** and Q**4**, a weight of 3 is assigned to the distribution destination pixel Q**2**, a weight of 2 is assigned to each of the distribution destination pixels Q**3** and Q**5**, and a weight of 1 is assigned to the distribution destination pixel Q**6**. Since a total of the weights assigned to the distribution destination pixels Q**1** to Q**6** is 16, each of the distribution ratios R**1** and R**4** is 4/16, the distribution ratio R**2** is 3/16, each of the distribution ratios R**3** and R**5** is 2/16, and the distribution ratio R**6** is 1/16.
(62) Note that since the error distributed to each distribution destination pixel Qi may be derived from the plurality of converted pixels PX**2**, errors other than the errors E**1** to E**6** illustrated in FIG. **3** may be included.
(63) As illustrated in FIG. **4**, the resolutions Rx and Ry may be set for the print image IM**0** in various ways. FIG. **4** schematically illustrates the various resolutions for the print image IM**0**. Here, the resolution Rx in the X direction is an example of a first direction resolution in the first direction, the resolution Ry in the Y direction is an example of a second direction resolution in the second direction, and the resolution ratio Ry/Rx is an example of a ratio of the second direction resolution to the first direction resolution.
(64) For example, when the resolution Rx is 2400 dpi, this means that the plurality of pixels PX**0** included in the print image IM**0** are arranged at a density of 2400 pixels per inch in the X direction. When the resolution Ry is 600 dpi, this means that the plurality of pixels PX**0** included in the print image IM**0** are arranged at a density of 600 pixels per inch in the Y direction. Therefore, when Rx×Ry=2400×600 dpi, on the print image IM**0**, an interval between the pixels PX**0** in the X direction is 1/4 of an interval between the pixels PX**0** in the Y direction, and the interval between the pixels PX**0** in the X direction is different from the interval between the pixels PX**0** in the Y direction. Conversely, when Rx×Ry=600×2400 dpi, on the print image IM**0**, the interval between the pixels PX**0** in the X direction is four times the interval between the pixels PX**0** in the Y direction, and the interval between the pixels PX**0** in the X direction is different from the interval between the pixels PX**0** in the Y direction. Of course, when both the resolutions Rx and Ry are 600 dpi, the interval between the pixels PX**0** in the X direction and the interval between the pixels PX**0**

in the Y direction are the same.

(65) When the halftone processing by the error diffusion method was performed in accordance with a common distribution ratio table for the various resolution ratios Ry/Rx, it was found that bias occurs in a dot arrangement depending on the resolution ratio Ry/Rx. For example, when a print image in which the resolution Ry in the Y direction is different from the resolution Rx in the X direction is formed using a distribution ratio table designed on the assumption of Ry=Rx, an undesired sequence of dots called a worm occurred in a low-tone portion in some cases. As described above, depending on the resolution ratio Ry/Rx, bias occurs in the dot arrangement, and particularly in a low-tone portion in a print image, the bias may appear as a decrease in granularity.

(66) In the specific example, by switching the distribution ratio table TA**0** in accordance with the resolution ratio Ry/Rx, the dots **38** are more evenly dispersed, and image quality of the print image IM**0** is improved in terms of granularity.

(67) Note that for convenience of description, one of the resolution ratios Ry/Rx at a plurality of stages is referred to as a first resolution ratio RR**1**, and a resolution ratio greater than the first resolution ratio RR**1** is referred to as a second resolution ratio RR**2**. FIG. **4** illustrates that Ry/Rx=1/4 is applied to the first resolution ratio RR**1** and Ry/Rx=1/2 is applied to the second resolution ratio RR**2**. Of course, since the first resolution ratio RR**1** and the second resolution ratio RR**2** can be applied in various ways, for example, Ry/Rx=1/2 may be applied to the first resolution ratio RR**1** and Ry/Rx=1 may be applied to the second resolution ratio RR**2**.

(68) FIG. **5** schematically illustrates the distribution ratio table TA**0** in accordance with the resolution ratio Ry/Rx. As illustrated in FIG. **5**, the distribution ratio table TA**0** that depends on the resolution ratio Ry/Rx is prepared. The controller **10** illustrated in FIG. **1** holds a plurality of the distribution ratio tables TA**0** corresponding to the resolution ratios Ry/Rx. FIG. **5** illustrates distribution ratio tables TA**1**, TA**2**, TA**3**, TA**4** and TA**5** associated with resolution ratios 1/4, 1/2, 1, 2 and 4, respectively. Each distribution ratio table TA**0** has a value representing the distribution ratio Ri assigned to the distribution destination pixel Qi with respect to the conversion target pixel P**0**. For example, the distribution ratio table TA**1** has values 3, 2, 2, 2, 1, 1, 1, 3, 1 in an order for i=1 to 9, where i is a variable for identifying the n=9 distribution destination pixels Qi. Since a total sum of these values is 16, the distribution ratios Ri are 3/16, 2/16, 2/16, 2/16, 1/16, 1/16, 1/16, 3/16, 1/16 in an order for i=1 to 9.

(69) Here, a total sum obtained by adding up a product of the distribution ratio Ri set for each distribution destination pixel Qi and a relative position Δxi of the distribution destination pixel Qi in the X direction with respect to the conversion target pixel P**0** for all i is a first direction total sum Sx. Further, a total sum obtained by adding up a product of the distribution ratio Ri set for each distribution destination pixel Qi and a relative position Δyi of the distribution destination pixel Qi in the Y direction with respect to the conversion target pixel P**0** for all i is a second direction total sum Sy. The total sums Sx and Sy are expressed by the following equations.

[Math. 1]

(70)
$$Sx = \underset{i=1}{\overset{n}{.Math.}} (Ri \times \;\; xi) \quad (1) \qquad Sy = \underset{i=1}{\overset{n}{.Math.}} (Ri \times \;\; yi) \quad (2)$$

(71) Each distribution ratio Ri is set such that Sx>0 and Sy>0.

(72) For example, in the distribution ratio table TA**1**, the first direction total sum Sx and the second direction total sum Sy are as follows.

$Sx=(3\times1+2\times2+2\times3+2\times4+1\times5-1\times2-1\times1+3\times0+1\times1)/16=24/16$

$Sy=(3\times0+2\times0+2\times0+2\times0+1\times0+1\times1+1\times1+3\times1+1\times1)/16=6/16$

(73) Further, a ratio of the second direction total sum Sy to the first direction total sum Sx is a total sum ratio Sy/Sx. In each distribution ratio table TA**0**, each distribution ratio Ri is set for the distribution destination pixel Qi so that the total sum ratio Sy/Sx coincides with the resolution ratio Ry/Rx.

(74) For example, the total sum ratio Sy/Sx in the distribution ratio table TA**1** is 1/4, which

coincides with the resolution ratio Ry/Rx=1/4. The total sum ratio Sy/Sx in the distribution ratio table TA**2** is 1/2, which coincides with the resolution ratio Ry/Rx=1/2. The total sum ratio Sy/Sx in the distribution ratio table TA**3** is 1, which coincides with the resolution ratio Ry/Rx=1. The total sum ratio Sy/Sx in the distribution ratio table TA**4** is 2, which coincides with the resolution ratio Ry/Rx=2. The total sum ratio Sy/Sx in the distribution ratio table TA**5** is 4, which coincides with the resolution ratio Ry/Rx=4.
(75) In addition, the total sum ratio Sy/Sx when the resolution ratio Ry/Rx is the first resolution ratio RR**1** is the first total sum ratio SR**1**, and the total sum ratio Sy/Sx when the resolution ratio Ry/Rx is the second resolution ratio RR**2** greater than the first resolution ratio RR**1** is the second total sum ratio SR**2**. For example, as illustrated in FIG. **4**, it is assumed that the resolution ratio Ry/Rx=1/4 is applied to the first resolution ratio RR**1** and the resolution ratio Ry/Rx=1/2 is applied to the second resolution ratio RR**2**. In this case, as illustrated in FIG. **5**, the total sum ratio Sy/Sx=1/4 is applied to the first total sum ratio SR**1**, and the total sum ratio Sy/Sx=1/2 is applied to the second total sum ratio SR**2**. Each distribution ratio Ri is set for the distribution destination pixel Qi so that the second total sum ratio SR**2** is greater than the first total sum ratio SR**1**. Of course, since the first total sum ratio SR**1** and the second total sum ratio SR**2** can be applied in various ways, for example, Sy/Sx=Ry/Rx=1/2 may be applied to the first total sum ratio SR**1**, and Sy/Sx=Ry/Rx=1 may be applied to the second total sum ratio SR**2**.
(76) As illustrated in FIGS. **6** and **7**, matching the total sum ratio Sy/Sx with the resolution ratio Ry/Rx is equivalent to matching an angle θs=tan.sup.−1(Sy/Sx) based on the total sum ratio Sy/Sx with an angle θr=tan.sup.−1(Ry/Rx) based on the resolution ratio Ry/Rx. FIG. **6** schematically illustrates an example in which the angle θs calculated from the distribution ratio table TA**2** associated with the resolution ratio Ry/Rx=1/2 is matched with the angle θr based on the resolution ratio Ry/Rx. FIG. **7** schematically illustrates an example in which the angle θs calculated from the distribution ratio table TA**4** associated with the resolution ratio Ry/Rx=2 is matched with the angle θr based on the resolution ratio Ry/Rx.
(77) The angle θr based on the resolution ratio Ry/Rx means an internal angle of a right triangle in which a length of an adjacent side is the resolution Rx and a length of an opposite side is the resolution Ry, and is represented by an arctangent value of the resolution ratio Ry/Rx.
θ*r*=tan.sup.−1(*Ry/Rx*) (3)
(78) In the example illustrated in FIG. **4**, the angle θr when the resolution ratio Ry/Rx is 1/4 is 14.04°, the angle θr when the resolution ratio Ry/Rx is 1/2 is 26.57°, the angle θr when the resolution ratio Ry/Rx is 1 is 45.00°, the angle θr when the resolution ratio Ry/Rx is 2 is 63.43°, and the angle θr when the resolution ratio Ry/Rx is 2 is 75.96.
(79) The angle θs based on the total sum ratio Sy/Sx means an internal angle of a right triangle in which a length of an adjacent side is the first direction total sum Sx and a length of an opposite side is the second direction total sum Sy, and is represented by an arctangent value of the sum ratio Sy/Sx.
θ*s*=tan.sup.−1(*Sy/Sx*)) (4)
(80) In the example illustrated in FIG. **5**, the angle θs when the total sum ratio Sy/Sx is 1/4 is 14.04°, the angle θs when the total sum ratio Sy/Sx is 1/2 is 26.57°, the angle θs when the total sum ratio Sy/Sx is 1 is 45.00°, the angle θs when the total sum ratio Sy/Sx is 2 is 63.43°, and the angle θs when the sum ratio Sy/Sx is 2 is 75.96°.
(81) When the angle θs is equal to the angle θr, the following relationship holds.
tan.sup.−1(*Sy/Sx*)=tan.sup.−1(*Ry/Rx*)) (5)
Sy/Sx=*Ry/Rx*) (6)
(82) Therefore, matching the angle θs with the angle θr is equivalent to matching the total sum ratio Sy/Sx with the resolution ratio Ry/Rx.
(83) As illustrated in FIG. **6**, when the resolution ratio Ry/Rx is 1/2, a length of the pixels PX**0** for Rx pieces in the X direction is equal to a length of the pixels PX**0** for Ry pieces in the Y direction

in the print image IM**0**. Therefore, in the print image IM**0**, an internal angle θp of a right triangle in which a length of an adjacent side is the length of the pixels PX**0** for the Rx pieces and a length of an opposite side is the length of the pixels PX**0** for the Ry pieces is 45°. Therefore, the halftone processing by the error diffusion method is performed so that the dots **38** are evenly dispersed in both the X direction and the Y direction in accordance with the resolution ratio Ry/Rx in the print image IM**0**.
(84) As illustrated in FIG. **7**, also when the resolution ratio Ry/Rx is 2, the length of the pixels PX**0** for the Rx pieces in the X direction is equal to the length of the pixels PX**0** for the Ry pieces in the Y direction in the print image IM**0**. Therefore, in the print image IM**0**, an internal angle θp of a right triangle in which a length of an adjacent side is the length of the pixels PX**0** for the Rx pieces and a length of an opposite side is the length of the pixels PX**0** for the Ry pieces is 45°. Thus, the halftone processing by the error diffusion method is performed so that the dots **38** are evenly dispersed in both the X direction and the Y direction in accordance with the resolution ratio Ry/Rx in the print image IM**0**.
(85) Further, when the resolution Rx in the X direction is greater than the resolution Ry in the Y direction as in the distribution ratio tables TA**1** and TA**2** illustrated in FIG. **5**, a range in which the plurality of distribution destination pixels Qi are arranged in the X direction is wider than a range in which the plurality of distribution destination pixels Qi are arranged in the Y direction. As a result, a range in which an error is diffused is wider in the X direction than in the Y direction, and the halftone processing by the error diffusion method is performed so that the dots **38** are more evenly dispersed in both the X direction and the Y direction in accordance with the resolution ratio Ry/Rx in the print image IM**0**.
(86) On the other hand, when the resolution Ry in the Y direction is greater than the resolution Rx in the X direction as in the distribution ratio tables TA**4** and TA**5** illustrated in FIG. **5**, a range in which the plurality of distribution destination pixels Qi are arranged in the Y direction is wider than a range in which the plurality of distribution destination pixels Qi are arranged in the X direction. As a result, a range in which an error is diffused is wider in the Y direction than in the X direction, and the halftone processing by the error diffusion method is performed so that the dots **38** are more evenly dispersed in both the X direction and the Y direction in accordance with the resolution ratio Ry/Rx in the print image IM**0**.
(87) Note that when the resolution Rx in the X direction is equal to the resolution Ry in the Y direction as in the distribution ratio table TA**3** illustrated in FIG. **5**, a range in which the plurality of distribution destination pixels Qi are arranged in the X direction may be equal to a range in which the plurality of distribution destination pixels Qi are arranged in the Y direction. In this case, the halftone processing by the error diffusion method is performed so that the dots **38** are evenly dispersed in both the X direction and the Y direction in accordance with the resolution ratio Ry/Rx=1 in the print image IM**0**.
(3) Specific Example of Print Control Processing Including Halftone Processing by Error Diffusion Method
(88) FIG. **8** schematically illustrates print control processing including halftone processing by an error diffusion method. The print control processing illustrated in FIG. **8** is performed by the controller **10** illustrated in FIG. **1**. For example, when receiving a print job J**1** serving as the original image data DA**1** from the host device HO**1**, the controller **10** starts the print control processing. The print job J**1** is stored in, for example, the RAM **21**. FIG. **9** schematically illustrates the halftone processing performed by the controller **10**. Here, steps S**204** to S**206** correspond to the conversion unit U**1** and the conversion step ST**1**, and steps S**208** to S**210** correspond to the diffusion unit U**2** and a diffusion step ST**2**. In the following description, the term “step” may be omitted, and a reference numeral corresponding to a step may be written in parentheses. Further, the description below is given by also referring to FIGS. **1** to **7**.
(89) The print job J**1** includes a header HE**1**, a body data BO**1**, and the like. The header HE**1**

includes printing resolutions Rx and Ry. The body data BO**1** corresponds to the original image data DA**1**, and may be the original image data DA**1** itself, for example, RGB data in a bitmap format, or may be a drawing data that is converted into the original image data DA**1** by interpretation.
(90) When the print control processing starts, the controller **10** acquires the printing resolutions Rx and Ry from the print job J**1** (S**102**). Note that the controller **10** may acquire the printing resolutions Rx and Ry by receiving setting of the printing resolutions Rx and Ry with the operating panel **24**. In this case, the controller **10** may acquire the original image data DA**1** from a memory card (not illustrated) or the like.
(91) After acquiring the printing resolutions Rx and Ry, the controller **10** acquires the original image data DA**1** from the print job J**1**, the memory card, or the like, and when resolutions of the original image data DA**1** are different from the printing resolutions Rx and Ry, converts the resolutions of the original image data DA**1** into the printing resolutions Rx and Ry. Then, the controller **10** performs color conversion processing of converting the original image data DA**1** into the ink amount data DA**2** in the color conversion unit **12** (S**104**). When the original image data DA**1** is RGB data and the ink amount data DA**2** is CMK data having a 256-tone pixel value for, for example, C, M, Y and K, the controller **10** performs known color conversion processing of converting the RGB data into the CMYK data.
(92) After the color conversion processing, the controller **10** selects a distribution ratio table associated with the resolution ratio Ry/Rx from among the plurality of distribution ratio tables TA**0** in the halftone processing unit **13** (S**106**). For example, when the controller **10** holds the distribution ratio tables TA**1** to TA**5** illustrated in FIG. **5**, a distribution ratio table having the distribution ratio Ri that leads to the total sum ratio Sy/Sx matching the resolution ratio Ry/Rx is selected from among the plurality of distribution ratio tables TA**0**. Here, it is assumed that the second resolution ratio RR**2** is greater than the first resolution ratio RR**1**, the first total sum ratio SR**1** corresponds to the first resolution ratio RR**1**, and the second total sum ratio SR**2** corresponds to the second resolution ratio RR**2**. When the resolution ratio Ry/Rx is the first resolution ratio RR**1**, the distribution ratio table TA**0** that leads to the first total sum ratio SR**1** is selected, and when the resolution ratio Ry/Rx is the second resolution ratio RR**2**, the distribution ratio table TA**0** that leads to the second total sum ratio SR**2** greater than the first total sum ratio SR**1** is selected. In the examples illustrated in FIGS. **4** and **5**, when the resolution ratio Ry/Rx is 1/4, the distribution ratio table TA**1** that leads to the total sum ratio Sy/Sx of 1/4 is selected, and when the resolution ratio Ry/Rx is 1/2, the distribution ratio table TA**2** that leads to the total sum ratio Sy/Sx of 1/2 is selected.
(93) After selecting the distribution ratio table TA**0**, the controller **10** performs the halftone processing by the error diffusion method in the halftone processing unit **13** (S**108**).
(94) FIG. **9** illustrates the halftone processing performed in S**108**. The halftone processing illustrated in FIG. **9** is performed for each of the colors C, M, Y and K.
(95) When the halftone processing is started, the halftone processing unit **13** sets a position of the conversion target pixel P**0** as illustrated in FIG. **3** (S**202**). The processing in S**202** can be said to be processing of selecting a target pixel of conversion for reducing the number of tones from among the plurality of pixels PX**0** constituting the ink amount data DA**2**.
(96) After setting the position of the conversion target pixel P**0**, the halftone processing unit **13** calculates a correction value CP**0** by adding the received error EP**0** to the pixel value MP**0** in the conversion target pixel P**0** (S**204**). The received error EP**0** is an error distributed to the conversion target pixel P**0**, and when errors are distributed from a plurality of pixels, the received error EP**0** is a total of the distributed errors.
(97) After calculating the correction value CP**0**, the halftone processing unit **13** compares the correction value CP**0** with a threshold value TH**0**, and determines a dot value D**0** representing a formation state of the dot **38** in the conversion target pixel P**0** based on a result of the comparison (S**206**).

(98) For example, it is assumed that the pixel value MP**0** is a tone value from 0 to 255, the dot value DT**0** is a binary value of 0 or 1, and the threshold value TH**0** is greater than 1 and less than 255. When the correction value CP**0** is equal to or greater than the threshold value TH**0**, the halftone processing unit **13** can determine the dot value DT**0** to be 1, which means “dot formation”. When the corrected value CP**0** is less than the threshold value TH**0**, the halftone processing unit **13** can determine the dot value DT**0** to be 0 which means “no dot”. As described above, the conversion unit U**1** determines the formation state of the dot **38** based on the pixel value MP**0** and the distributed error EP**0** in the conversion target pixel P**0** included in the plurality of pixels PX**0** constituting the ink amount data DA**2**.
(99) In addition, the halftone processing unit **13** calculates the error E**0** generated along with the determination of the dot value DT**0** (S**208**). In the above-described example, when the dot value DT**0** is determined to be 1, the halftone processing unit **13** can determine a value obtained by subtracting 255 from the correction value CP**0** to be the error E**0**. When the dot value DT**0** is determined to be 0, the halftone processing unit **13** can determine the correction value CP**0** to be the error E**0**.
(100) After calculating the error E**0**, the halftone processing unit **13** diffuses the error Ei to each distribution destination pixel Qi according to the distribution ratio table TA**0** selected in accordance with the resolution ratio Ry/Rx (S**210**). The halftone processing unit **13** determines the error Ei to be distributed to each distribution destination pixel Qi by multiplying the error E**0** by the distribution ratio Ri determined from the distribution ratio table TA**0** illustrated in the lower part of FIG. **3**.
(101) As described above, the diffusion unit U**2** diffuses the error E**0** generated in the conversion target pixel P**0**, in accordance with the distribution ratio Ri set for each of the plurality of distribution destination pixels Qi that are not converted, to the plurality of distribution destination pixels Qi.
(102) After the diffusion of the error Ei, the halftone processing unit **13** determines whether the processing from S**202** to S**210** are performed with all the pixels P**0** included in the ink amount data DA**2** as the conversion target pixels P**0** or not (S**212**). When the unconverted pixel PX**1** remains as illustrated in FIG. **3**, the halftone processing unit **13** repeats the processing from S**202** to S**212**. When the unconverted pixel PX**1** does not remain, the halftone processing unit **13** ends the halftone processing illustrated in FIG. **9**. Accordingly, the dot data DA**3** having the dot value DT**0** representing the formation state of the dot **38** in each pixel PX**0** is obtained.
(103) Note that the dot value DT**0** may have three or more values. For example, when the dot value DT**0** may have four values, a first threshold value greater than 0 and less than 253 (referred to as TH**1**), a second threshold value greater than the first threshold value TH**1** and less than 254 (referred to as TH**2**), and a third threshold value greater than the second threshold value TH**2** and less than 255 (referred to as TH**3**) may be prepared. When the correction value CP**0** is equal to or greater than the threshold value TH**3**, the halftone processing unit **13** may determine the dot value DT**0** to be 3, which means “large dot formation”, and may determine a value obtained by subtracting, for example, 255 from the correction value CP**0** to be the error E**0**. When the correction value CP**0** is equal to or greater than the threshold value TH**2** and less than the threshold value TH**3**, the halftone processing unit **13** may determine the dot value DT**0** to be 2, which means “medium dot formation”, and may determine a value obtained by subtracting, for example, 128 from the correction value CP**0** to be the error E**0**. When the correction value CP**0** is equal to or greater than the threshold value TH**1** and less than the threshold value TH**2**, the halftone processing unit **13** may determine the dot value DT**0** to be 1, which means “small dot formation”, and may determine a value obtained by subtracting, for example, 64 from the correction value CP**0** to be the error E**0**. When the correction value CP**0** is less than the threshold value TH**1**, the halftone processing unit **13** may determine the dot value DT**0** to be 0, which means “no dot”, and may determine the correction value CP**0** to be the error E**0**.

(104) After the halftone processing illustrated in FIG. **9**, the controller **10** generates the raster data RA**0** by performing rasterization processing in which the dot data DA**3** is rearranged in an order in which the dots **38** are formed by the drive unit **50**, in the rasterization processing unit **14** (S**110**). Note that the rasterization processing is optional processing, and is not performed when the printer **2** is a line printer, for example.
(105) After the rasterization processing, the controller **10** generates the drive signal SG**1** corresponding to a voltage signal applied to the drive element **32** from the raster data RA**0** in the drive signal transmission unit **15**, and outputs the drive signal SG**1** to the drive circuit **31** of the printing head **30** (S**112**). As a result, the printer **2** forms the print image IM**0** having the output resolutions Rx and Ry on the medium ME**0** in accordance with the dot data DA**3** by driving the printing head **30** and the drive unit **50**. When the rasterization processing in S**110** is not performed, the controller **10** may generate the drive signal SG**1** corresponding to the voltage signal applied to the drive element **32** from the dot data DA**3** in the drive signal transmission unit **15**, and output the drive signal SG**1** to the drive circuit **31** of the printing head **30**. After the processing in S**112**, the controller **10** ends the print control processing.
(4) Actions and Effects According to Specific Example
(106) FIG. **10** schematically illustrates an example in which the dots **38** are arranged so as to be evenly dispersed by bringing the total sum ratio Sy/Sx calculated from the distribution ratio Ri close to the resolution ratio Ry/Rx. FIG. **10** schematically illustrates partial dot arrangements **111**, **112**, **121** and **122** that may appear in a low-tone portion in a print image according to the resolution ratio Ry/Rx and the total sum ratio Sy/Sx. Of course, an actual dot arrangement is not necessarily the dot arrangement **111**, **112**, **121** or **122** illustrates in FIG. **10**.
(107) When the resolution ratio Ry/Rx is 1/4 and the resolution Rx in the X direction is greater than the resolution Ry in the Y direction, and the total sum ratio Sy/Sx is 1 and weights of the distribution ratio Ri are the same in the X direction and the Y direction, a dot arrangement may be biased as in the dot arrangement **111**, for example. A bias in a dot arrangement in a low-tone portion may appear as undesired sequence of dots called a worm.
(108) Here, when halftone processing by a dither method is performed on a low-tone portion of an image using a Bayer mask that achieves a regular dot arrangement, a periodic pattern is necessarily generated in some tones. Since such a periodic pattern is conspicuous, image quality of a print image is deteriorated. When halftone processing by a dither method is performed on a low-tone portion of an image using a dither mask in which threshold values are arranged so as to exclude a tone that leads to a periodic pattern, a tone property is not secured.
(109) In the specific example, an even dot arrangement in both the X direction and the Y direction is achieved by bringing the total sum ratio Sy/Sx in the distribution ratio table TA**0** close to the resolution ratio Ry/Rx while ensuring a tone property by performing the halftone processing by the error diffusion method.
(110) For example, when the resolution ratio Ry/Rx is 1/4 and the total sum ratio Sy/Sx is matched with 1/4, the dots are evenly dispersed in both the X direction and the Y direction as in the dot arrangement **112**. Therefore, the print image IM**0** with high quality in which a tone property and an even dot arrangement are compatible is formed.
(111) When the resolution ratio Ry/Rx is 4 and the resolution Ry in the Y direction is greater than the resolution Rx in the X direction, and the total sum ratio Sy/Sx is 1 and weights of the distribution ratio Ri are the same in the X direction and the Y direction, a dot arrangement may be biased as in the dot arrangement **121**, for example. A bias in a dot arrangement in a low-tone portion may appear as undesired sequence of dots called a worm.
(112) For example, when the resolution ratio Ry/Rx is 4 and the total sum ratio Sy/Sx is matched with 4, the dots are evenly dispersed in both the X direction and the Y direction as in the dot arrangement **122**. Therefore, the print image IM**0** with high quality in which a tone property and an even dot arrangement are compatible is formed.

(113) As described above, even when the resolution Rx in the X direction and the resolution Ry in the Y direction are different from each other, the dots **38** are arranged so as to be evenly dispersed in both the X direction and the Y direction. Therefore, the specific example can improve quality of the print image IM**0** in terms of granularity particularly in a low-tone portion, and can contribute to improvement of granularity in accordance with the resolution ratio Ry/Rx of the print image IM**0**.
(5) Modified Examples
(114) Various modification examples of the present disclosure are conceivable.
(115) For example, types of color materials forming a print image on a medium are not limited to C, M, Y and K, and may include, in addition to C, M, Y and K, orange, green, light cyan with a lower density than C, light magenta with a lower density than M, dark yellow with a higher density than Y, light black with a lower density than K, a colorless color material for image quality improvement, and the like. In addition, the present technique is applicable also to a case where some of color materials of C, M, Y and K are not used.
(116) The entity that performs the above-described processing is not limited to the CPU, and may be an electronic component other than the CPU, such as an ASIC. Naturally, a plurality of CPUs may perform the above-described processing in cooperation, or a CPU and another electronic component (for example, an ASIC) may perform the above-described processing in cooperation.
(117) The above-described processing can be appropriately changed, for example, reordered. For example, in the print control processing illustrated in FIG. **8**, the distribution ratio table selection processing in S**106** can be performed immediately before the color conversion processing in S**104**.
(118) A part of the above-described processing may be performed by the host device HO**1**. In this case, a combination of the controller **10** and the host device HO**1** is an example of the printing apparatus **1**. When the host device HO**1** performs halftone processing by an error diffusion method, the host device HO**1** is an example of the image processing apparatus U**0**.
(119) Although the total sum ratio Sy/Sx is matched with the resolution ratio Ry/Rx in the above-described specific example, the total sum ratio Sy/Sx may be deviated from the resolution ratio Ry/Rx as long as the relationship between the resolution ratio (RR**1**, RR**2**) and the total sum ratio (SR**1**, SR**2**) is satisfied. For example, it is assumed that the first resolution ratio RR**1** is 1/4 and the second resolution ratio RR**2** is 1/2. In this case, the first total sum ratio SR**1** may be 11/40 increased by 10% and the second total sum ratio may be 11/20 increased by 10%, or the first total sum ratio SR**1** may be 9/40 decreased by 10% and the second total sum ratio may be 9/20 decreased by 10%. Of course, the degree of increase or decrease can be changed in various ways such as 15% increase, 5% increase, 5% decrease, 15% decrease, and the like. The same applies to a case where the first resolution ratio RR**1** is 1/2 and the second resolution ratio RR**2** is 1, a case where the first resolution ratio RR**1** is 1 and the second resolution ratio RR**2** is 2, a case where the first resolution ratio RR**1** is 2 and the second resolution ratio RR**2** is 4, and the like.
(120) Incidentally, in a low-tone portion of the print image IM**0**, graininess of the dots **38** is more noticeable when the dots **38** are formed in a plurality of colors and bleeding occurs than when the dots **38** are formed in a single color. In particular, when the dots **38** of at least one of C and M are sparsely formed with Y as a background, and the arrangement of the dots **38** is biased, uncomfortable feeling may occur. Therefore, the halftone processing by the error diffusion method described above may be performed only when the dots **38** of at least one of C and M are sparsely formed with Y as a background.
(121) FIG. **11** schematically illustrates another example of the print control processing performed by the controller **10** illustrated in FIG. **1**. Note that in the print control processing illustrated in FIG. **11**, a portion where the same processing as that in the print control processing illustrated in FIG. **8** is performed is denoted by the reference numeral illustrated in FIG. **8**, and detailed description thereof is omitted.
(122) When the print control processing illustrated in FIG. **11** is started, the controller **10** acquires the printing resolutions Rx and Ry (S**102**), and performs color conversion processing for

converting the original image data DA**1** into the ink amount data DA**2** (S**104**). The ink amount data DA**2** has a pixel value for C, M, Y and K for each pixel PX**0**. Here, it is sufficient that the ink amount data DA**2** has at least a pixel value for C, M and Y for each pixel PX**0**, and a pixel value for K need not be included.
(123) After the color conversion processing, the controller **10** determines whether to form the dots **38** of at least one of C and M with Y as a background or not in the halftone processing unit **13** based on the ink amount data DA**2** (S**302**). For example, it is assumed that the pixel value of the ink amount data DA**2** is a tone value from 0 to 255, and a threshold value (referred to as THY) for determining the background of Y is greater than 128 and less than 255. Further, it is assumed that a threshold value (referred to as THZ) for determining that the dots **38** other than Y are sparsely formed is greater than 0 and less than 127. That is, 0<THZ<THY<255. When there is a pixel for which a pixel value of Y is equal to or greater than the threshold value THY and a pixel value of at least one of C and M is equal to or less than the threshold value THZ in the plurality of pixels PX**0** constituting the ink amount data DA**2**, the controller **10** can determine that the condition is satisfied in the S**302**. On the other hand, when there is no pixel for which a pixel value of Y is equal to or greater than the threshold value THY and a pixel value of at least one of C and M is equal to or less than the threshold value THZ in the plurality of pixels PX**0** constituting the ink amount data DA**2**, the controller **10** can determine that the condition is not satisfied in the S**302**.
(124) When determining that the condition is satisfied in S**302**, the controller **10** selects the distribution ratio table TAO associated with the resolution ratio Ry/Rx in the halftone processing unit **13** (S**106**), and performs the halftone processing by the error diffusion method illustrated in FIG. **9** (S**108**). On the other hand, when determining that the condition is not satisfied in the S**302**, the controller **10** performs halftone processing different from that in S**108**, for example, halftone processing by a dither method in the halftone processing unit **13** (S**304**).
(125) After the halftone processing in S**108** or the halftone processing in S**304**, the controller **10** performs optional rasterization processing (S**110**) and outputs the drive signal SG**1** to the drive circuit **31** of the printing head **30** (S**112**). As a result, the printer **2** forms the print image IM**0** having the output resolutions Rx and Ry on the medium ME**0** in accordance with the dot data DA**3** by driving the printing head **30** and the drive unit **50**.
(126) In the example illustrated in FIG. **11**, when the dots **38** of at least one of C and M are formed with y as a background, the dots **38** are arranged so as to be more evenly dispersed in accordance with the resolution ratio Ry/Rx of the print image IM**0**, so that image quality of the print image IM**0** can be improved.
(127) Note that even when Ry>Rx and a range in which the plurality of distribution destination pixels Qi are arranged in the Y direction is not wider than a range in which the plurality of distribution destination pixels Qi are arranged in the X direction, a basic effect that contributes to improvement of granularity in accordance with the resolution ratio Ry/Rx of an image is obtained.
(128) Even when Rx>Ry and the range in which the plurality of distribution destination pixels Qi are arranged in the X direction is not wider than the range in which the plurality of distribution destination pixels Qi are arranged in the Y direction, a basic effect that contributes to improvement of granularity in accordance with the resolution ratio Ry/Rx of an image is obtained.
(6) Conclusion
(129) As described above, according to various aspects of the present disclosure, it is possible to provide a technique or the like that contributes to improvement of granularity in accordance with a resolution ratio of an image. Naturally, even technology including only the components recited in the independent claims produces the above-described basic actions and effects.
(130) Furthermore, the aspects of the present disclosure can implement configurations resulting from mutual replacement of components disclosed in the above-described examples or a change in the combination of the components, configurations resulting from mutual replacement of components disclosed in the known art and the above-described examples or a change in the

combination of the components, and the like. The aspects of the present disclosure include these configurations and the like.

Claims

1. A printing apparatus comprising: an image processing; and a print head, the image processing apparatus being configured to convert digital image data, in which a first direction resolution in a first direction and a second direction resolution in a second direction intersecting the first direction are set, into digital dot data representing a dot formation state by an error diffusion method, the image processing apparatus including a controller configured to determine the dot formation state based on a pixel value and a distributed error in a conversion target pixel included in a plurality of pixels constituting the digital image data, and diffuse an error generated in the conversion target pixel to a plurality of distribution destination pixels that are not converted, the controller holding a plurality of distribution ratio tables in each of which a total sum obtained by multiplying a distribution ratio set for each of the distribution destination pixels by a relative position of the distribution destination pixel in the first direction with respect to the conversion target pixel is a first direction total sum, and the first direction total sum is not 0, a total sum obtained by multiplying the distribution ratio set for each of the distribution destination pixels by a relative position of the distribution destination pixel in the second direction with respect to the conversion target pixel is a second direction total sum, and the second direction total sum is not 0, and a ratio of the second direction total sum to the first direction total sum is a total sum ratio, the plurality of distribution ratio tables including at least a first distribution ratio table and a second distribution ratio table, a first total sum ratio for the first distribution ratio table being the total sum ratio for a first resolution ratio that is one of resolution ratios which are settable for the digital image data and each of which indicates a ratio of the second direction resolution to the first direction resolution, a second total sum ratio for the second distribution ratio table being the total sum ratio for a second resolution ratio that is a different one of the resolution ratios and is greater than the first resolution ratio, and the second total sum ratio for the second distribution ratio table being greater than the first total sum ratio for the first distribution ratio table, and the controller being configured to diffuse the error in accordance with one of the distribution ratio tables that is selected from the distribution ratio tables based on a resolution ratio of the digital image data that is a ratio of the second direction resolution to the first direction resolution, and the print head being configured to form a print image having the first direction resolution in the first direction and the second direction resolution in the second direction on a medium in accordance with the digital dot data.
2. The printing apparatus according to claim 1, wherein the distribution ratio is set for the distribution destination pixel so that the total sum ratio matches the resolution ratio.
3. The printing apparatus according to claim 1, wherein the digital image data includes the pixel value for at least cyan, magenta and yellow for each of the pixels, and the digital image data is converted into the digital dot data by the error diffusion method when the dot of at least one of the cyan and the magenta is formed with the yellow as a background.
4. The printing apparatus according to claim 1, wherein in a distribution ratio table, among the plurality of distribution ratio tables, in which the first direction resolution is greater than the second direction resolution, a range in which the plurality of distribution destination pixels are arranged in the first direction is wider than a range in which the plurality of distribution destination pixels are arranged in the second direction, and in a distribution ratio table, among the plurality of distribution ratio tables, in which the second direction resolution is greater than the first direction resolution, the range in which the plurality of distribution destination pixels are arranged in the second direction is wider than the range in which the plurality of distribution destination pixels are arranged in the first direction.
5. A printing method and an image processing method of converting digital image data, in which a

first direction resolution in a first direction and a second direction resolution in a second direction intersecting the first direction are set, into digital dot data representing a dot formation state by an error diffusion method, the image processing method comprising: determining, by a controller, the dot formation state based on a pixel value and a distributed error in a conversion target pixel included in a plurality of pixels constituting the digital image data; diffusing, by the controller, an error generated in the conversion target pixel to a plurality of distribution destination pixels that are not converted; and forming, at a print head, a print image having the first direction resolution in the first direction and the second direction resolution in the second direction on a medium in accordance with the digital dot data, the controller holding a plurality of distribution ratio tables in each of which a total sum obtained by multiplying a distribution ratio set for each of the distribution destination pixels by a relative position of the distribution destination pixel in the first direction with respect to the conversion target pixel is a first direction total sum, and the first direction total sum is not 0, a total sum obtained by multiplying the distribution ratio set for each of the distribution destination pixels by a relative position of the distribution destination pixel in the second direction with respect to the conversion target pixel is a second direction total sum, and the second direction total sum is not 0, and a ratio of the second direction total sum to the first direction total sum is a total sum ratio, the plurality of distribution ratio tables including at least a first distribution ratio table and a second distribution ratio table, a first total sum ratio for the first distribution ratio table being the total sum ratio for a first resolution ratio that is one of resolution ratios which are settable for the digital image data and each of which indicates a ratio of the second direction resolution to the first direction resolution, a second total sum ratio for the second distribution ratio table being the total sum ratio for a second resolution ratio that is a different one of the resolution ratios and is greater than the first resolution ratio, and the second total sum ratio for the second distribution ratio table being greater than the first total sum ratio for the first distribution ratio table, and the diffusing of the error being performed in accordance with one of the distribution ratio tables that is selected from the distribution ratio tables based on a resolution ratio of the digital image data that is a ratio of the second direction resolution to the first direction resolution.