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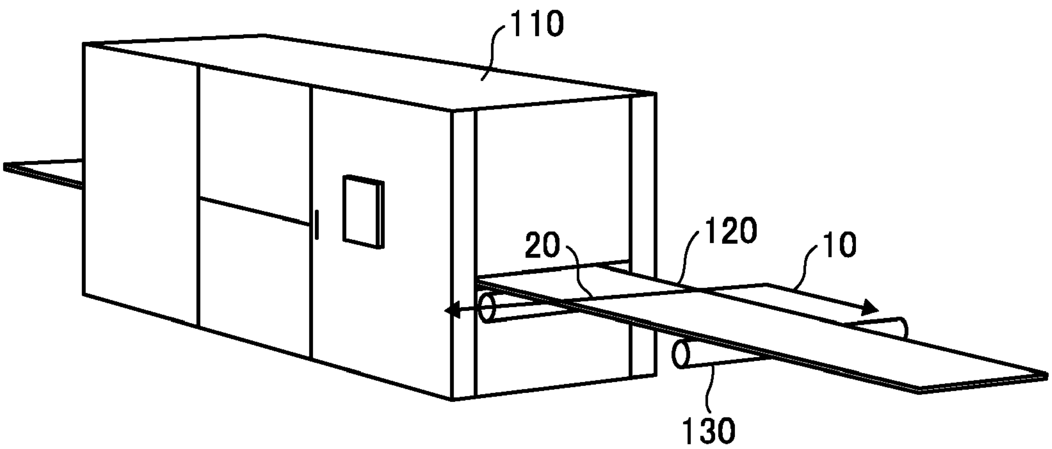
(54) IMAGE FORMING APPARATUS AND CONVEYANCE CONTROL METHOD

(57) An image forming apparatus (110) includes a conveying mechanism (230), a printing unit (210), an origin detection unit (ENC), an image capturing unit (OS), a movement-amount calculation unit (CAL), a correction unit (CAL), and a control unit (110F30). The movement-amount calculation unit calculates movement amounts of a recording medium based on correlations between captured images of the medium, and performs accumulation to calculate a cumulative movement amount. The correction unit performs correction for causing the cumulative movement amount to coincide with a reference movement amount for a predetermined cycle obtained from a mechanical configuration of the conveying mechanism, for each predetermined cycle of the conveying mechanism detected by the origin detection unit. The control unit controls the conveying mechanism, based on a corrected value of the cumulative movement amount, to perform conveyance control, and controls the printing unit to perform printing on the medium conveyed under the conveyance control.

FIG. 1



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Description

BACKGROUND

Technical Field

[0001] Embodiments of the present disclosure relate to an image forming apparatus and a conveyance control method.

Related Art

[0002] In recent years, there has been known a technology for correcting discharge timing of ink droplets in accordance with the amount of movement of a roll-shaped recording medium (web or roll paper) detected by an encoder attached to a driven roller in front of a head, to prevent deterioration in print quality.

[0003] For example, Japanese Unexamined Patent Application Publication No. 2003-266828 discloses an image forming apparatus that can convey a sheet with high accuracy regardless of the type and state of the sheet. In the image forming apparatus, a motion sensor provided in a sheet conveyance path irradiates an outer peripheral surface of an idle roller rotating together with conveyance of a sheet with laser light from a semiconductor laser. The motion sensor receives reflected light of laser light by a two-dimensional semiconductor image sensor. A sheet position detection unit detects the position of the sheet based on a speckle pattern obtained by the reflected light. Thus, the position of the sheet can be accurately detected, and the sheet can be conveyed with high accuracy.

[0004] However, conventional methods of detecting the amount of movement of the web including the technique of Japanese Unexamined Patent Application Publication No. 2003-266828 has a problem in that it is difficult to correctly detect the amount of movement of the web, when the diameter of a driven roller is changed due to thermal expansion or when eccentricity occurs in the driven roller, and the print quality is degraded.

SUMMARY

[0005] In light of the above-described problem, an object of the present invention is to provide an image forming apparatus and a conveyance control method that can detect the movement amount of a recording medium with high accuracy to enhance print quality.

[0006] According to an aspect of the present disclosure, there is provided an image forming apparatus that includes a conveying mechanism, a printing unit, an origin detection unit, an image capturing unit, a movement-amount calculation unit, a correction unit, and a control unit. The conveying mechanism conveys a recording medium. The printing unit performs printing on the recording medium. The origin detection unit is provided on the conveying mechanism. The image capturing unit captures an image of the recording medium. The movement-amount calculation unit calculates movement amounts of the recording medium based on correlations between captured images of the recording medium captured at different times with the image capturing unit, and performs accumulation processing on the movement amounts of the recording medium to calculate a cumulative movement amount. The correction unit performs correction for causing the cumulative movement amount to coincide with a reference movement amount of the recording medium for a predetermined cycle obtained from a mechanical configuration of the conveying mechanism, for each predetermined cycle of the conveying mechanism detected by the origin detection unit. The control unit controls the conveying mechanism, based on a corrected value of the cumulative movement amount obtained by the correction of the correction unit, to perform conveyance control of the recording medium, and controls the printing unit to perform printing on the recording medium that is conveyed under the conveyance control.

[0007] According to another aspect of the present disclosure, there is provided a conveyance control method that includes capturing, calculating, performing accumulation processing, performing correction, controlling the conveying mechanism, and controlling the printing unit. The capturing captures images of a recording medium conveyed by a conveying mechanism, at different times with an image capturing unit. The calculating calculates, with a movement-amount calculation unit, movement amounts of the recording medium based on correlations between the images of the recording medium captured at the different times with the image capturing unit. The performing of the accumulation processing performs, with the movement-amount calculation unit, accumulation processing on the movement amounts of the recording medium to calculate a cumulative movement amount. The performing of the correction performs, with a correction unit, correction for causing the cumulative movement amount to coincide with a reference movement amount of the recording medium for a predetermined cycle obtained from a mechanical configuration of the conveying mechanism, for each predetermined cycle of the conveying mechanism detected by an origin detection unit provided on the conveying mechanism. The controlling controls the conveying mechanism with a control unit, based on a corrected value of the cumulative movement amount obtained by the correction of the correction unit, to perform conveyance control of the recording medium.

[0008] According to the present invention, advantageous effects can be obtained that the amount of movement of a recording medium is detected with high accuracy and print quality is enhanced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] A more complete appreciation of the disclosure and many of the attendant advantages and features thereof can be readily obtained and understood from the following detailed description with reference to the accompanying drawings, wherein:

FIG. 1 is a perspective view of an external appearance of an image forming apparatus according to an embodiment of the present disclosure;
FIG. 2 is a diagram schematically illustrating a configuration of a main part of an image forming apparatus according to an embodiment of the present disclosure;
FIG. 3 is a block diagram of a sensor device disposed in the image forming apparatus;
FIG. 4 is an illustration of an external appearance of the sensor device of FIG. 3;
FIG. 5 is a block diagram of a main part of an image forming apparatus according to an embodiment of the present disclosure;
FIG. 6 is a functional block diagram of a computing unit provided in an image forming apparatus according to an embodiment of the present disclosure;
FIG. 7 is a graph representing a method of searching for a peak value in a peak-position search unit;
FIG. 8 is a graph illustrating a correlation intensity distribution of a cross-correlation function;
FIG. 9 is a graph representing an actual conveyance position of a web and a conveyance position of a web calculated based on an encoder signal;
FIG. 10 is a graph representing the amount of deviation of landing position of ink with respect to the web;
FIG. 11 is a diagram illustrating an operation of calculating a cumulative movement amount; and
FIG. 12 is a diagram illustrating an operation of correcting the cumulative movement amount.

[0010] The accompanying drawings are intended to depict embodiments of the present disclosure and should not be interpreted to limit the scope thereof. The accompanying drawings are not to be considered as drawn to scale unless explicitly noted.

DETAILED DESCRIPTION

[0011] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.
[0012] In describing embodiments illustrated in the drawings, specific terminology is employed for the sake of clarity. However, the disclosure of this specification is not intended to be limited to the specific terminology so selected and it is to be understood that each specific element includes all technical equivalents that have a similar function, operate in a similar manner, and achieve a similar result.
[0013] With reference to drawings, descriptions are given below of embodiments of the present disclosure. It is to be noted that elements (for example, mechanical parts and components) having the same functions and shapes are denoted by the same reference numerals throughout the specification and redundant descriptions are omitted.
[0014] Hereinafter, an image forming apparatus according to an embodiment of the present disclosure is described with reference to the accompanying drawings.

Overall configuration

[0015] FIG. 1 is a perspective view of an external appearance of an image forming apparatus according to an embodiment of the present disclosure that discharges ink droplets onto a roll-shaped recording medium (web or roll sheet of paper) to form an image. In FIG. 1, in an image forming apparatus 110 according to the present embodiment, the tension of a web 120 is adjusted by a roller 130 or the like, and the web 120 is conveyed in a conveyance direction 10. The image forming apparatus 110 discharges inks of four colors, for example, black (K), cyan (C), magenta (M), and yellow (Y) onto the web 120 being conveyed, to form a desired image. Hereinafter, a direction orthogonal to the conveyance direction 10 is referred to as an "orthogonal direction 20".

Configuration of Main Part

[0016] FIG. 2 is a diagram schematically illustrating a configuration of a main part of the image forming apparatus 110. As illustrated in FIG. 2, the image forming apparatus 110 includes four liquid discharge head units 210K, 210C, 210M, and 210Y (collectively referred to as liquid discharge head units 210) to discharge inks of four colors of K, C, M, and Y, respectively. The liquid discharge head units 210 discharge the respective color inks onto the web 120 conveyed in the conveyance direction 10. The web 120 is conveyed by two pairs of nip rollers and a conveying roller 230 that are an example of a conveying mechanism. One of the two pairs of nip rollers is a first nip roller pair NR1 disposed upstream from the liquid discharge head units 210 in the conveyance direction 10. The other is a second nip roller pair NR2 disposed downstream from the first nip roller pair NR1 and the liquid discharge head units 210 in the conveyance direction 10.

[0017] The image forming apparatus 110 includes an encoder ENC that is an example of an origin detection unit. The encoder ENC includes a rotary plate and a rotation sensor to read surface data of the rotary plate. The rotary plate of the encoder ENC is attached to the rotation shaft of the roller 230. As the conveying roller 230 rotates, the rotary plate rotates, and the rotation sensor outputs an encoder pulse ENP corresponding to the amount of rotation of the rotary plate.

[0018] As will be described later, the image forming apparatus 110 according to the present embodiment corrects the calculated web movement amount every time the conveying roller 230 makes, for example, one rotation (or every predetermined rotation) based on the encoder pulse ENP.

[0019] Each liquid discharge head unit (an example of a printing unit) is arranged in the order of black (K), cyan (C), magenta (M), and yellow (Y) from the upstream side toward the downstream side in the conveyance direction of the web 120. That is, the black liquid discharge head unit 210K is provided on the most upstream side. A cyan liquid discharge head unit 210C is provided next to the black liquid discharge head unit 210K. A magenta liquid discharge head unit 210M is provided next to the cyan liquid discharge head unit 210C. On the most downstream side, a yellow liquid discharge head unit 210Y is provided.

[0020] Each liquid discharge head unit 210 discharges the corresponding color ink to a predetermined position on the web 120, according to image data. The landing position of the ink discharged onto the web 120 is substantially immediately below the discharge position of the liquid discharge head unit.

[0021] In this example, black ink is discharged to a black landing position PK of the black liquid discharge head unit 210K, and cyan ink is discharged to a cyan landing position PC of the cyan liquid discharge head unit 210C. Similarly, magenta ink is discharged to a magenta landing position PM of the magenta liquid discharge head unit 210M, and yellow ink is discharged to a yellow landing position PY of the yellow liquid discharge head unit 210Y

[0022] The control of the ink discharge timing in each liquid discharge head unit and the control of an actuator ACT provided in each liquid discharge head unit are performed by a control unit 110F30 connected to each liquid discharge head unit.

[0023] Each of the liquid discharge head units 210 is provided with a plurality of driven rollers. The plurality of driven rollers are provided upstream and downstream from each liquid discharge head unit. That is, in the conveyance path of the web 120, for each liquid discharge head unit, a first roller that supports the web 120 is provided upstream from each landing position, and a second roller that supports the web 120 is provided downstream from each landing position.

[0024] That is, the first black roller CR1K is provided upstream from the black landing position PK in the conveyance direction of the web 120. On the other hand, a second black roller CR2K is provided downstream from the black landing position PK in the conveyance direction of the web 120.

[0025] Similarly, a first cyan roller CR1C and a second cyan roller CR2C are provided for the cyan liquid discharge head unit 210C. Further, a first magenta roller CR1M and a second magenta roller CR2M are provided for the magenta liquid discharge head unit 210M. A first yellow roller CR1Y and a second yellow roller CR2Y are provided for the yellow liquid discharge head unit 210Y

Configuration of Sensor Device

[0026] Next, in the image forming apparatus 110, as illustrated in FIG. 2, sensor devices SEN are provided between the conveying roller 230 and the first black roller CR1K. FIG. 3 is a block diagram of a sensor device SEN. As illustrated in FIG. 3, the sensor device SEN includes a light source LG, an image capturing unit OS, a control circuit 52, a storage unit 53, and a control unit 110F30. For example, a light source that emits infrared light, a light emitting diode (LED), an organic electroluminescence (EL), or the like can be used as the light source LG.

[0027] For example, a charge coupled device (CCD) camera or a complementary metal oxide semiconductor (CMOS) camera can be used as the image capturing unit OS. The image capturing unit OS preferably includes a global shutter. As compared with a rolling shutter or the like, the global shutter can more restrain a so-called image shift that occurs due to a shift in timing at which the shutter is opened with respect to a subject having a high moving speed.

[0028] The control circuit 52 controls the image capturing unit OS, the light source LG, and the like in the sensor device

SEN. Specifically, the control circuit 52 outputs, for example, a trigger signal to the image capturing unit OS to control the timing at which the image capturing unit OS opens the shutter. The control circuit 52 causes the image capturing unit OS to capture a two-dimensional image and acquires the two-dimensional image from the image capturing unit OS. The control circuit 52 supplies image information for each time captured by the image capturing unit OS to the recording unit 53. The recording unit 53 stores the image information for each time supplied from the control circuit 52 or the like.

[0029] The control unit 110F30 calculates the movement amount of the web 120 base on the correlation between the images of the image information at different times stored in the recording unit 53 and performs accumulation processing. Thus, the movement amount of the web 120 can be accurately recognized. Details will be described later.

[0030] FIG. 4 is an external appearance of the sensor device SEN. As illustrated in FIG. 4, the sensor device SEN irradiates the web 120 with detection light from the light source LG. Specifically, the sensor device SEN includes a light source (LG) such as a semiconductor laser or a light emitting diode (LED) and an optical system such as a collimating optical system. To acquire an image of an image capturing pattern, the sensor device SEN includes the image capturing unit OS (in this example, a CMOS image sensor) and a telecentric optics (TO) to condense light to image the image capturing pattern on the image capturing unit OS.

Detailed Configuration of Main Part

[0031] FIG. 5 is a block diagram of a main part of the image forming apparatus 110. As illustrated in FIG. 5, the sensor device SEN of the image forming apparatus 110 includes the image capturing unit OS including the light source LG, the control circuit 52, and the recording unit 53. The image capturing unit OS captures an image of the web 120 conveyed in the conveyance direction 10.

[0032] The control circuit 52 includes a shutter control unit 141A and an image acquiring unit 142A. The image acquiring unit 142A acquires image information of the image captured by the image capturing unit OS at each time. The shutter control unit 141A controls the image capturing timing of the image capturing unit OS so as to capture an image at each time. The recording unit 53 stores the image information for each time acquired by the image acquiring unit 142A from the image capturing unit OS.

[0033] As illustrated in FIG. 5, the image forming apparatus 110 includes a computing unit 53F, a measuring unit 110F20, an adjustment unit 110F40, a cooling unit 250, and a notification unit 251.

[0034] The computing unit 53F calculates the position of a pattern of the web 120, the moving speed at which the web 120 is conveyed, and the moving amount at which the web 120 is conveyed, based on the image information of the image at each time stored in the recording unit 53. The output such as the movement amount calculated by the computing unit 53F is supplied to the adjustment unit 110F40 and the control unit 110F30. The adjustment unit 110F40 performs shutter control of the image capturing unit OS via the shutter control unit 141A based on the output such as the movement amount calculated by the computing unit 53F.

[0035] The control unit 110F30 (an example of a control unit) detects thermal expansion of the conveying roller 230 based on the movement amount of the web 120 calculated by the computing unit 53F, and performs a cooling process on the conveying roller 230 via the cooling unit 250 when thermal expansion of a predetermined amount or more occurs. The control unit 110F30 also performs stop control of the image forming apparatus 110 (system stop) when thermal expansion of a predetermined amount or more occurs. Further, the control unit 110F30 performs predetermined notification control such as display of a predetermined error message of (and) sound generating control of a warning sound via the notification unit 251 when thermal expansion of a predetermined value or more occurs.

[0036] The measuring unit 110F20 counts the encoder pulses ENP output from the encoder ENC attached to the conveying roller 230 illustrated in FIG. 2 and supplies timing pulses to the computing unit 53F every time the conveying roller 230 makes one rotation (or may make a plurality of rotations). As described above, the computing unit 53F calculates the movement amount of the web 120 based on the correlation between images at different times and performs accumulation processing. However, if the accumulation processing is continued, there is a concern that the difference from the actual behavior of the web between image acquisition cycles may increase. For this reason, the computing unit 53F resets the difference from the actual behavior of the web between the image acquisition cycles every time the conveying roller 230 makes one rotation, for example. Thus, accumulation of errors due to accumulation processing of the movement amount of the web 120 can be prevented.

Image Capturing Pattern

[0037] The web 120 has diffusiveness on a surface thereof or in an interior thereof. Accordingly, when the web 120 is irradiated with light (e.g., laser beam), the reflected light is diffused. The diffuse reflection creates a pattern of spots (image capturing pattern) on the web 120.

[0038] When the web 120 is conveyed, the image capturing pattern of the web 120 is also conveyed. Therefore, the computing unit 53F calculates the movement amount of the web 120 based on the captured images of the same image capturing pattern captured at different times. The computing unit 53F converts the movement amount per unit time to calculate the moving speed of the web 120.

Functional Block Configuration of Calculation Unit

[0039] FIG. 6 is a functional block diagram of the computing unit 53F. As illustrated in FIG. 6, the computing unit 53F performs a cross-correlation calculation on image data D1(n) and D2(n) acquired at specified different times by the sensor devices SEN. Hereinafter an image generated by the cross-correlation calculation is referred to as "correlated image data". For example, based on the correlated image data, the computing unit 53F calculates a deviation amount $\Delta D(n)$ that is an amount of deviation from the position detected with the previous frame or by another sensor device.

[0040] The cross-correlation calculation is performed based on the following equation (1). In the following equation (1), the image data D1(n) is image data captured at an earlier time out of two pieces of image data captured successively at specified different times. In the following equation (1), the image data D2(n) is image data captured at a later time out of the two pieces of image data captured successively at the specified different times. In the equation (1), "F[]" represents Fourier transform, and "F^{-1} []" represents inverse Fourier transform. In the equation (1), "*" represents a complex conjugate, and "*" represents a cross-correlation calculation.

$$D1 \bigstar D2^* = F^{-1}[F[D1] \cdot F[D2]^*] \cdots (1)$$

[0041] As represented by the equation (1), when the cross-correlation calculation "D1★D2" is performed on the image data D1 and D2, the correlation image data indicating the correlation between the images can be obtained. When the image data D1 and the image data D2 are two-dimensional image data, the correlation image data is two-dimensional image data. On the other hand, when the image data D1 and the image data D2 are one-dimensional image data, the correlation image data is one-dimensional image data.

[0042] In such correlation image data, for example, in a case in which a luminance distribution (broad luminance distribution) having little difference between regions becomes a problem, a phase-only correlation method represented by the following equation (2) may be used. In the equation (2), "P []" indicates that only the phase is extracted in the complex amplitude. The amplitude is assumed to be "1".

$$D1 \bigstar D2^* = F^{-1}[P[F[D1]] \cdot P[F[D2]^*]] \cdots (2)$$

[0043] Using such a phase-only correlation method can facilitate calculation of the deviation amount $\Delta D(n)$ based on the correlation image even in the case of a broad luminance distribution.

[0044] The correlation image indicates the correlation between the image data D1 and the image data D2. Specifically, as the degree of coincidence between the image data D1 and the image data D2 increases, a luminance of a steep peak, i.e., a so-called correlation peak is output at a position closer to the center of the correlation image. When the image data D1 and the image data D2 coincide with each other, the center and the peak position of the correlation image overlap each other.

Example of Correlation Calculation

[0045] Details of the correlation calculation are described below.

[0046] As illustrated in FIG. 6, the computing unit 53F includes a first two-dimensional Fourier transform unit FT1, a second two-dimensional Fourier transform unit FT2, a correlation-image-data generation unit DMK, a peak-position search unit SR, a calculation unit CAL, and a transform result storing unit MEM. The calculation unit CAL is an example of a movement-amount calculation unit, a correction unit, a comparison unit, and a detection unit.

[0047] The first two-dimensional Fourier transform unit FT1 transforms first image data D1. The first two-dimensional Fourier transform unit FT1 includes a Fourier transform unit FT1a for the orthogonal direction and a Fourier transform unit FT1b for the conveyance direction.

[0048] The Fourier transform unit FT1a for the orthogonal direction performs one-dimensional Fourier transform on the first image data D1 in the orthogonal direction orthogonal to the conveyance direction. The Fourier transform unit FT1b for the conveyance direction performs one-dimensional Fourier transform on the first image data D1 in the conveyance direction, based on the transform result by the Fourier transform unit FT1a for the orthogonal direction. Thus, the Fourier transform unit FT1a and the Fourier transform unit FT1b perform one-dimensional transform in the orthogonal direction 20 and the conveyance direction 10, respectively. The first two-dimensional Fourier transform unit FT1 outputs the transform result thus transformed, to the correlation-image-data generation unit DMK.

[0049] Similarly, the second two-dimensional Fourier transform unit FT2 transforms the second image data D2. The second two-dimensional Fourier transform unit FT2 includes a Fourier transform unit FT2a for the orthogonal direction, a Fourier transform unit FT2b for the conveyance direction, and a complex conjugate unit FT2c.

[0050] The Fourier transform unit FT2a for the orthogonal direction performs one-dimensional Fourier transform on the second image data D2 in the orthogonal direction. The Fourier transform unit FT2b for the conveyance direction performs one-dimensional Fourier transform on the second image data D2 in the conveyance direction, based on the transform result by the Fourier transform unit FT2a for the orthogonal direction. Thus, the Fourier transform unit FT2a and the Fourier transform unit FT2b perform one-dimensional transform in the orthogonal direction 20 and the conveyance direction 10, respectively.

[0051] Subsequently, the complex conjugate unit FT2c calculates a complex conjugate of the results of transform by the Fourier transform unit FT2a (for orthogonal direction) and the Fourier transform unit FT2b (for conveyance direction). The second two-dimensional Fourier transform unit FT2 outputs, to the correlation-image-data generation unit DMK, the complex conjugate calculated by the complex conjugate unit FT2c.

[0052] The correlation-image-data generation unit DMK generates the correlation image data, based on the transform result of the first image data D1, which is output from the first two-dimensional Fourier transform FT1, and the transform result of the second image data D2, which is output from the second two-dimensional Fourier transform FT2.

[0053] The correlation-image-data generation unit DMK includes an integration unit DMKa and a two-dimensional inverse Fourier transform unit DMKb.

[0054] The integration unit DMKa integrates the transform results of the first image data D1 and the transform result of the second image data D2 and supplies the integrated output to the two-dimensional inverse Fourier transform unit DMKb. The two-dimensional inverse Fourier transform unit DMKb performs two-dimensional inverse Fourier transform on the result generated by the integration unit DMKa. Thus, the correlation image data is generated through two-dimensional inverse Fourier transform.

[0055] Subsequently to the integration processing on the transform result of the first image data D1 and the transform result of the second image data D2, the integration unit DMKa sequentially performs integration processing on the transform result of the second image data D2 and the transform result of the third image data D3, performs integration processing on the transform result of the third image data D3 and the transform result of the fourth image data D4, and so forth. The two-dimensional inverse Fourier transform unit DMKb sequentially performs two-dimensional inverse Fourier transform processing on the integration result supplied from the integration unit DMKa to generate correlation image data, and supplies the correlation image data to the peak-position search unit SR.

[0056] As an example, a matrix of luminance values can be used as the correlation image data. The peak-position search unit SR searches for a peak luminance (peak value) that rises most steeply in such correlation image data.

[0057] FIG. 7 is a graph illustrating a method of searching for a peak value in the peak-position search unit SR. In FIG. 7, the horizontal axis indicates the position in the conveyance direction in an image indicated by correlation image data, and the vertical axis indicates the luminance of the image indicated by the correlation image data.

[0058] Hereinafter, three values of a first data value q1, a second data value q2, and a third data value q3 are described as examples. In other words, in this example, the peak-position search unit SR searches for the peak position P in a curve k connecting the first data value q1, the second data value q2, and the third data value q3.

[0059] Initially, the peak-position search unit SR calculates each difference between luminance values indicated by the correlation image data. The peak-position search unit SR extracts a largest difference combination meaning a combination of luminance values between which the difference is largest among the calculated differences.

[0060] Then, the peak-position search unit SR extracts combinations of luminance values adjacent to the largest difference combination. Thus, three values such as the first data value q1, the second data value q2, and the third data value q3 can be extracted. The peak-position search unit SR calculates the curve k by connecting the three extracted data values, and searches for the peak position P.

[0061] Thus, the amount of calculation such as sub-pixel processing can be reduced, and the peak position P can be searched at higher speed. The position of the combination of luminance values between which the difference is largest means the position at which rising is sharpest.

[0062] The luminance values used as the correlation image data are arranged at a pixel pitch interval (pixel size interval) of an area sensor. For this reason, the search for the peak value is preferably performed after so-called sub-pixel processing. Performing the sub-pixel processing allows the peak position to be searched with high accuracy. Such a configuration can accurately calculate the position, the movement amount, the movement speed, and the like.

[0063] Next, FIG. 8 is a graph illustrating a correlation intensity distribution of a cross-correlation function. The X axis and the Y axis in FIG. 8 indicate serial numbers of pixels. The peak value exemplified as the "correlation peak" in FIG. 8 is searched by the peak-position search unit SR.

[0064] Next, the calculation unit CAL illustrated in FIG. 6 calculates the relative position, the movement amount, the movement speed, and the like of the web 120. For example, the calculation unit CAL calculates the relative position and the movement amount by calculating the difference between the positions of peak values of correlation image data corresponding to the image data captured at predetermined time intervals, and accumulates the calculated movement amount by a predetermined amount. The calculation unit CAL also calculates the movement speed by dividing the movement amount by the time. The calculation unit CAL supplies information on the relative position, the movement amount, and the movement speed calculated in this manner to the adjustment unit 110F40 and the control unit 110F30 illustrated in FIG. 5.

[0065] Here, a pair of a first roller CR1 and a second roller CR2 are disposed below each liquid discharge head unit 210, to restrain fluttering of the web 120 immediately below each liquid discharge head unit 210. An encoder ENC is mounted on the rotation shaft of the conveying roller 230 disposed upstream from the liquid discharge head units 210 in the conveyance direction of the web 120. When the conveying roller 230 rotates to convey the web 120, an encoder signal is output from the encoder ENC. The control unit 110F30 illustrated in FIG. 5 controls the ink discharge timing of each liquid discharge head unit 210 based on the encoder signal.

[0066] Normally, each liquid discharge head unit 210 is disposed at a position of an integral multiple of the circumferential length of the conveying roller 230 provided with the encoder ENC, and can cancel a deviation due to the eccentricity of the conveying roller 230 synchronized with the rotation cycle of the conveying roller 230. With respect to the deviation in the mechanical position of the liquid discharge head unit 210, normally, the ink discharge timing is corrected based on the result of the test print performed before the start of printing, to cancel the deviation.

[0067] However, the position of the web 120 directly below the liquid discharge head unit 210 that ejects ink and the position calculated from the encoder signal are usually shifted due to factors such as thermal expansion of the conveying roller 230, slippage between the web 120 and the conveying roller 230, and elongation of the web 120 itself. In FIG. 9, a broken-line graph indicates the actual conveyance position of the web 120, and a solid-line graph indicates the conveyance position of the web 120 calculated based on the encoder signal. As can be seen by comparing the broken-line graph and the solid-line graph, when the discharge of each liquid discharge head unit 210 is controlled based on the encoder signal, there occurs a disadvantage that ink lands at a position (δ) deviated from a desired landing position on the web 120.

[0068] The solid-line graph illustrated in FIG. 10 indicates the deviation amount of the landing position of ink in a case in which the eccentricity of the conveying roller 230 provided with the encoder ENC occurs. The broken-line graph indicates the deviation amount of the landing position of ink in a case in which the eccentricity and the thermal expansion of the conveying roller 230 occur. A graph represented by an alternate long and short dash line indicates the deviation amount of the landing position of ink in a case in which the eccentricity of the conveying roller 230 and slippage between the web 120 and the conveying roller 230 occur.

[0069] Generally, the deviation (indicated by the broken-line graph in FIG. 10) due to the eccentricity of the conveying roller 230 has a cycle synchronized with the rotation cycle of the conveying roller 230, and the deviation occurs in the same manner every time. The amount of deviation increases in proportion to the amount of eccentricity but does not accumulate.

[0070] On the other hand, the linear expansion of the conveying roller 230 and the slippage between the web 120 and the conveying roller 230 are accumulated, and the states thereof differ for each printing. Accordingly, it may very difficult to correct the deviation amount of the landing position of ink with the encode signal from the encoder ENC provided in the conveying roller 230.

[0071] In addition, the elongation of the web 120 may be caused by applying tension in order to restrain the meandering of the web 120. Such elongation of the web 120 also varies depending on the thickness of th web, the width of the web, and the application amount of ink, and is an example of deviation in which the state varies for each printing. Accordingly, it may be difficult to correct such deviation.

Timing Control of Each Unit by Accumulated Movement Amount

[0072] For this reason, in the case of the image forming apparatus 110 according to the present embodiment, as illustrated in FIG. 11, the calculation unit CAL of the computing unit 53F illustrated in FIG. 6 sequentially performs accumulation processing on the movement amounts between the images calculated by the correlation operation based on the images captured at the specified different times. Specifically, the amount of movement between the captured image captured by the image capturing unit OS and the immediately-preceding captured image captured by the image capturing unit OS is calculated by the correlation operation, and the calculated amounts of movement are cumulatively calculated as follows.

$$\text{Movement amount} = (L1 + L2 + L3 + L4 + L5 + \ldots + Ln)$$

[0073] Using the movement amount calculated by the accumulation operation instead of the above-described encoder signal allows the movement amount of the web 120 to be accurately recognized. Thus, the timing of each unit can be accurately controlled. That is, the movement amount calculated by the accumulation operation is supplied to the adjustment unit 110F40 and the control unit 110F30.

[0074] The adjustment unit 110F40 performs shutter control of the image capturing unit OS via the shutter control unit 141A based on the movement amount of the web 120. Accordingly, since the shutter control of the image capturing unit OS can be performed at the optimum timing based on the accurate movement amount of the web 120, the image capturing of the web 120 can be performed at the accurate movement position of the web 120.

[0075] The control unit 110F30 controls discharge of each liquid discharge head unit 210 via a moving unit 110F80 based on the movement amount of the web 120. Accordingly, ink can be accurately landed on a target position on the web 120, thus enhancing printing accuracy.

Operation of Detecting Thermal Expansion of Conveying Roller

[0076] Next, a measuring unit 110F20 of the image forming apparatus 110 according to the present embodiment supplies one encode pulse to the computing unit 53F every time the conveying roller 230 makes one rotation based on the encode signal from the encoder ENC of the conveying roller 230.

[0077] The calculation unit CAL of the computing unit 53F stores the sheet movement amount (initial movement amount) per rotation of the conveyance roller 230 cumulatively calculated with a reference sheet for adjustment, and detects the difference between the sheet movement amount per rotation obtained from a cumulatively calculated movement amount at that time and the initial movement amount, every time the encode pulse is supplied from the measuring unit 110F20 to the computing unit 53D. That is, the calculation unit CAL detects the difference between the sheet movement amount per rotation obtained from the current cumulative movement amount and the initial movement amount, every time the conveying roller 230 makes one rotation (or may make a plurality of rotations), and supplies the difference to the control unit 110F30.

[0078] When the difference between the current cumulative movement amount and the initial movement amount is equal to or larger than a predetermined value, the control unit 110F30 determines that the conveying roller 230 is thermally expanded.

Discharge Operation According to Thermal Expansion of Conveying roller

[0079] When the control unit 110F30 determines that the conveying roller 230 is thermally expanded, the control unit 110F30 controls the discharge amount of each liquid discharge head unit 210 so that the discharge amount of ink corresponds to the degree of thermal expansion. Such control allows printing to be performed with an appropriate amount of ink and printing accuracy to be enhanced.

Notification Operation of Thermal Expansion

[0080] When the control unit 110F30 detects the occurrence of thermal expansion of the conveying roller 230, the control unit 110F30 performs notification control for notifying the occurrence of thermal expansion via the notification unit 251 illustrated in FIG. 5. For example, in a case in which the notification unit 251 is a monitor device, the control unit 110F30 controls display of an error message such as "the conveying roller is at a high temperature" on the monitor device. In addition, in a case in which the notification unit 251 is a speaker unit, the control unit 110F30 notifies the user that the conveying roller 230 is thermally expanded, by an acoustic output such as an acoustic message or an electronic sound. This notification operation allows the user to take measures such as temporarily stopping the image forming apparatus 110 until the conveying roller 230 returns to the state before thermal expansion.

[0081] The display control for the monitor device and the acoustic output control via the speaker unit may be used in combination. The control unit 110F30 may notify an administrator or the like of the thermal expansion of the conveying roller 230 via a network.

Cooling Operation of Conveying Roller

[0082] When the control unit 110F30 detects the occurrence of the thermal expansion with respect to the conveying roller 230, the control unit 110F30 controls the cooling unit 250 so as to increase the cooling strength of the cooling unit 250 that cools the conveying roller 230 illustrated in FIG. 5 by a predetermined amount. Thus, the conveying roller 230 can be cooled, and the conveying roller 230 can be returned to the state before thermal expansion.

Stop Control of System

[0083] When the control unit 110F30 detects the occurrence of thermal expansion of the conveying roller 230, the control unit 110F30 controls, for example, a power supply unit to stop or controls the conveying roller 230 and the like to stop via a power supply control unit. Note that only the conveying roller 230 may be controlled to stop. Thus, the progress of the thermal expansion of the conveying roller 230 can be stopped, and the conveying roller 230 can be returned to the state before the thermal expansion.

Operation of Correcting Cumulative Movement Amount

[0084] Next, in the case of the image forming apparatus 110 according to the present embodiment, only the relative movement amount of the captured images captured at specified different times is detected. Accordingly, when a sheet (web) behavior, a slip, a speed variation, or the like equal to or less than the detection cycle occurs, an error from the actual conveyance amount may occur. When such an error is accumulated by the above-described accumulation calculation, there is a possibility that a difference from the actual behavior of the web 120 between the image acquisition cycles might increase.

[0085] Therefore, the calculation unit CAL of the computing unit 53F corrects the cumulative movement amount with the encode pulse supplied from the measuring unit 110F20 every time the conveying roller 230 makes one rotation. In other words, the movement amount of the web 120 for one rotation of the conveying roller 230 is a movement amount obtained by the diameter of the conveying roller 230. Therefore, the calculation unit CAL performs correction processing for causing the cumulative movement amount to coincide with the movement amount obtained by the diameter of the conveying roller 230 using the encode pulse as a trigger.

[0086] FIG. 12 illustrates such correction processing, in which the solid line is a graph of the cumulative movement amount and the broken line is the movement amount obtained by the diameter of the conveying roller 230. As illustrated in FIG. 12, at the timing when the encode pulse (output pulse signal) is supplied, the calculation unit CAL causes the cumulative movement amount of the solid line to coincide with the movement amount of the broken line obtained by the diameter of the conveying roller 230. Such a configuration can cancel the error every time the conveying roller 230 makes one rotation, thus allowing the movement amount of the web 120 to be calculated with higher accuracy.

Advantageous Effects of Embodiment

[0087] As is clear from the above description, the image forming apparatus 110 according to the present embodiment performs the correlation calculation of captured images of the web 120 captured at specified different times to calculate the movement amount of the web 120, accumulate the movement amount by a predetermined amount, and calculate a cumulative movement amount. The cumulative movement amount is corrected to coincide with the movement amount calculated from the diameter of the conveying roller 230 of the web 120 every time the conveying roller 230 of the web 120 makes one rotation (or a plurality of rotations). Such a configuration can cancel an error occurring in the cumulative movement amount and can control each device or unit based on the movement amount of the web 120 with higher accuracy.

Variation

[0088] In the description of the above-described embodiment, the correction target value (indicate by a broken line in FIG. 12) is determined by obtaining the "actual movement amount of the web" illustrated in FIG. 12 from the encode pulse (output pulse signal) for each rotation of the conveying roller 230.

[0089] However, the correction target value may be determined by obtaining a cumulative value of the movement amount of the web detected by an image sensor at the timing of one rotation of the conveying roller 230 and calculating the average value of a plurality of rotations (for example, 10 rotations). Thus, the actual movement amount of the web including the slip can be set as the correction target value, and each device or unit can be controlled based on the more accurate movement amount of the web 120.

[0090] The embodiments described above are presented as examples and are not intended to limit the scope of the present disclosure. The above-described embodiments can be implemented in various other forms, and various omissions, substitutions, and changes can be made without departing from the gist of the present disclosure. Further, embodiments and variations of the embodiments of the present disclosure are included in the scope and spirit of the present disclosure.

Claims

1. An image forming apparatus (110), comprising:

a conveying mechanism (230) configured to convey a recording medium (120);
a printing unit (210) configured to perform printing on the recording medium;
an origin detection unit (ENC) provided on the conveying mechanism (230);
an image capturing unit (OS) configured to capture an image of the recording medium;
a movement-amount calculation unit (CAL) configured to:

calculate movement amounts of the recording medium based on correlations between captured images of the recording medium captured at different times with the image capturing unit; and
perform accumulation processing on the movement amounts of the recording medium to calculate a cumulative movement amount;

a correction unit (CAL) configured to:

perform correction for causing the cumulative movement amount to coincide with a reference movement amount of the recording medium for a predetermined cycle obtained from a mechanical configuration of the conveying mechanism, for each predetermined cycle of the conveying mechanism detected by the origin detection unit; and

a control unit (110F30) configured to:

control the conveying mechanism, based on a corrected value of the cumulative movement amount obtained by the correction of the correction unit, to perform conveyance control of the recording medium; and
control the printing unit to perform printing on the recording medium that is conveyed under the conveyance control.

2. The image forming apparatus according to claim 1, further comprising:

a comparison unit (CAL) configured to compare an initial value of the cumulative movement amount with a current value of the cumulative movement amount for each predetermined cycle of the conveying mechanism; and
a detection unit (CAL) configured to detect a thermal expansion of the conveying mechanism when the current value of the cumulative movement amount is equal to or greater than the initial value.

3. The image forming apparatus according to claim 2, further comprising a cooling unit (250) configured to cool the conveying mechanism,
wherein the control unit is configured to control a cooling intensity of the cooling unit to cool the conveying mechanism when the thermal expansion of the conveying mechanism is detected by the detection unit.

4. The image forming apparatus according to claim 2 or 3,
wherein the control unit is configured to cause the conveying mechanism to stop when the thermal expansion of the conveying mechanism is detected by the detection unit.

5. The image forming apparatus according to any one of claims 2 to 4,
wherein the printing unit is configured to discharge ink onto the recording medium to perform the printing, and
wherein the control unit is configured to control a discharge amount of the ink discharged from the printing unit according to an amount of the thermal expansion of the conveying mechanism detected by the detection unit.

6. The image forming apparatus according to any one of claims 2 to 5, further comprising a notification unit (251),
wherein the control unit is configured to perform notification control via the notification unit when the thermal expansion of the conveying mechanism is detected by the detection unit.

7. A conveyance control method, comprising:

capturing images of a recording medium conveyed by a conveying mechanism, at different times with an image capturing unit;
calculating, with a movement-amount calculation unit (CAL), movement amounts of the recording medium based on correlations between the images of the recording medium captured at the different times with the image capturing unit;

performing, with the movement-amount calculation unit (CAL), accumulation processing on the movement amounts of the recording medium to calculate a cumulative movement amount;
performing, with a correction unit (CAL), correction for causing the cumulative movement amount to coincide with a reference movement amount of the recording medium for a predetermined cycle obtained from a mechanical configuration of the conveying mechanism, for each predetermined cycle of the conveying mechanism detected by an origin detection unit provided on the conveying mechanism; and
controlling the conveying mechanism with a control unit (110F30), based on a corrected value of the cumulative movement amount obtained by the correction of the correction unit, to perform conveyance control of the recording medium.

FIG. 1

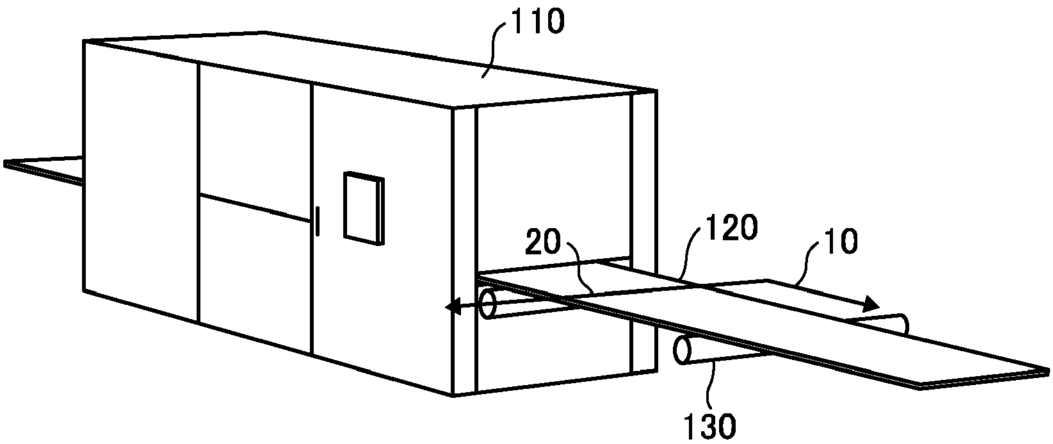


FIG. 2

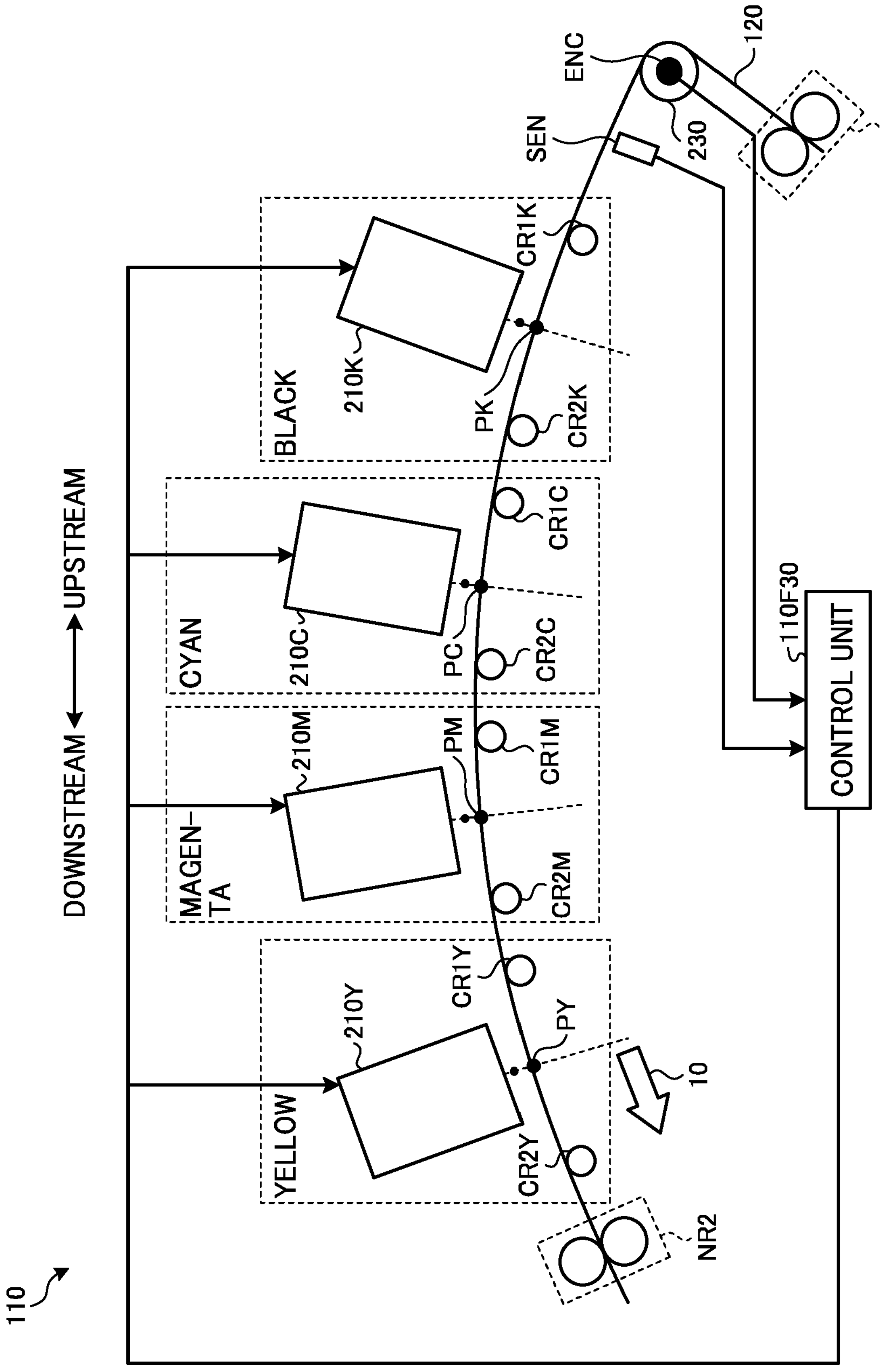

110
DOWNSTREAM
UPSTREAM
YELLOW
MAGEN-
TA
CYAN
BLACK
210Y
210M
210C
210K
CR1Y
CR2Y
PY
CR1M
CR2M
PM
CR1C
CR2C
PC
CR1K
CR2K
PK
10
NR2
NR1
SEN
ENC
230
120
110F30
CONTROL UNIT

FIG. 3

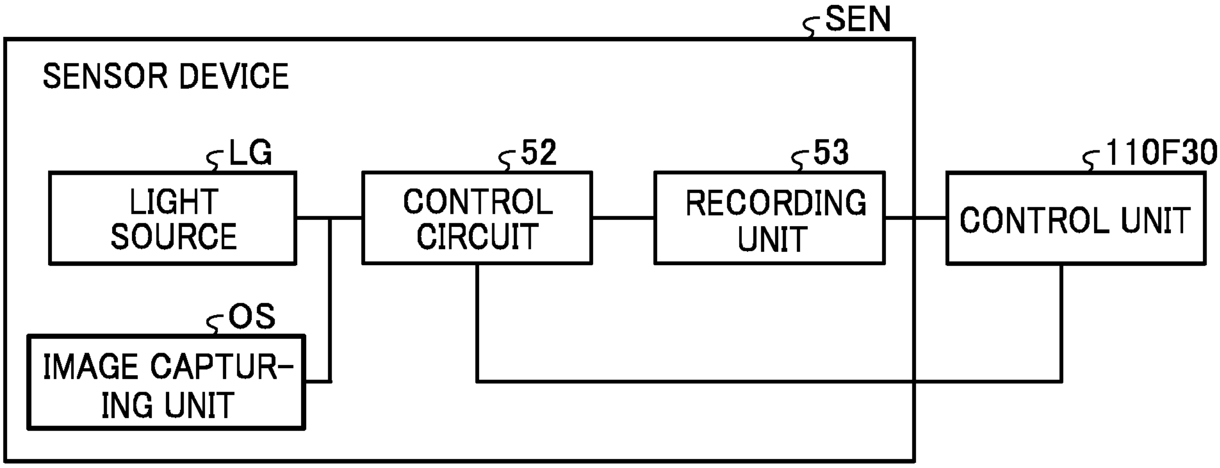

SEN
SENSOR DEVICE
LG
LIGHT SOURCE
52
CONTROL CIRCUIT
53
RECORDING UNIT
110F30
CONTROL UNIT
OS
IMAGE CAPTURING UNIT

FIG. 4

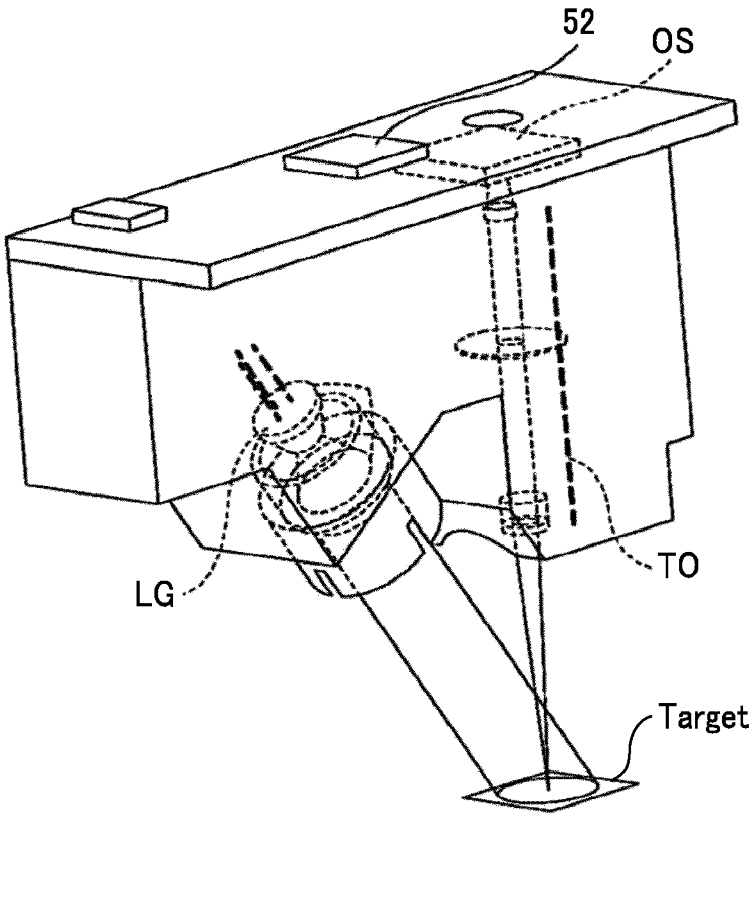

52
OS
LG
TO
Target

FIG. 5

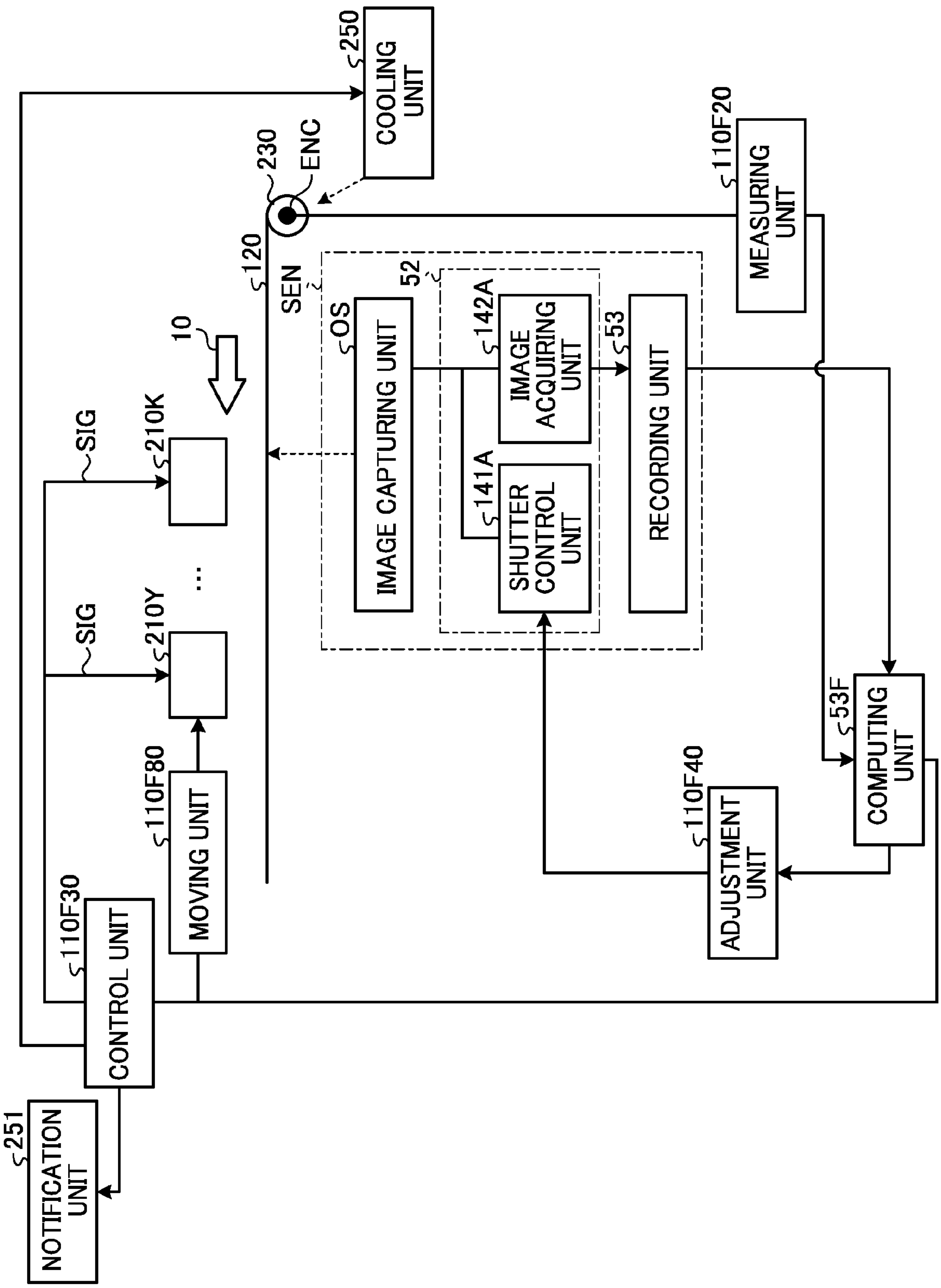

COOLING UNIT
250
230
ENC
120
110F20
MEASURING UNIT
SEN
52
OS
IMAGE CAPTURING UNIT
142A
IMAGE ACQUIRING UNIT
53
RECORDING UNIT
141A
SHUTTER CONTROL UNIT
10
SIG
210K
SIG
210Y
...
110F80
MOVING UNIT
110F30
CONTROL UNIT
110F40
ADJUSTMENT UNIT
53F
COMPUTING UNIT
251
NOTIFICATION UNIT

FIG. 6

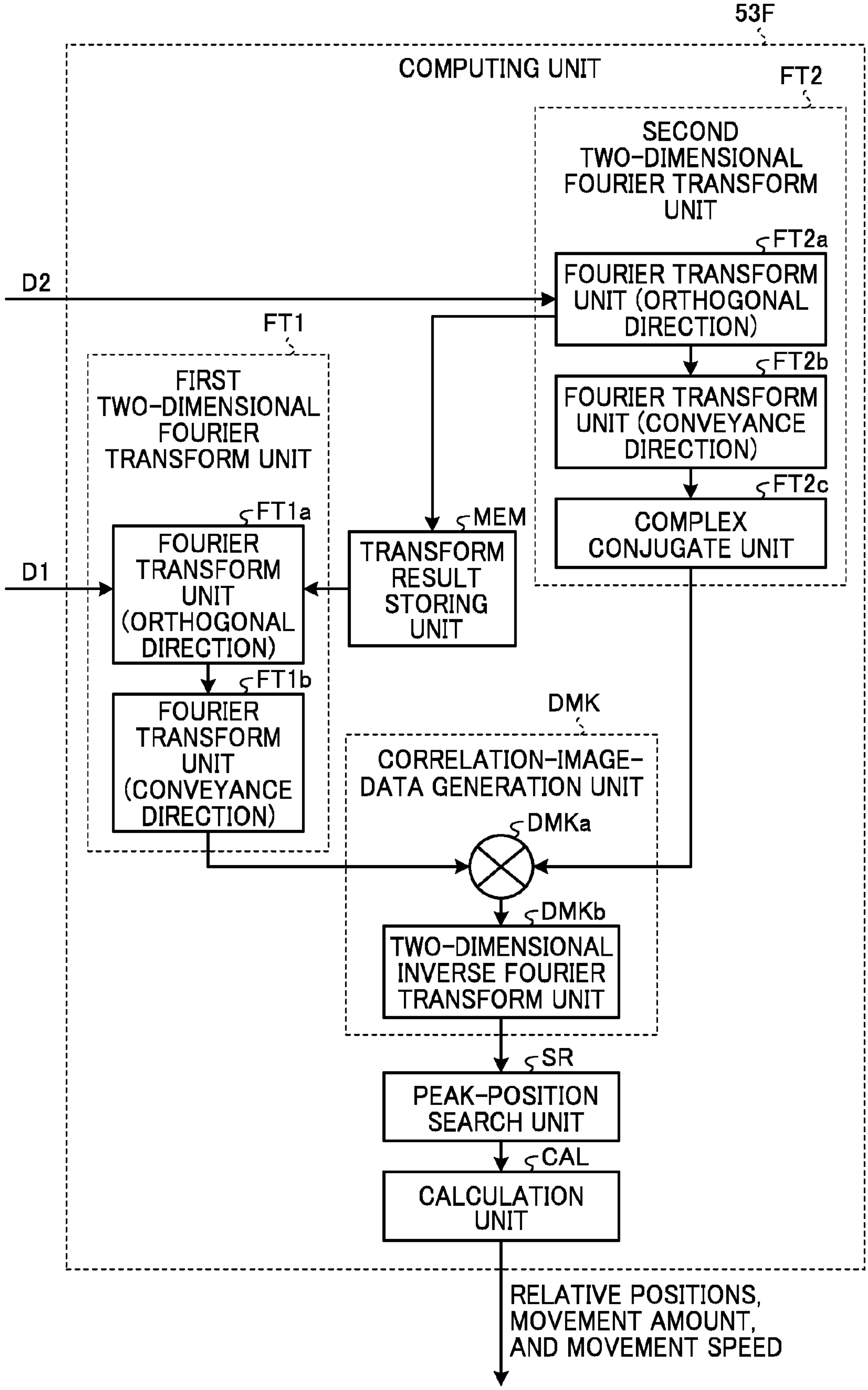

53F
COMPUTING UNIT
FT2
SECOND TWO-DIMENSIONAL FOURIER TRANSFORM UNIT
FT2a
FOURIER TRANSFORM UNIT (ORTHOGONAL DIRECTION)
D2
FT1
FIRST TWO-DIMENSIONAL FOURIER TRANSFORM UNIT
FT2b
FOURIER TRANSFORM UNIT (CONVEYANCE DIRECTION)
FT2c
COMPLEX CONJUGATE UNIT
FT1a
MEM
FOURIER TRANSFORM UNIT (ORTHOGONAL DIRECTION)
TRANSFORM RESULT STORING UNIT
D1
FT1b
FOURIER TRANSFORM UNIT (CONVEYANCE DIRECTION)
DMK
CORRELATION-IMAGE-DATA GENERATION UNIT
DMKa
DMKb
TWO-DIMENSIONAL INVERSE FOURIER TRANSFORM UNIT
SR
PEAK-POSITION SEARCH UNIT
CAL
CALCULATION UNIT
RELATIVE POSITIONS, MOVEMENT AMOUNT, AND MOVEMENT SPEED

FIG. 7

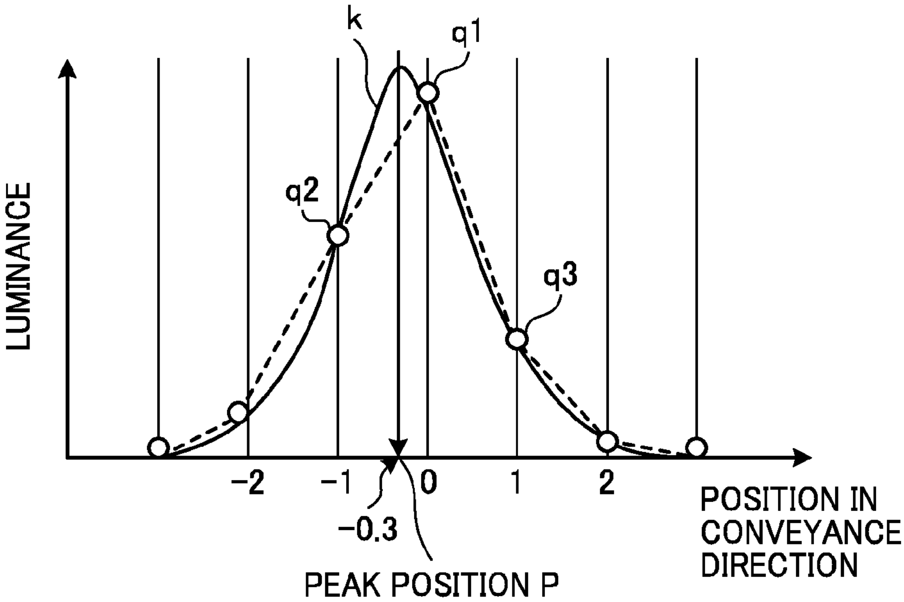

k
q1
q2
q3
LUMINANCE
−2
−1
0
1
2
−0.3
PEAK POSITION P
POSITION IN CONVEYANCE DIRECTION

FIG. 8

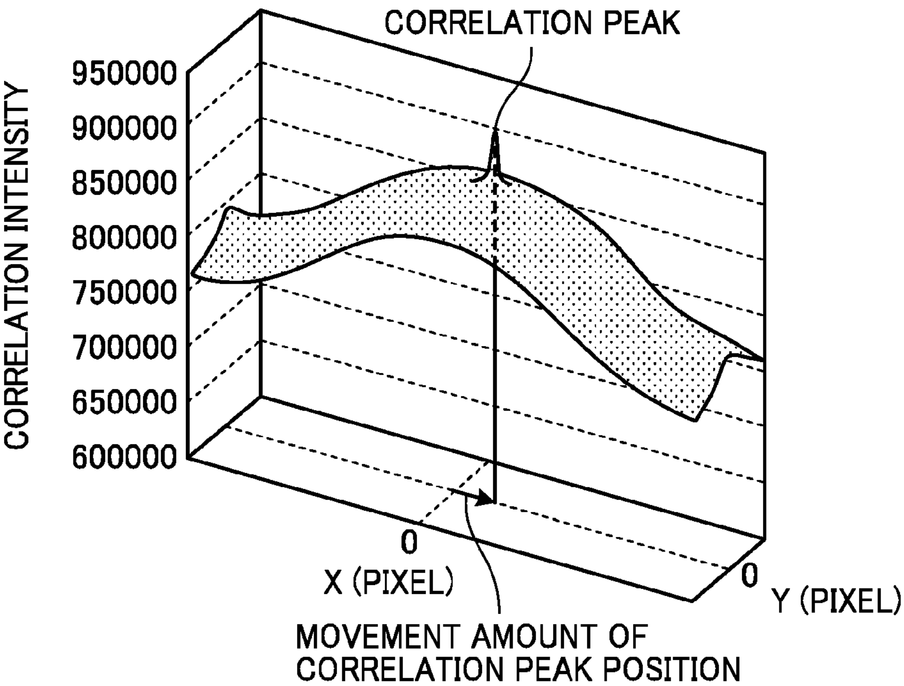

CORRELATION PEAK
CORRELATION INTENSITY
950000
900000
850000
800000
750000
700000
650000
600000
0
X (PIXEL)
0
Y (PIXEL)
MOVEMENT AMOUNT OF CORRELATION PEAK POSITION

FIG. 9

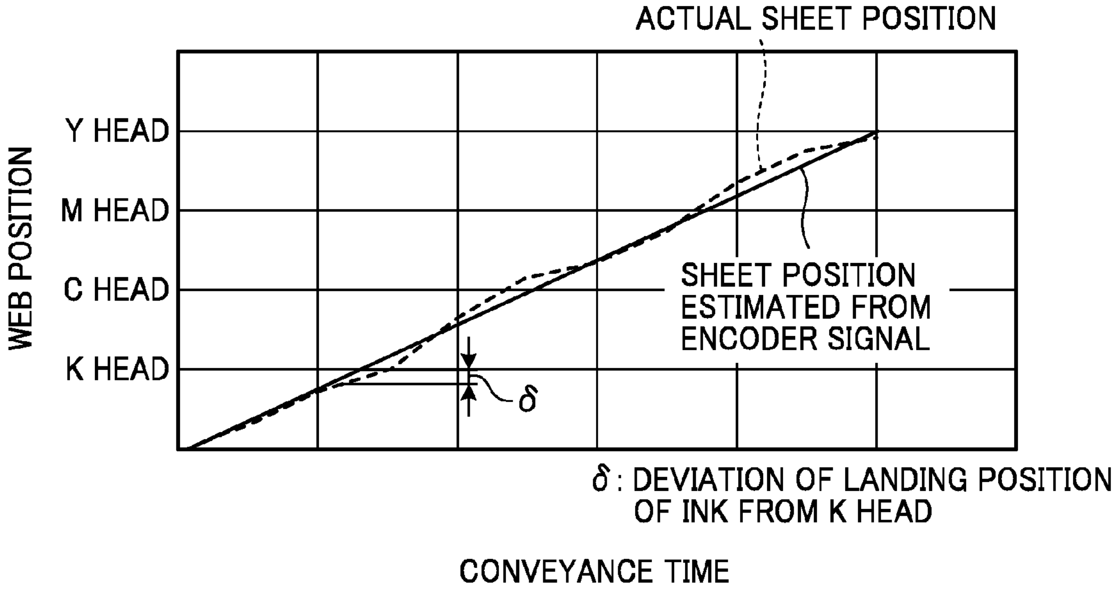

ACTUAL SHEET POSITION
WEB POSITION
Y HEAD
M HEAD
C HEAD
K HEAD
SHEET POSITION
ESTIMATED FROM
ENCODER SIGNAL
δ
δ: DEVIATION OF LANDING POSITION
OF INK FROM K HEAD
CONVEYANCE TIME

FIG. 10

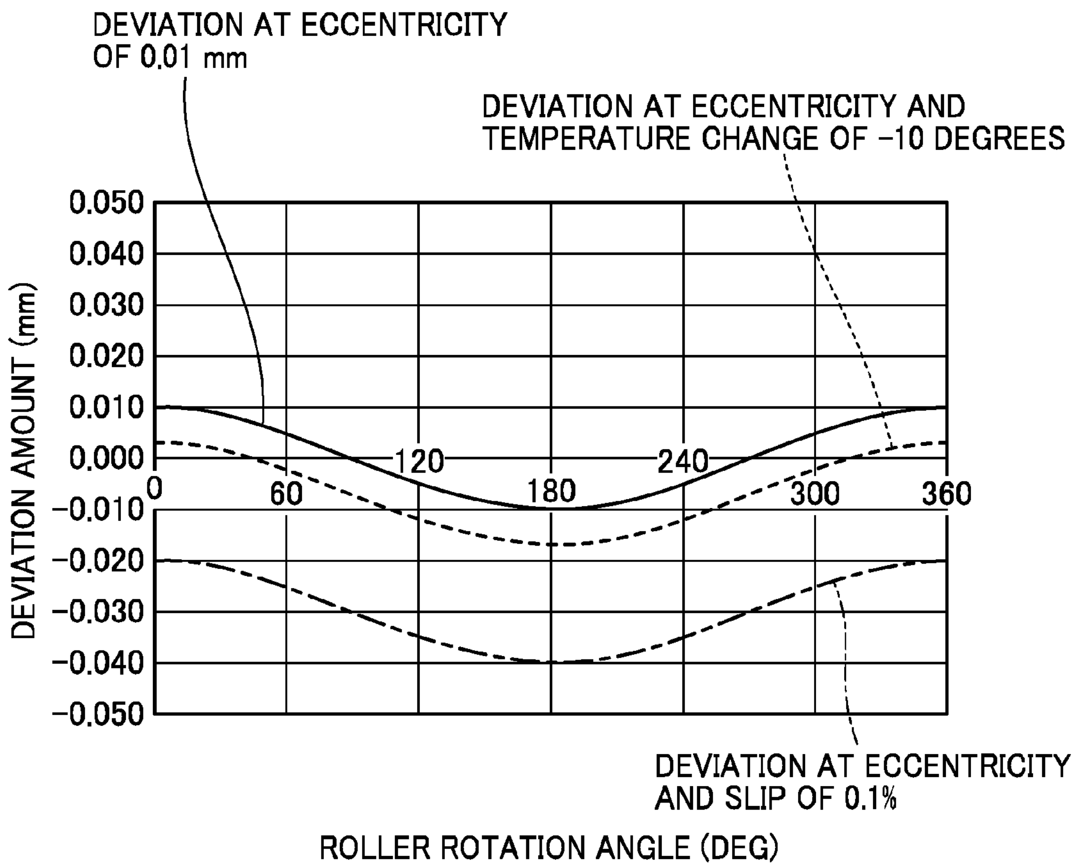

DEVIATION AT ECCENTRICITY
OF 0.01 mm
DEVIATION AT ECCENTRICITY AND
TEMPERATURE CHANGE OF −10 DEGREES
DEVIATION AMOUNT (mm)
0.050
0.040
0.030
0.020
0.010
0.000
−0.010
−0.020
−0.030
−0.040
−0.050
0
60
120
180
240
300
360
DEVIATION AT ECCENTRICITY
AND SLIP OF 0.1%
ROLLER ROTATION ANGLE (DEG)

FIG. 11

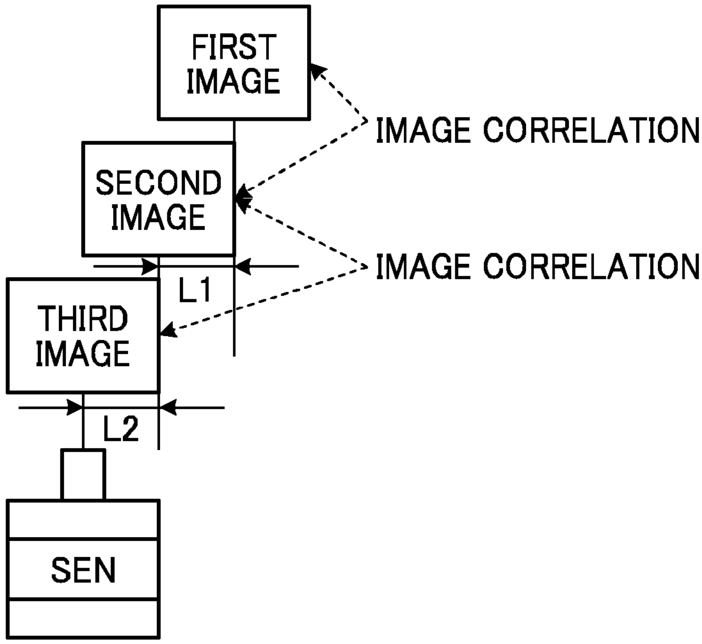
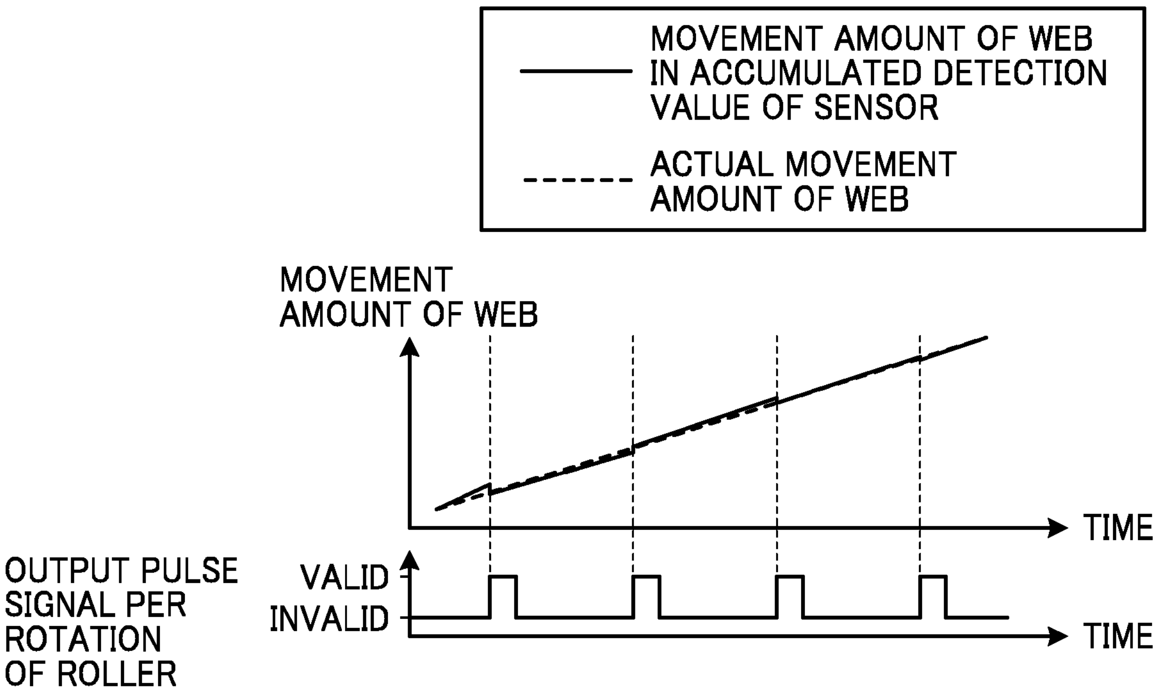

FIRST IMAGE
SECOND IMAGE
THIRD IMAGE
IMAGE CORRELATION
IMAGE CORRELATION
L1
L2
SEN

FIG. 12


MOVEMENT AMOUNT OF WEB IN ACCUMULATED DETECTION VALUE OF SENSOR
ACTUAL MOVEMENT AMOUNT OF WEB
MOVEMENT AMOUNT OF WEB
TIME
OUTPUT PULSE SIGNAL PER ROTATION OF ROLLER
VALID
INVALID
TIME

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EUROPEAN SEARCH REPORT

Application Number
EP 21 17 3860

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 2018/272694 A1 (GOHDA MITSUNOBU [JP] ET AL) 27 September 2018 (2018-09-27) * paragraphs [0040] - [0045], [0083] - [0106], [0134], [0166] - [0235]; figures 1-23 * -----	1-7	INV. B41J11/00 B41J11/42 B41J13/08 B41J15/04 B41J2/21
X	EP 3 219 497 A1 (RICOH CO LTD [JP]) 20 September 2017 (2017-09-20) * paragraphs [0027] - [0168]; figures 1-16 * -----	1-7	
X	JP 2018 158573 A (RICOH CO LTD) 11 October 2018 (2018-10-11) * paragraphs [0031] - [0221]; figures 1-25 * -----	1-7	
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	24 September 2021	Bitane, Rehab

CATEGORY OF CITED DOCUMENTS

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24-09-2021

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