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(72) Inventors:
• **BANJOYA, Toshihiko**
Hyogo, 670-8567 (JP)
• **IKEMOTO, Ryo**
Hyogo, 670-8567 (JP)

(74) Representative: **SSM Sandmair**
Patentanwälte Rechtsanwalt
Partnerschaft mbB
Joseph-Wild-Straße 20
81829 München (DE)

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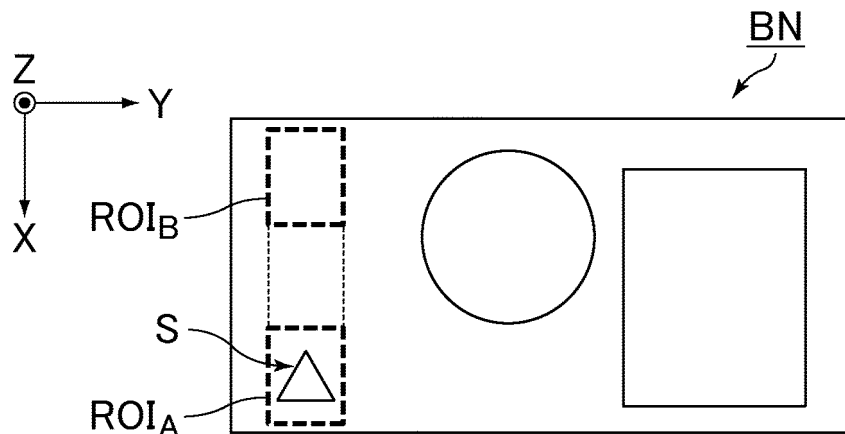
(71) Applicant: **GLORY LTD.**
Himeji-shi
Hyogo 670-8567 (JP)

(54) **SHEET RECOGNITION UNIT AND SHEET RECOGNITION METHOD**

(57) Provided are a sheet recognition unit, a sheet recognition method, and a sheet recognition program each capable of improving the recognition accuracy on a sheet. The sheet recognition unit is a sheet recognition unit for recognizing a sheet provided with an object to be recognized, including: a light source configured to apply light to the sheet; a light receiver configured to receive light traveling from the sheet; and a controller configured to acquire output data from the light receiver, the control-

ler being configured to acquire first data being output data from the light receiver and corresponding to a region including the object to be recognized and second data being output data from the light receiver and corresponding to a region not including the object to be recognized, to correct the first data using the second data to generate third data, and to recognize the sheet based on the third data.

FIG.2



Description

TECHNICAL FIELD

5 **[0001]** The disclosure relates to sheet recognition units, sheet recognition methods, and sheet recognition programs.

BACKGROUND ART

10 **[0002]** Sheet recognition units for recognizing sheets such as banknotes utilize various sensors to acquire features of a sheet. Generally, based on the acquired features of the sheet, the kind (denomination), authenticity, fitness, and the like of the sheet are recognized (determined).

[0003] For example, WO 2019/082251 and WO 2020/208806 each disclose an optical sensor configured to apply infrared light beams of multiple wavelengths to a banknote from a light source, to receive light reflected on or light transmitted through the banknote by a light receiver.

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SUMMARY OF INVENTION

20 **[0004]** Unfortunately, output data from such a light receiver may vary due to environmental reasons such as variations in properties among light-emitting elements (e.g., LEDs) of a light source, shift of the peak wavelength of the light source depending on the temperature, and fluctuation in transmittance of a light guide (e.g., an acrylic resin light guide) of the light source depending on the wavelength. When a recognition processing is executed based on such output data with variations, the recognition accuracy on the sheets is reduced. Variations in output data due to such environmental reasons tend to be significant particularly in an infrared region. Thus, the accuracy tends to be particularly reduced in the case of executing a recognition processing on sheets based on output data in an infrared region.

25 **[0005]** When light beams of multiple wavelengths are applied to a sheet and then the sheet is recognized based on output data relating to light beams of multiple wavelengths and from a light receiver, the recognition processing is typically executed using the output data relating to light beams of the multiple wavelengths alone. Such processing may have an insufficient discrimination ability between authentic and counterfeit objects to be recognized (e.g., special ink) on sheets. An insufficient discrimination ability between authentic and counterfeit objects to be recognized unfortunately reduces the recognition accuracy on the sheets.

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[0006] In response to the above current state of the art, an object of the disclosure is to provide a sheet recognition unit, a sheet recognition method, and a sheet recognition program each capable of improving the recognition accuracy on a sheet.

35 **[0007]** In order to solve the above issue and to achieve the object, (1) a sheet recognition unit according to a first aspect of the disclosure is a sheet recognition unit for recognizing a sheet provided with an object to be recognized, including: a light source configured to apply light to the sheet; a light receiver configured to receive light traveling from the sheet; and a controller configured to acquire output data from the light receiver, the controller being configured to acquire first data being output data from the light receiver and corresponding to a region including the object to be recognized and second data being output data from the light receiver and corresponding to a region not including the object to be recognized, to correct the first data using the second data to generate third data, and to recognize the sheet based on the third data.

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[0008] (2) In the sheet recognition unit according to the item (1), the light source may apply light beams of multiple wavelengths to the sheet, the light receiver may receive the light beams of multiple wavelengths traveling from the sheet, the first data and the second data may each include data pieces relating to the light beams of multiple wavelengths, and the controller may correct the data pieces of the first data relating to the light beams of multiple wavelengths using the data pieces of the second data relating to the light beams of the respective wavelengths to generate third data relating to the light beams of the multiple wavelengths, and may recognize the sheet based on the third data relating to the light beams of multiple wavelengths.

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[0009] (3) In the sheet recognition unit according to the item (2), the controller may calculate: first multiplication data by multiplying a data piece relating to a light beam of a first wavelength by a data piece relating to a light beam of a second wavelength, both belonging to the first data relating to the light beams of multiple wavelengths; and second multiplication data by multiplying a data piece relating to a light beam of the first wavelength by a data piece relating to a light beam of the second wavelength, both belonging to the second data relating to the light beams of multiple wavelengths, may correct the first multiplication data using the second multiplication data to generate fourth data, and may recognize the sheet based on the third data relating to the light beams of multiple wavelengths and the fourth data.

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[0010] (4) In the sheet recognition unit according to any of the items (1) to (3), the controller may use as the second data a representative value of output data corresponding to the region not including the object to be recognized.

[0011] (5) In the sheet recognition unit according to any of the items (1) to (4), the light source may include an acrylic

resin light guide stick and a light-emitting element opposing at least one of two end surfaces of the light guide, and the light source may apply light to the sheet through the light guide.

[0012] (6) In the sheet recognition unit according to any of the items (1) to (5), the light source may apply light extending linearly in a main scanning direction to the sheet, the light receiver may receive the light traveling from the sheet and extending linearly in the main scanning direction, and the controller may use as the second data output data corresponding to a position of the region including the object to be recognized in the main scanning direction.

[0013] (7) A sheet recognition unit according to a second aspect of the disclosure is a sheet recognition unit for recognizing a sheet provided with an object to be recognized, including: a light source configured to apply light beams of multiple wavelengths to the sheet; a light receiver configured to receive the light beams of multiple wavelengths traveling from the sheet; and a controller configured to acquire output data relating to the light beams of multiple wavelengths from the light receiver, the controller being configured to calculate multiplication data by multiplying a data piece relating to a light beam of a first wavelength by a data piece relating to a light beam of a second wavelength, both belonging to the acquired output data relating to the light beams of multiple wavelengths, and to recognize the sheet based on the output data relating to the light beams of multiple wavelengths and the multiplication data.

[0014] (8) In the sheet recognition unit according to any of the items (1) to (7), the light source may apply infrared light to the sheet, and the infrared light may include a light beam of a wavelength of 850 nm or longer and 950 nm or shorter.

[0015] (9) In the sheet recognition unit according to any of the items (1) to (8), the light receiver may receive light emitted from the light source and then reflected on the sheet, and the output data may include data relating to light reflected on the sheet.

[0016] (10) In the sheet recognition unit according to any of the items (1) to (9), the sheet to be recognized may include as the object to be recognized at least one of an ink whose reflectance is lower at a longer wavelength in an infrared region or an ink whose reflectance is higher at a longer wavelength in an infrared region.

[0017] (11) A sheet recognition method according to a third aspect of the disclosure is a sheet recognition method for recognizing a sheet provided with an object to be recognized, including: a step (A) of acquiring output data from a light receiver having received light emitted from a light source and then traveling from the sheet; a step (B) of acquiring first data being output data from the light receiver and corresponding to a region including the object to be recognized and second data being output data from the light receiver and corresponding to a region not including the object to be recognized; a step (C) of generating third data by correcting the first data using the second data; and a step (D) of recognizing the sheet based on the third data.

[0018] (12) In the sheet recognition method according to the item (11), the light source may apply light beams of multiple wavelengths to the sheet, the light receiver may receive the light beams of multiple wavelengths traveling from the sheet, the first data and the second data may each include data pieces relating to the light beams of multiple wavelengths, the step (C) may include correcting the data pieces of the first data relating to the light beams of multiple wavelengths using the data pieces of the second data relating to light beams of the respective wavelengths to generate third data relating to the light beams of the multiple wavelengths, and the step (D) may include recognizing the sheet based on the third data relating to the light beams of multiple wavelengths.

[0019] (13) In the sheet recognition method according to the item (12), the method may further include a step (E) of calculating: first multiplication data by multiplying a data piece relating to a light beam of a first wavelength by a data piece relating to a light beam of a second wavelength, both belonging to the first data relating to light beams of multiple wavelengths; and second multiplication data by multiplying a data piece relating to a light beam of the first wavelength by a data piece relating to a light beam of the second wavelength, both belonging to the second data relating to light beams of multiple wavelengths, the step (C) may include correcting the first multiplication data using the second multiplication data to generate fourth data, and the step (D) may include recognizing the sheet based on the third data relating to light beams of multiple wavelengths and the fourth data.

[0020] (14) In the sheet recognition method according to any of the items (11) to (13), the step (C) may include using as the second data a representative value of output data corresponding to the region not including the object to be recognized.

[0021] (15) In the sheet recognition method according to any of the items (11) to (14), the light source may include an acrylic resin light guide stick and a light-emitting element opposing at least one of two end surfaces of the light guide, and the light source may apply light to the sheet through the light guide.

[0022] (16) In the sheet recognition method according to any of the items (11) to (15), the light source may apply light extending linearly in a main scanning direction to the sheet, the light receiver may receive the light traveling from the sheet and extending linearly in the main scanning direction, and the step (C) may include using as the second data output data corresponding to a position of the region including the object to be recognized in the main scanning direction.

[0023] (17) A sheet recognition method according to a fourth aspect of the disclosure is a sheet recognition method for recognizing a sheet provided with an object to be recognized, including:

a step of acquiring output data relating to light beams of multiple wavelengths from a light receiver having received

the light beams of multiple wavelengths emitted from a light source and then traveling from the sheet;
 a step of calculating multiplication data by multiplying a data piece relating to a light beam of a first wavelength by
 a data piece relating to a light beam of a second wavelength, both belonging to the acquired output data relating to
 the light beams of multiple wavelengths; and
 a step of recognizing the sheet based on the output data relating to the light beams of multiple wavelengths and the
 multiplication data.

[0024] (18) In the sheet recognition method according to any of the items (11) to (17), the light source may apply
 infrared light to the sheet, and the infrared light may include a light beam of a wavelength of 850 nm or longer and 950
 nm or shorter.

[0025] (19) In the sheet recognition method according to any of the items (11) to (18), the light receiver may receive
 light emitted from the light source and then reflected on the sheet, and the output data may include data relating to the
 light reflected on the sheet.

[0026] (20) In the sheet recognition method according to any of the items (11) to (19), the sheet to be recognized may
 include as the object to be recognized at least one of an ink whose reflectance is lower at a longer wavelength in an
 infrared region or an ink whose reflectance is higher at a longer wavelength in an infrared region.

[0027] (21) A sheet recognition program according to a fifth aspect of the disclosure is a sheet recognition program
 for recognizing a sheet provided with an object to be recognized using a sheet recognition unit, allowing the sheet
 recognition unit to execute: a process (A) of acquiring output data from a light receiver having received light emitted
 from a light source and then traveling from the sheet; a process (B) of acquiring first data being output data from the
 light receiver and corresponding to a region including the object to be recognized and second data being output data
 from the light receiver and corresponding to a region not including the object to be recognized; a process (C) of generating
 third data by correcting the first data using the second data; and a process (D) of recognizing the sheet based on the
 third data.

[0028] (22) In the sheet recognition program according to the item (21), the light source may apply light beams of
 multiple wavelengths to the sheet, the light receiver may receive the light beams of multiple wavelengths traveling from
 the sheet, the first data and the second data may each include data pieces relating to the light beams of multiple
 wavelengths, and the process (C) may include correcting pieces of the first data relating to the light beams of multiple
 wavelengths using pieces of the second data relating to light beams of the respective wavelengths to generate third
 data relating to the light beams of the multiple wavelengths, and the process (D) may include recognizing the sheet
 based on the third data relating to light beams of multiple wavelengths.

[0029] (23) In the sheet recognition program according to the item (22), the program may further include a process
 (E) of calculating: first multiplication data by multiplying a data piece relating to a light beam of a first wavelength by a
 data piece relating to a light beam of a second wavelength, both belonging to the first data relating to the light beams
 of multiple wavelengths; and second multiplication data by multiplying a data piece relating to a light beam of the first
 wavelength by a data piece relating to a light beam of the second wavelength, both belonging to the second data relating
 to the light beams of multiple wavelengths, the process (C) may include correcting the first multiplication data using the
 second multiplication data to generate fourth data by, and the process (D) may include recognizing the sheet based on
 the third data relating to light beams of multiple wavelengths and the fourth data.

[0030] (24) In the sheet recognition program according to any of the items (21) to (23), the process (C) may include
 using as the second data a representative value of output data corresponding to the region not including the object to
 be recognized.

[0031] (25) In the sheet recognition program according to any of the items (21) to (24), the light source may include
 an acrylic resin light guide stick and a light-emitting element opposing at least one of two end surfaces of the light guide,
 and the light source may apply light to the sheet through the light guide.

[0032] (26) In the sheet recognition program according to any of the items (21) to (25), the light source may apply light
 extending linearly in a main scanning direction to the sheet, the light receiver may receive the light traveling from the
 sheet and extending linearly in the main scanning direction, and the process (C) may include using as the second data
 output data corresponding to a position of the region including the object to be recognized in the main scanning direction.

[0033] (27) A sheet recognition program according to a sixth aspect of the disclosure is a sheet recognition program
 for recognizing a sheet provided with an object to be recognized using a sheet recognition unit, allowing the sheet
 recognition unit to execute: a process of acquiring output data relating to light beams of multiple wavelengths from a
 light receiver having received light beams of multiple wavelengths emitted from a light source and then traveling from
 the sheet; a process of calculating multiplication data by multiplying a data piece relating to a light beam of a first
 wavelength by a data piece relating to a light beam of a second wavelength, both belonging to the acquired output data
 relating to light beams of multiple wavelengths; and a process of recognizing the sheet based on the output data relating
 to light beams of multiple wavelengths and the multiplication data.

[0034] (28) In the sheet recognition program according to any of the items (21) to (27), the light source may apply

infrared light to the sheet, and the infrared light may include a light beam of a wavelength of 850 nm or longer and 950 nm or shorter.

[0035] (29) In the sheet recognition program according to any of the items (21) to (28), the light receiver may receive light emitted from the light source and then reflected on the sheet, and the output data may include data relating to the light reflected on the sheet.

[0036] (30) In the sheet recognition program according to any of the items (21) to (29), the sheet to be recognized may include as the object to be recognized at least one of an ink whose reflectance is lower at a longer wavelength in an infrared region or an ink whose reflectance is higher at a longer wavelength in an infrared region.

[0037] The disclosure can provide a sheet recognition unit, a sheet recognition method, and a sheet recognition program each capable of improving the recognition accuracy on a sheet.

BRIEF DESCRIPTION OF DRAWINGS

[0038]

FIG. 1 is a schematic view of an example of the structure of a sheet recognition unit according to Embodiment 1, viewing a transport path of a banknote from a side.

FIG. 2 is a schematic plan view of an example of a banknote to be recognized of Embodiment 1.

FIG. 3 is an exemplary graph showing the reflectance of inks on the banknote to be recognized of Embodiment 1 in an infrared region.

FIG. 4 is a schematic perspective view of an example of the structure of the sheet recognition unit according to Embodiment 1.

FIG. 5 is a schematic view of an example of the structure of the sheet recognition unit according to Embodiment 1, viewing the transport path of a banknote from the top.

FIG. 6 is a schematic view of image data showing an entire banknote.

FIG. 7 is a flowchart of an example of the operation of the sheet recognition unit according to Embodiment 1.

FIG. 8 is a schematic view of an example of the structure of a sheet recognition unit according to Embodiment 2, viewing a transport path of a banknote from a side.

FIG. 9 is a schematic plan view of an example of a banknote to be recognized of Embodiment 2.

FIG. 10 is a schematic perspective view of an example of the structure of the sheet recognition unit according to Embodiment 2.

FIG. 11 is a schematic view of an example of the structure of the sheet recognition unit according to Embodiment 2, viewing the transport path of a banknote from the top.

FIG. 12 is a flowchart of an example of the operation of the sheet recognition unit according to Embodiment 2.

FIG. 13 is a schematic perspective view of an example of the appearance of a sheet handling device that may include a sheet recognition unit according to Embodiment 3.

FIG. 14 is a block diagram of an example of the structure of the sheet recognition unit according to Embodiment 3.

FIG. 15 is a schematic cross-sectional view of an example of the structure of an optical line sensor of the sheet recognition unit according to Embodiment 3.

DESCRIPTION OF EMBODIMENTS

[0039] Embodiments of the sheet recognition unit, the sheet recognition method, and the sheet recognition program according to the disclosure are described hereinbelow with reference to the drawings. Various sheets such as banknotes,

checks, vouchers, bills, business forms, documents of value, and card-like media are applicable as sheets used in the disclosure. The disclosure describes a case of a unit for handling a banknote as an example in the following. The sheet recognition program may be preliminarily introduced into the sheet recognition unit or may be given to an operator through network or a recording medium readable with a computer. Hereinafter, like reference signs refer to the same portions or the portions having the same function throughout the drawings, and redundant description of already described portions is omitted as appropriate. Figures for illustrating structures show an XYZ coordinate system as appropriate in which the X, Y, and Z directions are perpendicular to each other.

(Embodiment 1)

[0040] The structure of the sheet recognition unit according to the present embodiment is described with reference to FIG. 1. FIG. 1 is a schematic view of an example of the structure of a sheet recognition unit according to the present embodiment, viewing a transport path of a banknote from a side. As shown in FIG. 1, a sheet recognition unit 1a according to the present embodiment includes a light source 11a for applying light to a banknote BN, a light receiver 13a for receiving light traveling from the banknote BN, and a controller 20a for acquiring output data from the light receiver 13a. The sheet recognition unit 1a can be installed in, for example, a sheet handling device intended to handle banknotes as objects to be handled. The banknote BN to be recognized may be transported in the X direction in the XY plane.

[0041] FIG. 2 is a schematic plan view of an example of a banknote to be recognized of the present embodiment. FIG. 3 is an exemplary graph showing the reflectances of inks on the banknote to be recognized of the present embodiment in an infrared region. As shown in FIG. 2, the banknote BN to be recognized of the present embodiment is provided with an object S to be recognized (e.g., a print) on at least one main surface. The main surface of the banknote BN is set to include, for example, a rectangular region ROI_A including the object S to be recognized and, for example, a rectangular region ROI_B not including the object S to be recognized.

[0042] The banknote BN to be recognized may contain as the object S to be recognized at least one of an ink whose reflectance is lower at a longer wavelength in the infrared region (hereinafter, referred to as a negative ink) or an ink whose reflectance is higher at a longer wavelength in the infrared region (hereinafter, referred to as a positive ink) as shown in FIG. 3. The sheet recognition unit 1a can recognize a banknote BN having such an ink at high accuracy. Hereinafter, the negative ink and the positive ink may be collectively referred to as a special ink. In FIG. 3, IR1 is 800 nm, for example, IR2 is 870 nm, for example, and IR3 is 940 nm, for example.

[0043] The light source 11a applies light to the banknote BN. Light emitted from the light source 11a may be light in a wavelength band including a peak wavelength and wavelength(s) around the peak wavelength. Light of any kind (of any wavelength) may be emitted from the light source 11a, and examples thereof include visible light including white light, red light, green light, and blue light, and infrared light.

[0044] The light receiver 13a receives light traveling from the banknote BN. In other words, the light receiver 13a can function as an optical sensor. The light receiver 13a may receive light emitted from the light source 11a and then reflected on the banknote BN. In other words, while the light source 11a emits light, the light receiver 13a may receive the light emitted from the light source 11a and then reflected on the banknote BN. Here, the light receiver 13a can function as a sensor at least sensitive to the wavelength band in which light emitted from the light source 11a falls. The light receiver 13a may output, as output data, electrical signals according to the amount of light received. Specifically, the light receiver 13a may include a light-receiving element. The light-receiving element may receive light and convert the light into an electrical signal according to the amount of light received. The light receiver 13a may output this electrical signal. The term "amount of light" herein means the physical amount that is proportional to the radiation strength of incident light and the duration of light incidence.

[0045] FIG. 4 is a schematic perspective view of an example of the structure of the sheet recognition unit according to the present embodiment. As shown in FIG. 4, the light source 11a and the light receiver 13a may constitute an optical line sensor 14a extending in the Y direction. In this case, the Y direction corresponds to the main scanning direction of the optical line sensor 14a, and the X direction corresponds to the sub-scanning direction of the optical line sensor 14a. The light source 11a may emit light extending linearly in the Y direction. The light receiver 13a may include light-receiving elements (light-receiving pixels) arranged in one line in the Y direction and may constitute a linear image sensor.

[0046] The lengths of the light source 11a and the light receiver 13a in the Y direction (main scanning direction) may be longer than the length of the banknote BN in the Y direction. The light source 11a may apply light to the banknote BN linearly and entirely in the Y direction, and the light receiver 13a may receive light reflected on the banknote BN entirely in the Y direction. Specifically, the light receiver 13a may output electrical signals via channels corresponding to the respective light-receiving elements (positions in the Y direction) according to the amount of light received. The channels represent the numbers serially given to the light-receiving elements in the Y direction. Here, the light receiver 13a may output, as output data, line data relating to light simultaneously received by the respective channels. While the banknote BN is transported in the X direction (sub-scanning direction), light application by the light source 11a and light reception by the light receiver 13a may be repeated, whereby data relating to reflective light of the entire banknote BN

may be acquired.

[0047] FIG. 5 is a schematic view of an example of the structure of the sheet recognition unit according to the present embodiment, viewing the transport path of a banknote from the top. As shown in FIG. 5, the light source 11a may include a light guide 15a and light-emitting elements 17a opposing the two respective end surfaces 15aa of the light guide 15a, and may apply light to the banknote BN through the light guide 15a.

[0048] The light guide 15a is a transparent rod-shaped optical element for making light from the light-emitting elements 17a emit linearly toward the banknote BN as an object to be irradiated, and converts light emitted from the light-emitting elements 17a into a linear beam.

[0049] The light guide 15a may be formed from an acrylic resin. An acrylic resin light guide 15a significantly influences the output data from the light receiver 13a and thus can particularly effectively reduce the variation in the first data described later. Accordingly, the recognition accuracy on the banknote BN can be particularly effectively improved.

[0050] The light-emitting elements 17a are each an element for emitting light toward the opposing end surface 15aa and may employ a light emitting diode (LED), for example. A plurality of the light-emitting elements 17a may be disposed for an opposing end surface. The light-emitting element(s) 17a is/are provided for only one of the two end surfaces 15aa.

[0051] The light source 11a may apply infrared light including light of a wavelength of 850 nm or longer and 950 nm or shorter to the banknote BN. The transmittance of the light guide 15a (e.g., acrylic resin light guide) of the light source 11a shows a significant change particularly in an infrared region around 900 nm. Accordingly, the above structure can particularly effectively reduce the variation in output data (the first data described later) and thus can particularly effectively improve the recognition accuracy on the banknote BN. The structure also enables a banknote BN including as the object S to be recognized an ink (e.g., special ink) whose reflectance changes in an infrared region around 900 nm to be recognized at a high accuracy.

[0052] The light-receiving pixels of the light receiver 13a may each include a light-receiving element sensitive to all of different wavelength bands or may each include multiple light-receiving elements selectively receiving light in different wavelength bands. In the former case, the light source 11a may apply light beams of multiple wavelengths sequentially to the banknote BN, and the light receiver 13a may receive a light beam of each wavelength at the timing when a light beam of the wavelength is applied. In the latter case, the light source 11a may apply light beams of multiple wavelengths simultaneously to the banknote BN, and the light receiver 13a may receive the light beams of multiple wavelengths by multiple light-receiving elements.

[0053] The controller 20a executes a processing for acquiring output data from the light receiver 13a. Specifically, the controller 20a acquires data according to the amount of light received by the light receiver 13a. The output data from the light receiver 13a and acquired by the controller 20a may be digital data. The controller 20a may acquire image data of the entire banknote BN as the output data from the light receiver 13a.

[0054] FIG. 6 is a schematic view of image data showing an entire banknote. The image data of the entire banknote BN is data (two-dimensional data) of a photographed image of the entire banknote BN, and may consist of pixels Pix arranged in a matrix pattern in the Y direction (main scanning direction) and in the X direction (sub-scanning direction) as shown in FIG. 6. The address of each pixel Pix may be specified by the channel of the light receiver 13a corresponding to the position in the Y direction and the line corresponding to the position in the X direction. Lines represent the numbers serially given to line data pieces sequentially output from the light receiver 13a.

[0055] The output data from the light receiver 13a and acquired by the controller 20a may include data relating to light reflected on the banknote BN. Thereby, a banknote BN having an ink with a special reflectance characteristic (e.g., a special ink) as the object S to be recognized can be recognized at a high accuracy.

[0056] Also, the controller 20a may acquire image data relating to reflective light of the entire banknote BN as the output data from the light receiver 13a. Hereinafter, image data relating to reflective light is referred to as reflected image data.

[0057] The resolution of the output data acquired by the controller 20a may be the same as or different from the resolution of the output data from the light receiver 13a, and may be lower in the Y direction (main scanning direction) and in the X direction (sub-scanning direction), for example.

[0058] The controller 20a may control each component of the sheet recognition unit 1a and may include programs for executing processings such as a sheet recognition program, a central processing unit (CPU) for executing the programs, and various types of hardware (e.g., field programmable gate array (FPGA)) controlled by the CPU, for example.

[0059] The controller 20a executes a processing for acquiring first data being output data from the light receiver 13a and corresponding to the region ROI_A including the object S to be recognized (refer to FIG. 2) and second data being output data from the light receiver 13a and corresponding to the region ROI_B not including the object S to be recognized (refer to FIG. 2).

[0060] The first data and the second data may each be partial data of the reflected image data of the entire banknote BN, i.e., reflected image data of a part of the banknote BN. The regions ROI_A and ROI_B may be preliminary set according to the denomination of the banknote BN. The controller 20a may extract the first data and the second data from the output data (e.g., reflected image data of the entire banknote BN) from the light receiver 13a based on the positional

information of the regions ROI_A and ROI_B having been set for each denomination.

[0061] Then, the controller 20a executes a processing for correcting the first data using the second data to generate third data (hereinafter, also referred to as a correction processing), and executes a processing for recognizing the banknote BN based on the third data (hereinafter, also referred to as a recognition processing). The output data from the light receiver 13a may vary due to environmental reasons such as variations in properties among light-emitting elements 17a (e.g., LEDs) of the light source 11a, shift of the peak wavelength of the light source 11a depending on the temperature, fluctuation in transmittance of the light guide 15a (e.g., acrylic resin light guide) of the light source 11a depending on the wavelength, and variations in properties among light-emitting elements of the light receiver 13a. The present embodiment generates third data by correcting first data being output data from the light receiver 13a and corresponding to the region ROI_A including the object S to be recognized, using second data being output data from the light receiver 13a and corresponding to the region ROI_B not including the object S to be recognized, and thereby can reduce the output data variation (in particular, variation in the first data) due to the environmental reasons. The banknote BN is then recognized based on the third data being corrected data and thus can be recognized based on data with reduced variation. Accordingly, the recognition accuracy on the banknote BN can be improved.

[0062] The controller 20a may generate the third data by standardizing the first data using the second data in the correction processing. For example, a processing may be executed in which output values (pixel values) of the first data are divided by the respective output values of the second data.

[0063] Also, the controller 20a may use as the second data a representative value (e.g., average value, median value) of output data from the light receiver 13a and corresponding to the region ROI_B not including the object S to be recognized. For example, the output values (pixel values) of the first data may be standardized with (divided by) the average value of the output values (pixel values) included in the reflective image data in the region ROI_B not including the object S to be recognized.

[0064] The light source 11a may apply light beams of multiple wavelengths to the banknote BN. The light receiver 13a may receive the light beams of multiple wavelengths traveling from the banknote BN. The first data and the second data may each include data pieces relating to the light beams of multiple wavelengths. In the correction processing, the controller 20a may correct the data pieces of the first data relating to the light beams of multiple wavelengths using the data pieces of the second data relating to light beams of the respective wavelengths to generate third data relating to light beams of multiple wavelengths. In the recognition processing, the banknote BN may be recognized based on the third data relating to light beams of multiple wavelengths. Thereby, the banknote BN provided with the object S to be recognized (e.g., special ink) whose property (e.g., reflectance) changes according to the wavelength can be recognized at a high accuracy.

[0065] In this case, the controller 20a may additionally execute a processing (hereinafter, also referred to as a multiplication processing) for calculating first multiplication data by multiplying a data piece relating to a light beam of a first wavelength by a data piece relating to a light beam of a second wavelength, both belonging to the first data relating to the light beams of multiple wavelengths, and second multiplication data by multiplying a data piece relating to a light beam of the first wavelength by a data piece relating to a light beam of the second wavelength, both belonging to the second data relating to the light beams of multiple wavelengths. In the correction processing, a processing for further correcting the first multiplication data using the second multiplication data to generate fourth data. In the recognition processing, the banknote BN may be recognized based on the third data relating to light beams of multiple wavelengths and the fourth data. This can improve the discrimination ability between authentic and counterfeit objects S to be recognized (in particular, special ink). Accordingly, the recognition accuracy on a banknote BN can be further improved.

[0066] Typical inks such as an infrared absorbing ink and an infrared non-absorbing ink hardly show a difference in reflectance in an infrared region. In an output data space according to infrared light, the output is distributed in the direction of a vector $(1,1,1)^T$ passing through the origin point. Meanwhile, special inks behave differently. Accordingly, the product of pieces of output data relating to light beams of multiple wavelengths tends to receive a greater influence on typical inks than on special inks, which contributes to improved discrimination between special inks and typical inks.

[0067] The term "light beams of multiple wavelengths" means light beam(s) including at least a first wavelength and a second wavelength, the wavelengths falling in different wavelength bands. The "light beams of multiple wavelengths" may be, for example, light beams of two wavelengths, i.e., a light beam of a first wavelength and a light beam of a second wavelength; and light beams of three wavelengths, i.e., a light beam of a first wavelength, a light beam of a second wavelength, and a light beam of a third wavelength. For example, light beams of multiple wavelengths may include light beams of different colors in the case of visible light, or light beams in overlapped wavelength bands or light beams in non-overlapped wavelength bands in the case of infrared light or ultraviolet light.

[0068] Also, the expression "first data (second data) according to light beams of multiple wavelengths" means first data (second data) based on data output by the light receiver 13a having received light beams of the multiple wavelengths, and includes from first data (second data) according to a light beam of the first wavelength to first data (second data) according to a light beam of the N-th (N represents an integer of 2 or greater) wavelength.

[0069] In the case of using light beams of two wavelengths, in the correction processing, the controller 20a may correct

a piece of the first data relating to a light beam of a first wavelength (hereinafter, referred to as a piece of the first data relating to λ_1) using a piece of the second data relating to the light beam of the first wavelength (hereinafter, referred to as a piece of the second data relating to λ_1) to generate a piece of the third data relating to the light beam of the first wavelength (hereinafter, referred to as a piece of the third data relating to λ_1), and may correct a piece of the first data relating to a light beam of a second wavelength (hereinafter, referred to as a piece of the first data relating to λ_2) using a piece of the second data relating to the light beam of the second wavelength (hereinafter, referred to as a piece of the second data relating to λ_2) to generate a piece of the third data relating to the light beam of the second wavelength (hereinafter, referred to as a piece of the third data relating to λ_2). In the case of using light beams of three wavelengths, in the correction processing, the controller 20a may further correct a piece of the first data relating to a light beam of a third wavelength (hereinafter, referred to as a piece of the first data relating to λ_3) using a piece of the second data relating to the light beam of the third wavelength (hereinafter, referred to as a piece of the second data relating to λ_3) to generate a piece of the third data relating to the light beam of the third wavelength (hereinafter, referred to as a piece of the third data relating to λ_3).

[0070] In the case of using light beams of two wavelengths, in the multiplication processing, the controller 20a may calculate: as the first multiplication data, a data piece by multiplying a piece of the first data relating to λ_1 by a piece of the first data relating to λ_2 (hereinafter, referred to as a piece of the first data relating to $\lambda_1 \times \lambda_2$); and as the second multiplication data, a data piece by multiplying a piece of the second data relating to λ_1 by a piece of the second data relating to λ_2 (hereinafter, referred to as a piece of the second data relating to $\lambda_1 \times \lambda_2$). In the correction processing, the controller 20a may correct the piece of the first data relating to $\lambda_1 \times \lambda_2$ using the piece of the second data relating to $\lambda_1 \times \lambda_2$ to generate a data piece as the fourth data (hereinafter, referred to as a piece of the fourth data relating to $\lambda_1 \times \lambda_2$).

[0071] In the case of using light beams of three wavelengths, in the multiplication processing, the controller 20a may further calculate: as the first multiplication data, a data piece by multiplying a piece of the first data relating to λ_1 by a piece of the first data relating to λ_3 (hereinafter, referred to as a piece of the first data relating to $\lambda_1 \times \lambda_3$) and a data piece by multiplying a piece of the first data relating to λ_2 by a piece of the first data relating to λ_3 (hereinafter, referred to as a piece of the first data relating to $\lambda_2 \times \lambda_3$); and as the second multiplication data, a data piece by multiplying a piece of the second data relating to λ_1 by a piece of the second data relating to λ_3 (hereinafter, referred to as a piece of the second data relating to $\lambda_1 \times \lambda_3$) and a data piece by multiplying a piece of the second data relating to λ_2 by a piece of the second data relating to λ_3 (hereinafter, referred to as a piece of the second data relating to $\lambda_2 \times \lambda_3$). In the correction processing, the controller 20a may further correct the piece of the first data relating to $\lambda_1 \times \lambda_3$ using the piece of the second data relating to $\lambda_1 \times \lambda_3$ to generate a data piece as the fourth data (hereinafter, referred to as a piece of the fourth data relating to $\lambda_1 \times \lambda_3$) and correct the piece of the first data relating to $\lambda_2 \times \lambda_3$ using the piece of the second data relating to $\lambda_2 \times \lambda_3$ to generate a data piece as the fourth data (hereinafter, referred to as a piece of the fourth data relating to $\lambda_2 \times \lambda_3$).

[0072] In the case of using light beams of two wavelengths, the first multiplication data may be data obtained by multiplying each output value (pixel value) of the first data relating to a light beam of a first wavelength by a corresponding output value (pixel value) of the first data relating to a light beam of a second wavelength (data obtained by multiplying output values according to the same point in the XY plane). In the case of using light beams of three wavelengths, similarly, the multiplication data may be data obtained by multiplying output values (pixel values) corresponding to each other (output values according to the same point in the XY plane).

[0073] In the case of using light beams of two wavelengths, the second multiplication data may be data obtained by multiplying a representative value of the second data relating to a light beam of a first wavelength by a representative value of the second data relating to a light beam of a second wavelength (data obtained by multiplying representative values of the same kind (e.g., average values)). In the case of using light beams of three wavelengths, similarly, the second multiplication data may be data obtained by multiplying representative values corresponding to each other (representative values of the same kind).

[0074] In the case of using light beams of two wavelengths, in the recognition processing, the controller 20a may recognize the banknote BN based on the piece of the third data relating to λ_1 and the piece of the third data relating to λ_2 (two-dimensional feature amounts), or may recognize the banknote BN based on the piece of the third data relating to λ_1 , the piece of the third data relating to λ_2 , and the piece of the fourth data relating to $\lambda_1 \times \lambda_2$ (three-dimensional feature amounts).

[0075] In the case of using light beams of three wavelengths, in the recognition processing, the controller 20a may recognize the banknote BN based on the piece of the third data relating to λ_1 , the piece of the third data relating to λ_2 , and the piece of the third data relating to λ_3 (three-dimensional feature amounts), or may recognize the banknote BN based on the piece of the third data relating to λ_1 , the piece of the third data relating to λ_2 , the piece of the third data relating to λ_3 , the piece of the fourth data relating to $\lambda_1 \times \lambda_2$, the piece of the fourth data relating to $\lambda_1 \times \lambda_3$, and the piece of the fourth data relating to $\lambda_2 \times \lambda_3$ (six-dimensional feature amounts).

[0076] In the case of using light beams of multiple wavelengths as described, while the light source 11a emits light

beams of multiple wavelengths, the light receiver 13a may receive the light beams of multiple wavelengths emitted from the light source 11a and then reflected on the banknote BN. Here, the light receiver 13a can function as a sensor sensitive to the wavelength band in which light emitted from the light source 11a falls. The light receiver 13a may output, as output data, electrical signals according to the amounts of light received for the respective wavelengths. Specifically, the light receiver 13a may include light-receiving element(s). The light-receiving element(s) may receive light and convert the light into an electrical signal according to the amount of light received. The light receiver 13a may output these electrical signals for the respective wavelengths.

[0077] In the case of using light beams of multiple wavelengths, light beams of the respective wavelengths emitted from the light source 11a may each fall in a wavelength band including a peak wavelength and wavelength(s) around the peak wavelength, and the light beams of multiple wavelengths emitted from the light source 11a may have different peak wavelengths. The light source 11a may include multiple light-emitting elements 17a having different peak wavelengths. For example, the light source 11a may emit infrared light beams of multiple wavelengths having different peak wavelengths and may include multiple light-emitting elements 17a that emit infrared light beams of multiple wavelengths having different peak wavelengths. The light receiver 13a may receive each of the infrared light beams of multiple wavelengths emitted from the light source 11a and then reflected on the banknote BN. Similarly, the first data and the second data may each be data relating to the infrared light beams of multiple wavelengths. Moreover, a variety of data pieces relating to light beams of multiple wavelengths and to be processed by the controller 20a may be data relating to the infrared light beams of multiple wavelengths.

[0078] For example, the light source 11a may emit infrared light beams of multiple wavelengths having different peak wavelengths (first and second infrared light beams or first to third infrared light beams). The light receiver 13a may receive the infrared light beams of multiple wavelengths (first and second infrared light beams or first to third infrared light beams) emitted from the light source 11a and then reflected on the banknote BN. The first data and the second data may each include data relating to the infrared light beams of multiple wavelengths (first and second infrared light beams or first to third infrared light beams). The data relating to the light beams of multiple wavelengths and to be processed by the controller 20a may be data relating to the infrared light beams of multiple wavelengths (e.g., first and second infrared light beams or first to third infrared light beams).

[0079] The first and second infrared light beams may be a combination of any of two selected from an infrared light beam having a peak wavelength in the wavelength band from 770 to 830 nm, an infrared light beam having a peak wavelength in the wavelength band from 840 to 900 nm, and an infrared light beam having a peak wavelength in the wavelength band from 910 to 970 nm. Either the first or second infrared light beam may have a longer wavelength.

[0080] Similarly, the first, second, and third infrared light beams may be a combination of an infrared light beam having a peak wavelength in the wavelength band from 770 to 830 nm, an infrared light beam having a peak wavelength in the wavelength band from 840 to 900 nm, and an infrared light beam having a peak wavelength in the wavelength band from 910 to 970 nm. The wavelengths of the first, second, and third infrared light beams may be in any order.

[0081] As shown in FIG. 4, the light source 11a may apply light linearly in the main scanning direction (Y direction) to the banknote BN. The light receiver 13a may receive light extending linearly in the main scanning direction (Y direction) and traveling from the banknote BN. The controller 20a may use, as the second data, output data corresponding to the position of the region ROI_A including the object S to be recognized in the main scanning direction (Y direction) (refer to FIG. 2). As the position in the main scanning direction changes, the distance of light traveling in the light guide 15a (e.g., an acrylic resin light guide) of the light source 11a also changes. Thus, output data varies in the main scanning direction and shows a significant change particularly in a central portion in the main scanning direction (a central portion of the light guide 15a). Fortunately, the above structure, using, as the second data for correction, output data corresponding to the position of the region ROI_A including the object S to be recognized in the main scanning direction, can reduce the variation in output data owing to positions in the main scanning direction. Also, variations in properties among light-emitting elements may occur in the main scanning direction, but the above structure can reduce such variations in properties among light-emitting elements. Accordingly, the recognition accuracy on the banknote BN can be further improved.

[0082] In this case, the region ROI_A including the object S to be recognized and the region ROI_B not including the object S to be recognized may be located at the same portion (in the same range) in the main scanning direction (Y direction) of the banknote BN. The first data and the second data may be data of the same channel range in the reflected image data of the entire banknote BN. For example, the first data and the second data may each be data of channel n through channel m (n and m are natural numbers satisfying $n < m$) of the reflected image data of the entire banknote BN.

[0083] The ranges in the sub-scanning direction (X direction), i.e., the numbers of lines, of the first data and the second data may be appropriately set and may be the same as or different from each other.

[0084] In the recognition processing, the controller 20a may apply a discriminant function to each pixel to determine whether the pixel has a special ink or not. In other words, the above-described data pieces used in the recognition processing may each be input to the discriminant function as feature amounts (e.g., two-dimensional, three-dimensional or six-dimensional feature amounts), and whether the banknote BN is provided with the object S to be recognized or

not may be determined based on the output from the discriminant function. Thereby, the controller 20a can increase the speed of the recognition processing.

[0085] Here, the discriminant function can be generated by supervised learning. Specifically, discriminant analysis, a support-vector machine, or neural network can be used, for example. Examples of supervised data include image data including an ink portion printed with a special ink and a background portion (peripheral portion) of a banknote printed with the special ink. Here, the special ink portion and the background portion, i.e., a non-special ink portion, can be used as class labels. For example, in the case of a negative ink, image data relating to infrared light having a peak wavelength in the wavelength band from 910 to 970 nm is binarized (separated into an ink portion and a background portion), and the results themselves can be used as class labels for the respective pixels. In the case of a positive ink, image data relating to infrared light having a peak wavelength in the wavelength band from 770 to 830 nm is binarized (separated into an ink portion and a background portion), and the results themselves can be used as class labels for the respective pixels. In either case, the binarization processing may be executed according to Otsu's binarization.

[0086] More specifically, in the case of using light beams of three wavelengths, for example, in the recognition processing, the controller 20a may determine whether the banknote BN is provided with the object S to be recognized or not based on the following formulas (1) to (6). The formula (3) may be replaced by the formula (3').

[0087] [Math. 1]

$$Result = \begin{cases} Pass & (\lambda \leq L) \\ Fail & (otherwise) \end{cases} \quad (1)$$

$$\lambda = \sum_{j \in ROI_A} P_j \quad (2)$$

$$P_j = \begin{cases} 1 & (f(x_j) < c) \\ 0 & (otherwise) \end{cases} \quad (3)$$

$$P_j = \begin{cases} f(x_j) & (f(x_j) < c) \\ 0 & (otherwise) \end{cases} \quad (3')$$

$$f(x_j) = \omega \varphi(x_j) \quad (4)$$

$$\omega = (w_0, w_1, w_2, w_3) \quad (5)$$

$$\varphi(x_j) = \left(1, \frac{x_{1j}}{\mu_1}, \frac{x_{2j}}{\mu_2}, \frac{x_{3j}}{\mu_3} \right)^T \quad (6)$$

[0088] In the formulas (1) and (2), L represents a threshold value. In the formula (1), when λ is L or greater, the banknote BN is determined to be provided with the object S to be recognized, while when λ is smaller than L, the banknote BN is determined not to be provided with the object S to be recognized.

[0089] In the formula (2), λ represents an evaluation value and the formula (2) calculates the sum of P_j in the region ROI_A including the object S to be recognized.

[0090] In each formula, P_j represents the result of the discriminant function $f(x)$ and can employ the sum of the pixels determined as being provided with a special ink (formula (3)) or the sum of sort scores being the outputs from the discriminant function $f(x)$ (formula (3')). In the formulas (3) and (3'), c represents a threshold value of the sort scores.

[0091] The discriminant function $f(x)$ is represented by the formula (4), and three-dimensional feature amounts are

input as shown in the formula (6). In the formula (5), ω (wo to w_3) represents a coefficient vector (weights) obtained through machine learning, and $\phi(x_j)$ shown in the formula (6) represents a vector of the feature amounts of a target pixel_j (j represents the number indicating the target pixel). In the formula (6), x_{1j} , x_{2j} , and x_{3j} represent pixel values according to the first, second, and third light beams (optionally first, second, and third infrared light beams), respectively, in the target pixel_j, and μ_1 , μ_2 , and μ_3 represent representative values of output data pieces according to the first, second, and third light beams (optionally first, second, and third infrared light beams), respectively, in the region ROI_B not including the object S to be recognized. Here, the discriminant function $f(x)$ is represented by a linear function.

[0092] In the formula (6), x_{1j}/μ_1 , x_{2j}/μ_2 , and x_{3j}/μ_3 correspond to the piece of the third data relating to λ_1 , the piece of the third data relating to λ_2 , and the piece of the third data relating to λ_3 described above, respectively.

[0093] Alternatively, in the case of using light beams of three wavelengths, in the recognition processing, the controller 20a may determine whether the banknote BN is provided with the object S to be recognized or not based on the following formulas (11) to (16). The formula (13) may be replaced by the formula (13').

[0094] [Math. 2]

$$Result = \begin{cases} Pass & (\lambda \leq L) \\ Fail & (otherwise) \end{cases} \quad (11)$$

$$\lambda = \sum_{j \in ROI_A} P_j \quad (12)$$

$$P_j = \begin{cases} 1 & (f(x_j) < c) \\ 0 & (otherwise) \end{cases} \quad (13)$$

$$P_j = \begin{cases} f(x_j) & (f(x_j) < c) \\ 0 & (otherwise) \end{cases} \quad (13')$$

$$f(x_j) = \omega \phi(x_j) \quad (14)$$

$$\omega = (w_0, w_1, w_2, w_3, w_4, w_5, w_6) \quad (15)$$

$$\phi(x_j) = \left(1, \frac{x_{1j}}{\mu_1}, \frac{x_{2j}}{\mu_2}, \frac{x_{3j}}{\mu_3}, \frac{x_{1j}x_{2j}}{\mu_1\mu_2}, \frac{x_{1j}x_{3j}}{\mu_1\mu_3}, \frac{x_{2j}x_{3j}}{\mu_2\mu_3} \right)^T \quad (16)$$

[0095] In the formulas (11) and (12), L represents a threshold value. In the formula (11), when λ is L or greater, the banknote BN is determined to be provided with the object S to be recognized, while when λ is smaller than L, the banknote BN is determined not to be provided with the object S to be recognized.

[0096] In the formula (12), λ represents an evaluation value and the formula (12) calculates the sum of P_j in the region ROI_A including the object S to be recognized.

[0097] In each formula, P_j represents the result of the discriminant function $f(x)$ and can employ the sum of the pixels determined as being provided with a special ink (formula (13)) or the sum of sort scores being the outputs from the discriminant function $f(x)$ (formula (13')). In the formulas (13) and (13'), c represents a threshold value of the sort scores.

[0098] The discriminant function $f(x)$ is represented by the formula (14), and six-dimensional feature amounts are input as shown in the formula (16). In the formula (15), ω (wo to w_6) represents a coefficient vector (weights) obtained through machine learning, and $\phi(x_j)$ shown in the formula (16) represents a vector of the feature amounts of a target pixel_j (j represents the number indicating the target pixel). In the formula (16), x_{1j} , x_{2j} , and x_{3j} represent pixel values according

to the first, second, and third light beams (optionally first, second, and third infrared light beams), respectively, in the target pixel_j, and μ_1 , μ_2 , and μ_3 represent representative values of output data pieces according to the first, second, and third light beams (optionally first, second, and third infrared light beams), respectively, in the region ROI_B not including the object S to be recognized. Here, the discriminant function $f(x)$ is represented by a formula obtained by extending a linear function to a non-linear model.

[0099] In the formula (16), x_1/μ_1 , x_2/μ_2 , x_3/μ_3 , $x_1x_2/\mu_1\mu_2$, $x_1x_3/\mu_1\mu_3$, and $x_2x_3/\mu_2\mu_3$ correspond to the piece of the third data relating to λ_1 , the piece of the third data relating to λ_2 , the piece of the third data relating to λ_3 , the piece of the fourth data relating to $\lambda_1 \times \lambda_2$, the piece of the fourth data relating to $\lambda_1 \times \lambda_3$, and the piece of the fourth data relating to $\lambda_2 \times \lambda_3$, respectively.

[0100] As described in the formulas (6) and (16), for example, the controller 20a may execute a multiplication processing simultaneously with the correction processing in the same calculation processing.

[0101] In the recognition processing, the controller 20a may recognize the authenticity of the banknote BN. For example, when the banknote BN is determined to be provided with the object S to be recognized, the banknote BN may be determined as a genuine note, while when the banknote BN is determined not to be provided with the object S to be recognized, the banknote BN may be determined as a counterfeit note.

[0102] Next, the operation of the sheet recognition unit 1a of the present embodiment is described with reference to FIG. 7. FIG. 7 is a flowchart of an example of the operation of the sheet recognition unit according to the present embodiment.

[0103] First, as shown in FIG. 7, the controller 20a acquires output data from the light receiver 13a having received light emitted from the light source 11a and then traveling from (e.g., reflected on) the banknote BN (step S11).

[0104] Next, the controller 20a acquires first data being output data from the light receiver 13a and corresponding to the region ROI_A including the object S to be recognized and second data being output data from the light receiver 13a and corresponding to the region ROI_B not including the object S to be recognized (step S12).

[0105] Then, the controller 20a executes a correction processing, i.e., corrects the first data using the second data (step S13) to generate third data. In step S13, the controller 20a may execute a multiplication processing together with the correction processing.

[0106] The controller 20a subsequently executes a recognition processing for recognizing the banknote BN based on the third data (step S14), whereby the operation of the sheet recognition unit 1a is terminated.

(Embodiment 2)

[0107] The structure of the sheet recognition unit according to the present embodiment is described with reference to FIG. 8. FIG. 8 is a schematic view of an example of the structure of a sheet recognition unit according to the present embodiment, viewing a transport path of a banknote from a side. As shown in FIG. 8, a sheet recognition unit 1b according to the present embodiment includes a light source 11b for applying light beams of multiple wavelengths to a banknote BN, a light receiver 13b for receiving light beams of multiple wavelengths traveling from the banknote BN, and a controller 20b for acquiring output data relating to light beams of multiple wavelengths from the light receiver 13b. The sheet recognition unit 1b can be installed in, for example, a sheet handling device intended to handle banknotes as objects to be handled. The banknote BN to be recognized may be transported in the X direction in the XY plane.

[0108] FIG. 9 is a schematic plan view of an example of a banknote to be recognized of the present embodiment. As shown in FIG. 9, the banknote BN to be recognized of the present embodiment is provided with an object S to be recognized (e.g., a print) on at least one main surface. The main surface of the banknote BN is set to include, for example, a rectangular region ROI_A including the object S to be recognized.

[0109] The banknote BN to be recognized may contain as the object S to be recognized at least one of an ink whose reflectance is lower at a longer wavelength in an infrared region (a negative ink) or an ink whose reflectance is higher at a longer wavelength in the infrared region (a positive ink) as shown in FIG. 3. The sheet recognition unit 1b can recognize a banknote BN having such an ink at high accuracy.

[0110] The light source 11b applies light beams of multiple wavelengths to the banknote BN. Light of any kind (of any wavelength) may be emitted from the light source 11b, and examples thereof include visible light including white light, red light, green light, and blue light, and infrared light.

[0111] The term "light beams of multiple wavelengths" means light including at least a light beam of a first wavelength and a light beam of a second wavelength, the wavelengths falling in different wavelength bands. The "light beams of multiple wavelengths" may include, for example, light beams of two wavelengths, i.e., a light beam of a first wavelength and a light beam of a second wavelength; and light beams of three wavelengths, i.e., a light beam of a first wavelength, a light beam of a second wavelength, and a light beam of a third wavelength. For example, light beams of multiple wavelengths may include light beams of different colors in the case of visible light, or light beams in overlapped wavelength bands or light in non-overlapped wavelength bands in the case of infrared light or ultraviolet light.

[0112] The light receiver 13b receives light beams of multiple wavelengths traveling from the banknote BN. In other

words, the light receiver 13b can function as an optical sensor. The light receiver 13b may receive the light beams of multiple wavelengths emitted from the light source 11b and then reflected on the banknote BN. In other words, while the light source 11b emits light beams of multiple wavelengths, the light receiver 13b may receive the light beams of multiple wavelengths emitted from the light source 11b and then reflected on the banknote BN. Here, the light receiver 13b can function as a sensor sensitive to the wavelength band in which light emitted from the light source 11b falls. The light receiver 13b may output, as output data, electrical signals according to the amounts of light received for the respective wavelengths. Specifically, the light receiver 13b may include light-receiving elements. The light-receiving elements may each receive light and convert the light into an electrical signal according to the amount of light received. The light receiver 13b may output these electrical signals for the respective wavelengths.

[0113] FIG. 10 is a schematic perspective view of an example of the structure of the sheet recognition unit according to the present embodiment. As shown in FIG. 10, the light source 11b and the light receiver 13b may constitute an optical line sensor 14b extending in the Y direction. In this case, the Y direction corresponds to the main scanning direction of the optical line sensor 14b, and the X direction corresponds to the sub-scanning direction of the optical line sensor 14b. The light source 11b may emit light extending linearly in the Y direction. The light receiver 13b may include light-receiving elements (light-receiving pixels) arranged in one line in the Y direction and may constitute a linear image sensor.

[0114] The lengths of the light source 11b and the light receiver 13b in the Y direction (main scanning direction) may be longer than the length of the banknote BN in the Y direction. The light source 11b may apply light to the banknote BN linearly and entirely in the Y direction, and the light receiver 13b may receive light reflected on the banknote BN entirely in the Y direction. Specifically, the light receiver 13b may output electrical signals via channels corresponding to the respective light-receiving elements (positions in the Y direction) according to the amount of light received. The channels represent the numbers serially given to the light-receiving elements in the Y direction. Here, the light receiver 13b outputs, as output data, line data relating to light simultaneously received by the respective channels. While the banknote BN is transported in the X direction (sub-scanning direction), light application by the light source 11b and light reception by the light receiver 13b may be repeated, whereby data relating to reflective light of the entire banknote BN may be acquired.

[0115] FIG. 11 is a schematic view of an example of the structure of the sheet recognition unit according to the present embodiment, viewing the transport path of a banknote from the top. As shown in FIG. 11, the light source 11b may include a light guide 15b and light-emitting elements 17b opposing the two respective surfaces 15ba of the light guide 15b, and may apply light to the banknote BN through the light guide 15b.

[0116] The light guide 15b is a transparent rod-shaped optical element for allowing light from the light-emitting elements 17b to emit linearly toward the banknote BN as an object to be irradiated, and allows light emitted from the light-emitting elements 17b to extend linearly.

[0117] The light guide 15b may be formed from an acrylic resin.

[0118] The light-emitting elements 17b are each an element for emitting light toward the opposing end surface 15ba and may employ an LED, for example. A plurality of the light-emitting elements 17b may be disposed for an opposing end surface. The light-emitting element(s) 17b is/are provided for only one of the two end surfaces 15ba.

[0119] The light source 11b may apply infrared light including light of a wavelength of 850 nm or longer and 950 nm or shorter to the banknote BN. Thereby, the light guide 15a can recognize a banknote BN including an ink (e.g., special ink) whose reflectance changes in an infrared region around 900 nm as the object S to be recognized at a high accuracy.

[0120] The light-receiving pixels of the light receiver 13b may each include a light-receiving element sensitive to all of different wavelength bands or may each include multiple light-receiving elements selectively receiving light in different wavelength bands. In the former case, the light source 11b may apply light beams of multiple wavelengths sequentially to the banknote BN, and the light receiver 13b may receive a light beam of each wavelength at the timing when a light beam of the wavelength is applied. In the latter case, the light source 11b may apply light beams of multiple wavelengths simultaneously to the banknote BN, and the light receiver 13b may receive the light beams of multiple wavelengths by multiple light-receiving elements.

[0121] The controller 20b executes a processing for acquiring output data relating to light beams of multiple wavelengths from the light receiver 13b. Specifically, the controller 20b acquires data pieces according to the amount of light received by the light receiver 13b for the respective wavelengths. Also, the expression "output data relating to light beams of multiple wavelengths" means data output by the light receiver 13b having received the light beams of the multiple wavelengths, and includes from an output data piece relating to a light beam of the first wavelength to an output data piece relating to a light beam of the N-th (N represents an integer of 2 or greater) wavelength. The output data from the light receiver 13b and acquired by the controller 20b may be digital data. The controller 20b may acquire image data of the entire banknote BN as the output data from the light receiver 13b.

[0122] The image data of the entire banknote BN is data (two-dimensional data) of a photographed image of the entire banknote BN, and may consist of pixels Pix arranged in a matrix pattern in the Y direction (main scanning direction) and in the X direction (sub-scanning direction) as shown in FIG. 6. The address of each pixel Pix may be specified by the channel of the light receiver 13b corresponding to the position in the Y direction and the line corresponding to the position

in the X direction. Lines represent the numbers serially given to line data pieces sequentially output from the light receiver 13b.

[0123] The output data from the light receiver 13b and acquired by the controller 20b may include data relating to light reflected on the banknote BN. Thereby, a banknote BN having an ink with a special reflectance characteristic (e.g., a special ink) as the object S to be recognized can be recognized at a high accuracy.

[0124] Also, the controller 20b may acquire image data relating to reflective light of the entire banknote BN, i.e., reflected image data of the entire banknote BN, as the output data from the light receiver 13b.

[0125] The resolution of the output data acquired by the controller 20b may be the same as or different from the resolution of the output data from the light receiver 13b, and may be lower in the Y direction (main scanning direction) and in the X direction (sub-scanning direction), for example.

[0126] The controller 20b may control each component of the sheet recognition unit 1b and may include programs for executing processings such as a sheet recognition program, a CPU for executing the programs, and various types of hardware (e.g., FPGA) controlled by the CPU, for example.

[0127] The controller 20b executes a processing (hereinafter, also referred to as a multiplication processing) for calculating multiplication data by multiplying a data piece (an output data piece) according to a light beam of a first wavelength by a data piece (an output data piece) according to a light beam of a second wavelength, both belonging to the acquired output data relating to light beams of multiple wavelengths, and a recognition processing (hereinafter, also referred to as a recognition processing) for recognizing the banknote BN based on the output data relating to light beams of multiple wavelengths and the multiplication data. This can improve the discrimination ability between authentic and counterfeit objects S to be recognized (in particular, special ink). Accordingly, the recognition accuracy on a banknote BN can be improved.

[0128] Typical inks such as an infrared absorbing ink and an infrared non-absorbing ink hardly show a difference in reflectance in an infrared region. In an output data space according to infrared light, the output is distributed in the direction of a vector $(1,1,1)^T$ passing through the origin point. Meanwhile, special inks behave differently. Accordingly, the product of pieces of output data relating to light beams of multiple wavelengths tends to receive a greater influence on typical inks than on special inks, which contributes to improved discrimination between special inks and typical inks.

[0129] The output data relating to light beams of multiple wavelengths acquired by the controller 20b from the light receiver 13b may be data corresponding to the region ROI_A including the object S to be recognized. In other words, the pieces of the output data relating to light beams of multiple wavelengths may each be a partial data piece of the reflected image data of the entire banknote BN, i.e., reflected image data of a part of the banknote BN. The region ROI_A may be preliminary set according to the denomination of the banknote BN. The controller 20b may extract data corresponding to the region ROI_A including the object S to be recognized from the output data (e.g., reflected image data of the entire banknote BN) from the light receiver 13b based on the positional information of the region ROI_A having been set for each denomination.

[0130] In the case of using light beams of two wavelengths, in the multiplication processing, the controller 20b may calculate multiplication data by multiplying a piece of the output data relating to a light beam of a first wavelength (hereinafter, referred to as a piece of the output data relating to λ_1) by a piece of the output data relating to a light beam of a second wavelength (hereinafter, referred to as a piece of the output data relating to λ_2) (hereinafter, the calculated data is referred to as a piece of the output data relating to $\lambda_1 \times \lambda_2$), and in the recognition processing, the controller 20b may recognize the banknote BN based on the piece of the output data relating to λ_1 , the piece of the output data relating to λ_2 , and the piece of the output data relating to $\lambda_1 \times \lambda_2$ (three-dimensional feature amounts).

[0131] In the case of using light beams of three wavelengths, in the multiplication processing, the controller 20b may further calculate multiplication data by multiplying the piece of the output data relating to λ_1 by a piece of the output data relating to a light beam of a third wavelength (hereinafter, referred to as a piece of the output data relating to λ_3) (hereinafter, the calculated data is referred to as a piece of the output data relating to $\lambda_1 \times \lambda_3$) and multiplication data by multiplying the piece of the output data relating to λ_2 by the piece of the output data relating to λ_3 (hereinafter, the calculated data is referred to as the piece of the output data relating to $\lambda_2 \times \lambda_3$), and in the recognition processing, the controller 20b may recognize the banknote BN based on the piece of the output data relating to λ_1 , the piece of the output data relating to λ_2 , the piece of the output data relating to λ_3 , the piece of the output data relating to $\lambda_1 \times \lambda_2$, the piece of the output data relating to $\lambda_1 \times \lambda_3$, and the piece of the output data relating to $\lambda_2 \times \lambda_3$ (six-dimensional feature amounts).

[0132] In the case of using light beams of two wavelengths, the multiplication data may be data obtained by multiplying each output value (pixel value) of the output data relating to a light beam of the first wavelength by a corresponding output value (pixel value) of the output data relating to a light beam of the second wavelength (data obtained by multiplying the output values according to the same point in the XY plane). In the case of using light beams of three wavelengths, similarly, the multiplication data may be data obtained by multiplying output values (pixel values) corresponding to each other (output values according to the same point in the XY plane).

[0133] In the present embodiment, the light beams of multiple wavelengths emitted from the light source 11b may fall

in a wavelength band including a peak wavelength and wavelength(s) around the peak wavelength, or the light beams of multiple wavelengths emitted from the light source 11b may have different peak wavelengths. The light source 11b may include multiple light-emitting elements 17b having different peak wavelengths. For example, the light source 11b may emit infrared light beams of multiple wavelengths having different peak wavelengths or may include multiple light-emitting elements 17b that emit infrared light beams of multiple wavelengths having different peak wavelengths. The light receiver 13b may receive each of the infrared light beams of multiple wavelengths emitted from the light source 11b and then reflected on the banknote BN. Similarly, the output data pieces relating to light beams of multiple wavelengths acquired by the controller 20b from the light receiver 13b may each be a data piece according to the infrared light beams of multiple wavelengths. Moreover, a variety of data relating to light beams of multiple wavelengths and to be processed by the controller 20b may be data relating to the infrared light beams of multiple wavelengths.

[0134] For example, the light source 11b may emit infrared light beams of multiple wavelengths having different peak wavelengths (first and second infrared light beams or first to third infrared light beams). The light receiver 13b may receive the infrared light beams of multiple wavelengths (first and second infrared light beams or first to third infrared light beams) emitted from the light source 11b and then reflected on the banknote BN. The controller 20b may acquire data relating to the infrared light beams of multiple wavelengths (first and second infrared light beams or first to third infrared light beams) from the light receiver 13b. The data pieces relating to light beams of multiple wavelengths and to be processed by the controller 20b may be data pieces according to the infrared light beams of multiple wavelengths (e.g., first and second infrared light beams or first to third infrared light beams).

[0135] The first and second infrared light beams may be a combination of any of two selected from an infrared light beam having a peak wavelength in the wavelength band from 770 to 830 nm, an infrared light beam having a peak wavelength in the wavelength band from 840 to 900 nm, and an infrared light beam having a peak wavelength in the wavelength band from 910 to 970 nm. Either the first or second infrared light beam may have a longer wavelength.

[0136] Similarly, the first, second, and third infrared light beams may be a combination of an infrared light beam having a peak wavelength in the wavelength band from 770 to 830 nm, an infrared light beam having a peak wavelength in the wavelength band from 840 to 900 nm, and an infrared light beam having a peak wavelength in the wavelength band from 910 to 970 nm. The wavelengths of the first, second, and third infrared light beams may be in any order.

[0137] In the recognition processing, the controller 20b may apply a discriminant function to each pixel to determine whether the pixel has a special ink or not. In other words, each of the above-described data pieces used in the recognition processing may be input to the discriminant function as feature amounts (e.g., three-dimensional or six-dimensional feature amounts), and whether the banknote BN is provided with the object S to be recognized or not may be determined based on the output from the discriminant function. Thereby, the controller 20b can increase the speed of the recognition processing.

[0138] Here, the discriminant function can be generated by supervised learning. Specifically, for example, discriminant analysis, a support-vector machine, or neural network can be used, for example. Examples of supervised data include image data including an ink portion printed with a special ink and a background portion (peripheral portion) of a banknote printed with the special ink. Here, the feature amounts according to the respective pieces of data (e.g., three-dimensional or six-dimensional feature amounts) can be used as input, and the special ink portion and the background portion, i.e., a non-special ink portion, can be used as class labels. For example, in the case of a negative ink, image data relating to infrared light having a peak wavelength in the wavelength band from 910 to 970 nm is binarized (separated into an ink portion and a background portion), and the results themselves can be used as class labels for the respective pixels. In the case of a positive ink, image data relating to infrared light having a peak wavelength in the wavelength band from 770 to 830 nm is binarized (separated into an ink portion and a background portion), and the results themselves can be used as class labels for the respective pixels. In either case, the binarization processing may be executed according to Otsu's binarization.

[0139] More specifically, in the case of using light beams of three wavelengths, for example, in the recognition processing, the controller 20b may determine whether the banknote BN is provided with the object S to be recognized or not based on the following formulas (21) to (26). The formula (23) may be replaced by the formula (23').

[0140] [Math. 3]

$$Result = \begin{cases} Pass & (\lambda \leq L) \\ Fail & (otherwise) \end{cases} \quad (21)$$

$$\lambda = \sum_{j \in ROI_A} P_j \quad (22)$$

$$P_j = \begin{cases} 1 & (f(x_j) < c) \\ 0 & (\text{otherwise}) \end{cases} \quad (23)$$

$$P_j = \begin{cases} f(x_j) & (f(x_j) < c) \\ 0 & (\text{otherwise}) \end{cases} \quad (23')$$

$$f(x_j) = \omega \phi(x_j) \quad (24)$$

$$\omega = (w_0, w_1, w_2, w_3, w_4, w_5, w_6) \quad (25)$$

$$\phi(x_j) = (1, x_{1j}, x_{2j}, x_{3j}, x_{1j}x_{2j}, x_{1j}x_{3j}, x_{2j}x_{3j})^T \quad (26)$$

[0141] In the formulas (21) and (22), L represents a threshold value. In the formula (21), when λ is L or greater, the banknote BN is determined to be provided with the object S to be recognized, while when λ is smaller than L , the banknote BN is determined not to be provided with the object S to be recognized.

[0142] In the formula (22), λ represents an evaluation value and the formula (22) calculates the sum of P_j in the region ROI_A including the object S to be recognized.

[0143] In each formula, P_j represents the result of the discriminant function $f(x)$ and can employ the sum of the pixels determined as being provided with a special ink (formula (23)) or the sum of sort scores being the outputs from the discriminant function $f(x)$ (formula (23')). In the formulas (23) and (23'), c represents a threshold value of the sort scores.

[0144] The discriminant function $f(x)$ is represented by the formula (24), and six-dimensional feature amounts are input as shown in the formula (26). In the formula (25), ω (w_0 to w_6) represents a coefficient vector obtained through machine learning, and $\phi(x_j)$ shown in the formula (26) represents a vector of the feature amounts of a target pixel $_j$ (j represents the number indicating the target pixel). In the formula (26), x_{1j} , x_{2j} , and x_{3j} represent pixel values according to the first, second, and third light beams (optionally first, second, and third infrared light beams), respectively, in the target pixel $_j$. Here, the discriminant function $f(x)$ is represented by a formula obtained by extending a linear function to a non-linear model.

[0145] In the formula (26), x_{1j} , x_{2j} , x_{3j} , $x_{1j}x_{2j}$, $x_{1j}x_{3j}$, and $x_{2j}x_{3j}$ correspond to the piece of the output data relating to λ_1 , the piece of the output data relating to λ_2 , the piece of the output data relating to λ_3 , the piece of the output data relating to $\lambda_1 \times \lambda_2$, the piece of the output data relating to $\lambda_1 \times \lambda_3$, and the piece of the output data relating to $\lambda_2 \times \lambda_3$, respectively.

[0146] In the recognition processing, the controller 20b may recognize the authenticity of the banknote BN. For example, when the banknote BN is determined to be provided with the object S to be recognized, the banknote BN may be determined as a genuine note, while when the banknote BN is determined not to be provided with the object S to be recognized, the banknote BN may be determined as a counterfeit note.

[0147] Next, the operation of the sheet recognition unit 1b of the present embodiment is described with reference to FIG. 12. FIG. 12 is a flowchart of an example of the operation of the sheet recognition unit according to the present embodiment.

[0148] First, as shown in FIG. 12, the controller 20b acquires output data from the light receiver 13b having received light beams of multiple wavelengths emitted from the light source 11b and then traveling from (e.g., reflected on) the banknote BN (step S21).

[0149] Next, the controller 20b executes multiplication (step S22), i.e., calculates multiplication data by multiplying a data piece relating to a light beam of a first wavelength by a data piece relating to a light beam of a second wavelength, both belonging to the acquired output data relating to light beams of multiple wavelengths.

[0150] In the case where the data relating to a light beam of the first wavelength and the data relating to a light beam of the second wavelength each correspond to data corresponding to the region ROI_A including the object S to be recognized, before step S22, a processing may be executed in which output data relating to light at the corresponding wavelength of the region ROI_A including the object S to be recognized (e.g., reflected image data in the region ROI_A including the object S to be recognized) is extracted from the data corresponding to the entire banknote BN (e.g., reflected

image data of the entire banknote BN).

[0151] The controller 20b subsequently executes a recognition processing for recognizing the banknote BN based on the output data (which may be data corresponding to the region ROI_A including the object S to be recognized) according to light beams of multiple wavelengths and acquired by the controller 20b from the light receiver 13b and the calculated multiplication data (step S23), whereby the operation of the sheet recognition unit 1b is terminated.

(Embodiment 3)

[0152] Next, the structure of a sheet handling device that may include the sheet recognition unit of the present embodiment is described with reference to FIG. 13. FIG. 13 is a schematic perspective view of an example of the appearance of a sheet handling device that may include a sheet recognition unit according to the present embodiment. The sheet handling device including the sheet recognition unit of the present embodiment may have the structure shown in FIG. 13, for example. A sheet handling device 300 shown in FIG. 13 includes the banknote recognition unit (not shown in FIG. 13) of the present embodiment that executes the banknote recognition processing; a hopper 301 in which a plurality of banknotes to be handled can be stacked; two rejecters 302 each of which feeds out a reject banknote; an operation unit 303 with which the operator inputs commands; four stackers 306a to 306d into each of which banknotes whose denomination, authenticity, and fitness have been recognized are sorted and stacked in a housing 310; and a display 305 that displays information including the banknote recognition and counting results and the stacking status in each of the stackers 306a to 306d.

[0153] Next, the structure of the sheet recognition unit of the present embodiment is described with reference to FIG. 14. FIG. 14 is a block diagram of an example of the structure of the sheet recognition unit according to the present embodiment. As shown in FIG. 14, a sheet recognition unit 100 of the present embodiment includes an optical line sensor 110, a controller 120, a storage 130, and a transporter 140.

[0154] The optical line sensor 110 detects various optical properties of a banknote to be transported and may include a light source 111 and a light receiver 113 along the transport path of a banknote. The light source 111 each apply light beams of multiple wavelengths to a banknote, and the light receiver 113 receives the light beams of multiple wavelengths emitted from each light source 111 and then reflected on the banknote and outputs data relating to the light beams of multiple wavelengths for the respective wavelengths.

[0155] The controller 120 includes programs for executing various processings stored in the storage 130, such as a sheet recognition program, a CPU for executing the programs, and various types of hardware (e.g., FPGA) controlled by the CPU, for example. The controller 120 controls the components of the sheet recognition unit 100 according to the programs stored in the storage 130. Also, the controller 120 has functions for executing processings including acquiring output data from the light receiver 113, correcting the acquired output data, multiplying the acquired output data, and recognizing a banknote using the various pieces of corrected and/or multiplied data using the programs stored in the storage 130. These processings executed by the controller 120 are not specifically described here because they are similar to the processings executed by the controller 10a or 10b described in Embodiment 1 or 2.

[0156] The controller 120 executes as the recognition processing a processing for recognizing at least the denomination and the authenticity of a banknote. The authenticity of a banknote can be recognized according to the recognition processing using the corrected and/or multiplied data as described in Embodiment 1 or 2. The controller 120 may have a function of determining the fitness of a banknote. In this case, the controller 120 has a function of determining whether the banknote is a fit note reusable in the market or an unfit note inappropriate for market circulation by detecting the presence or absence of a defect such as soil, fold, or tear in the banknote.

[0157] The storage 130 is defined by a volatile and/or nonvolatile storage device such as a semiconductor memory and a hard disc and stores various programs and various data for control of the sheet recognition unit 100.

[0158] The transporter 140 rotates a plurality of rollers, belts, and the like to transport banknotes one by one along the transport path in the sheet recognition unit 100.

[0159] Next, the structure of the optical line sensor 110 is described with reference to FIG. 15. FIG. 15 is a schematic cross-sectional view of an example of the structure of an optical line sensor of the sheet recognition unit according to the present embodiment. As shown in FIG. 15, the optical line sensor 110 includes a contact image sensor opposing the transport path 311 of the sheet handling device and is a part of the transport path 311. A banknote BN is transported in the transport path 311 (in the XY plane) in the X direction. The Y direction corresponds to the main scanning direction of the optical line sensor 110, and the X direction corresponds to the sub-scanning direction of the optical line sensor 110.

[0160] As shown in FIG. 15, the optical line sensor 110 may include two light sources for reflection 111, a condensing lens 112, the light receiver 113, and a substrate 114. The light sources for reflection 111 each include, for example, a light guide extending in the main scanning direction and multiple light-emitting elements opposing at least one end surface of the light guide and emitting light beams of different wavelengths, and sequentially apply light beams of multiple wavelengths to a main surface (hereinafter, referred to as surface A) of the banknote BN on the side of the light receiver 113. The condensing lens 112 includes, for example, a rod lens array in which rod lenses are arranged in the main

scanning direction, and collects light emitted from the light sources for reflection 111 and then reflected on the surface A of the banknote BN. The light receiver 113 includes, for example, a linear image sensor in which light-receiving elements (light-receiving pixels) are arranged in the main scanning direction. Each light-receiving element is sensitive to the wavelength band in which light beams of multiple wavelengths emitted from the light source 111 fall. Each light-receiving element can use, for example, a silicon (Si) photodiode sensitive to at least from the visible light region to an infrared region including a wavelength of 1100 nm. Each light-receiving element is mounted on the substrate 114, receives light collected by the condensing lens 112, transforms the light into an electrical signal according to the amount of light received, and outputs the electrical signal to the substrate 114. Each light-receiving element receives a light beam of a wavelength at the timing when the light beam of the wavelength is emitted from the light source 111. The substrate 114 includes, for example, a drive circuit for driving the light-receiving elements and a signal processing circuit for processing signals from the light-receiving elements and outputting the processed signals. The substrate 114 amplifies the output signals from the light receiver 113 (each light-receiving element), executes A/D transformation of the signals into digital data, and outputs the data.

[0161] The light sources 111 each apply, as light beams of multiple wavelengths, at least infrared light beams of multiple wavelengths, e.g., first to third infrared light beams of different peak wavelengths. Additionally, the light sources 111 may each apply visible light. Examples of the visible light include red light (R), green light (G), blue light (B), and white light (W) containing light of these three colors.

[0162] In the present embodiment, the controller 120 executes processings similarly to the controller 10a or 10b as described in Embodiment 1 or 2, and thus the recognition accuracy on a banknote can be improved as in Embodiment 1 or 2.

[0163] The embodiments describe the case of using output data relating to light emitted from light source(s) and then reflected on a banknote for a correction processing and a multiplication processing by a controller. Alternatively, the output data relating to light emitted from light source(s) and transmitted through a banknote may be used for a correction processing and a multiplication processing by a controller.

[0164] Embodiments of the disclosure have been described above with reference to the drawings. The disclosure is not limited to the embodiments. Also, the structures of the embodiments may be combined or modified as appropriate within the range not departing from the gist of the disclosure.

INDUSTRIAL APPLICABILITY

[0165] As described above, the disclosure provides a technique useful in improving the recognition accuracy on a sheet.

REFERENCE SIGNS LIST

[0166]

1a, 1b, 100: sheet recognition unit
 11a, 11b, 111: light source
 13a, 13b, 113: light receiver
 14a, 14b, 110: optical line sensor
 15a, 15b: light guide
 15aa, 15ba: end surface of light guide
 17a, 17b: light-emitting element
 20a, 20b, 120: controller
 112: condensing lens
 114: substrate
 130: storage
 140: transporter
 300: sheet handling device
 301: hopper
 302: rejecter
 303: operation unit
 305: display
 306a to 306d: stacker
 311: transport path
 BN: banknote
 S: object to be recognized
 ROI_A: region including object to be recognized

ROI_B: region not including object to be recognized

Pix: pixel

5 Claims

1. A sheet recognition unit for recognizing a sheet provided with an object to be recognized, comprising:

a light source configured to apply light to the sheet;
 a light receiver configured to receive light traveling from the sheet; and
 a controller configured to acquire output data from the light receiver,
 the controller being configured
 to acquire first data being output data from the light receiver and corresponding to a region including the object
 to be recognized and second data being output data from the light receiver and corresponding to a region not
 including the object to be recognized,
 to correct the first data using the second data to generate third data, and
 to recognize the sheet based on the third data.

2. The sheet recognition unit according to claim 1,

wherein the light source is configured to apply light beams of multiple wavelengths to the sheet,
 the light receiver is configured to receive the light beams of multiple wavelengths traveling from the sheet,
 the first data and the second data each include data pieces relating to the light beams of multiple wavelengths, and
 the controller is configured
 to correct the data pieces of the first data relating to the light beams of multiple wavelengths using the data
 pieces of the second data relating to the light beams of the respective wavelengths to generate third data relating
 to the light beams of the multiple wavelengths, and
 to recognize the sheet based on the third data relating to the light beams of multiple wavelengths.

3. The sheet recognition unit according to claim 2,

wherein the controller is configured
 to calculate: first multiplication data by multiplying a data piece relating to a light beam of a first wavelength by
 a data piece relating to a light beam of a second wavelength, both belonging to the first data relating to the light
 beams of multiple wavelengths; and second multiplication data by multiplying a data piece relating to a light
 beam of the first wavelength by a data piece relating to a light beam of the second wavelength, both belonging
 to the second data relating to the light beams of multiple wavelengths,
 to correct the first multiplication data using the second multiplication data to generate fourth data, and
 to recognize the sheet based on the third data relating to the light beams of multiple wavelengths and the fourth
 data.

4. The sheet recognition unit according to any one of claims 1 to 3,
 wherein the controller is configured to use as the second data a representative value of output data corresponding
 to the region not including the object to be recognized.

5. The sheet recognition unit according to any one of claims 1 to 4,

wherein the light source includes an acrylic resin light guide stick and a light-emitting element opposing at least
 one of two end surfaces of the light guide, and
 the light source is configured to apply light to the sheet through the light guide.

6. The sheet recognition unit according to any one of claims 1 to 5,

wherein the light source is configured to apply light extending linearly in a main scanning direction to the sheet,
 the light receiver is configured to receive the light traveling from the sheet and extending linearly in the main
 scanning direction, and
 the controller is configured to use as the second data output data corresponding to a position of the region
 including the object to be recognized in the main scanning direction.

7. The sheet recognition unit according to any one of claims 1 to 6,

wherein the light source is configured to apply infrared light to the sheet, and
the infrared light includes a light beam of a wavelength of 850 nm or longer and 950 nm or shorter.

8. The sheet recognition unit according to any one of claims 1 to 7,

wherein the light receiver is configured to receive light emitted from the light source and then reflected on the
sheet, and
the output data includes data relating to the light reflected on the sheet.

9. The sheet recognition unit according to any one of claims 1 to 8,

wherein the sheet to be recognized includes as the object to be recognized at least one of an ink whose reflectance
is lower at a longer wavelength in an infrared region or an ink whose reflectance is higher at a longer wavelength
in an infrared region.

10. A sheet recognition method for recognizing a sheet provided with an object to be recognized, comprising:

a step of acquiring output data from a light receiver having received light emitted from a light source and then
traveling from the sheet;

a step of acquiring first data being output data from the light receiver and corresponding to a region including
the object to be recognized and second data being output data from the light receiver and corresponding to a
region not including the object to be recognized;

a step of generating third data by correcting the first data using the second data; and

a step of recognizing the sheet based on the third data.

FIG.1

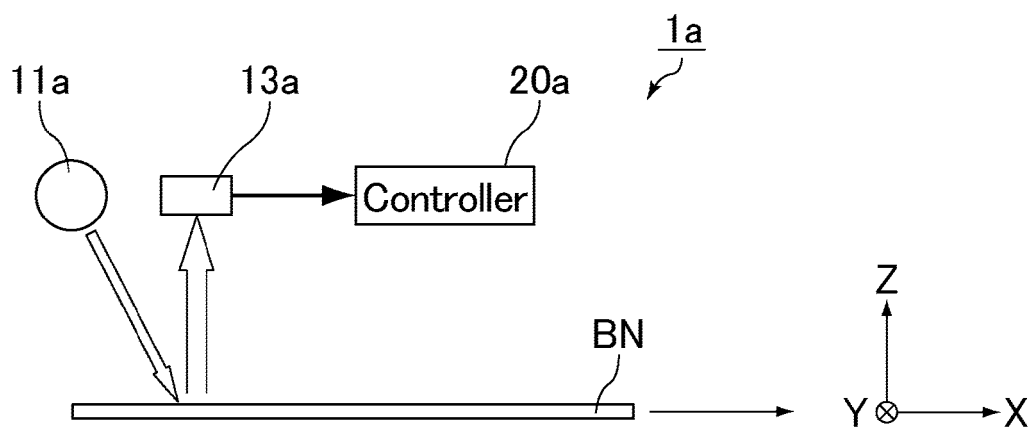


FIG.2

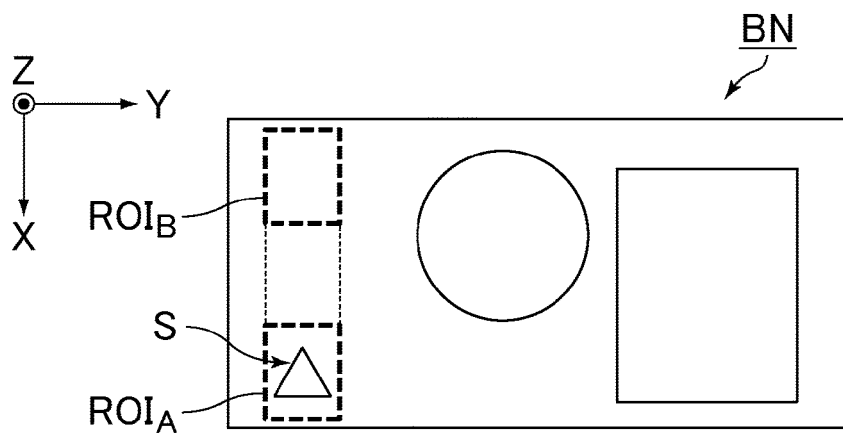


FIG.3

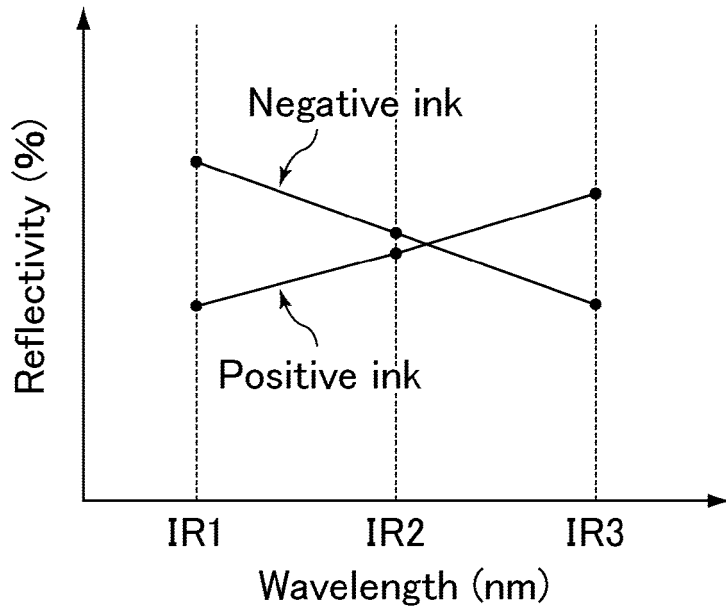


FIG.4

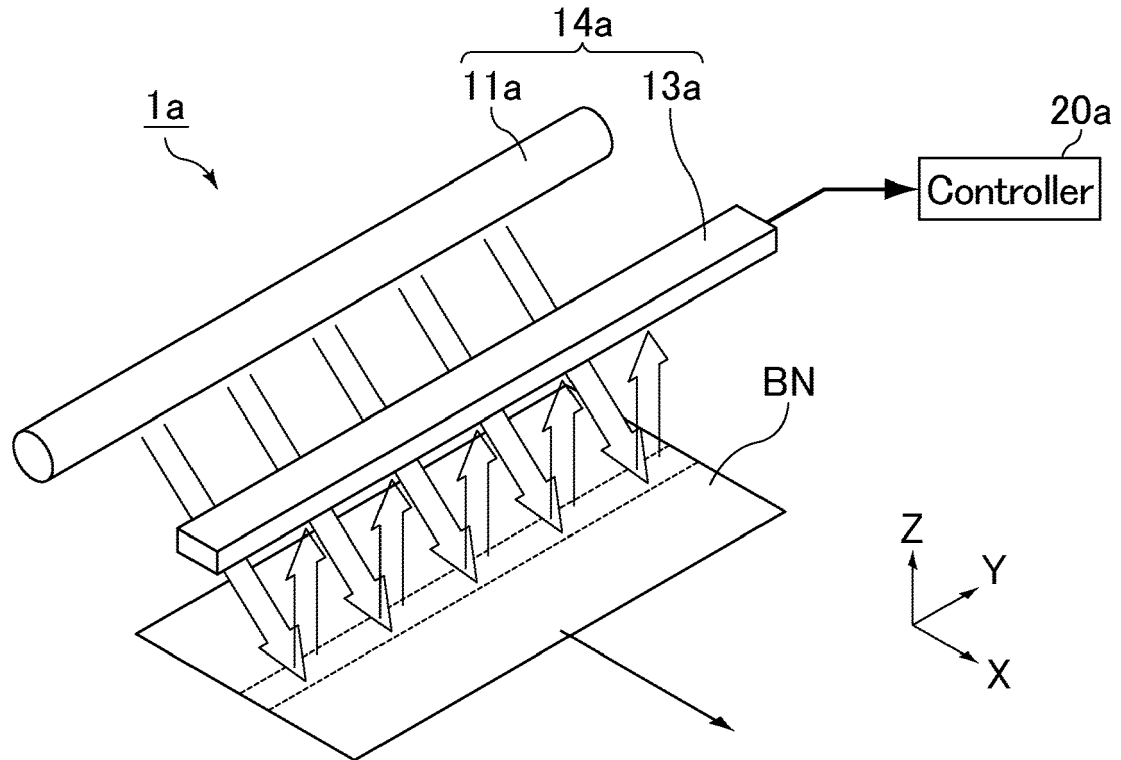


FIG.5

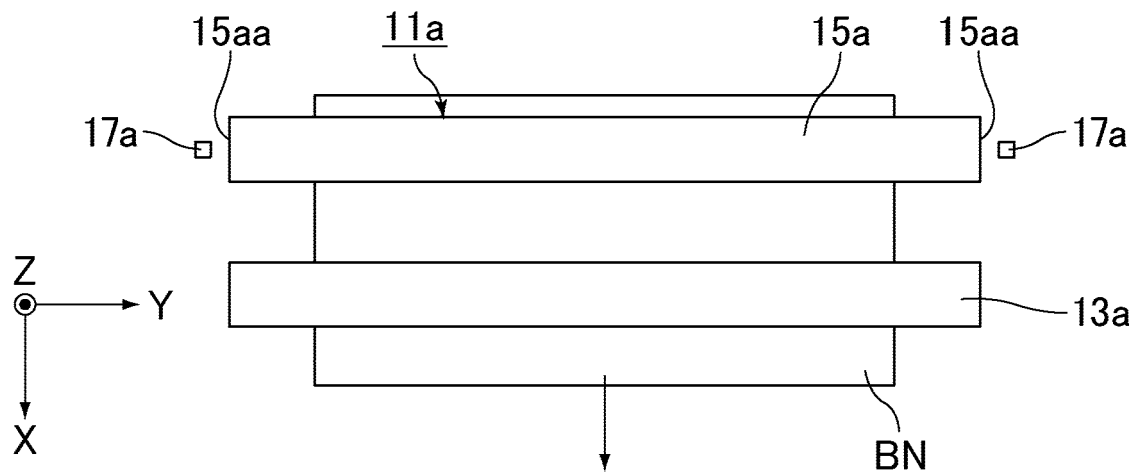


FIG.6

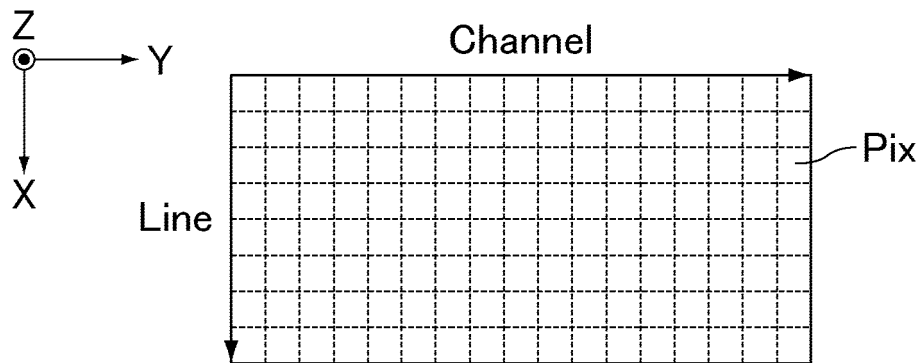


FIG.7

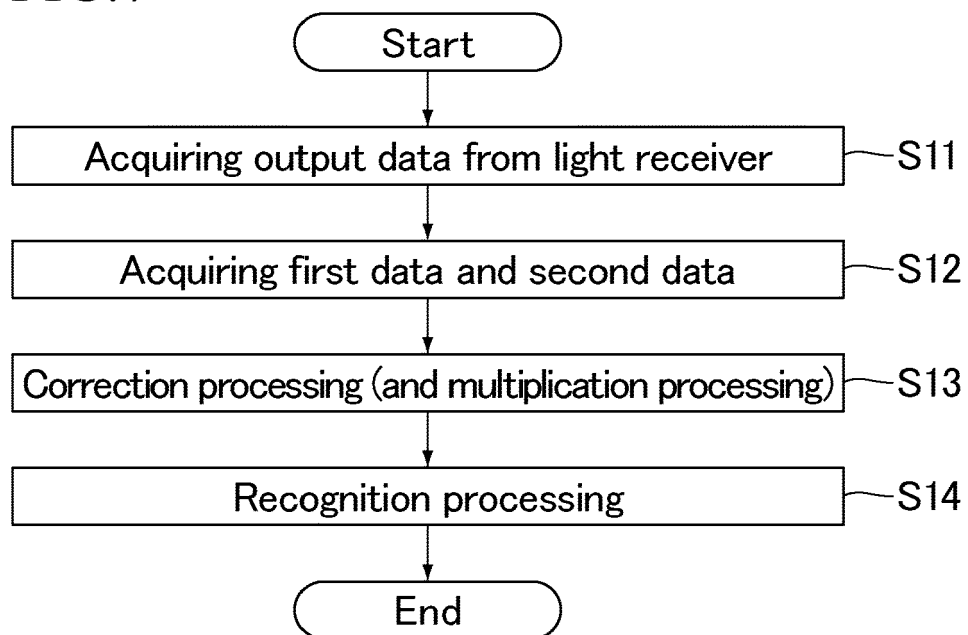


FIG.8

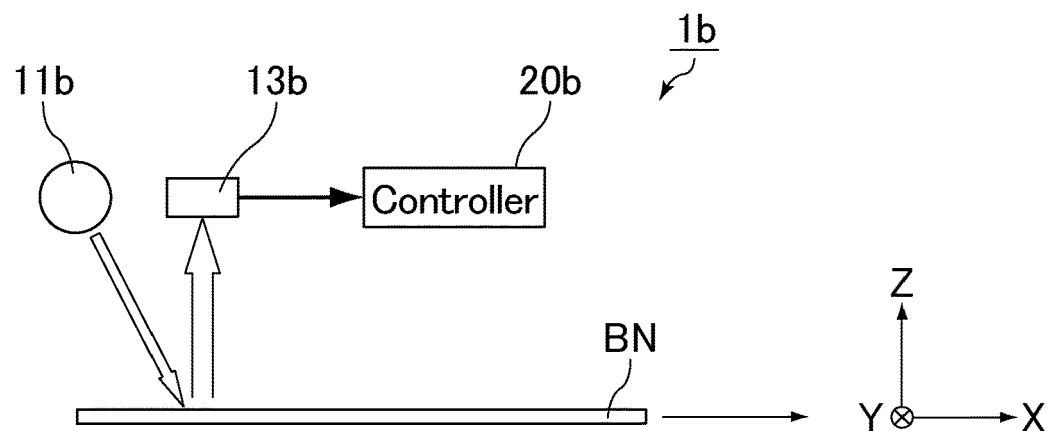


FIG.9

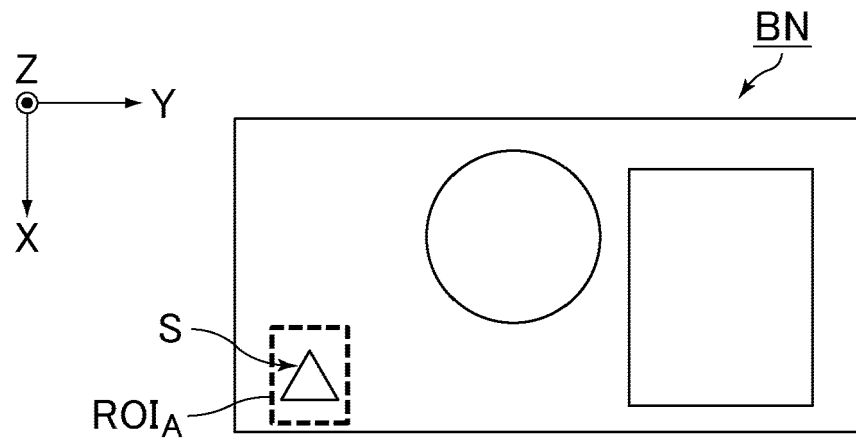


FIG.10

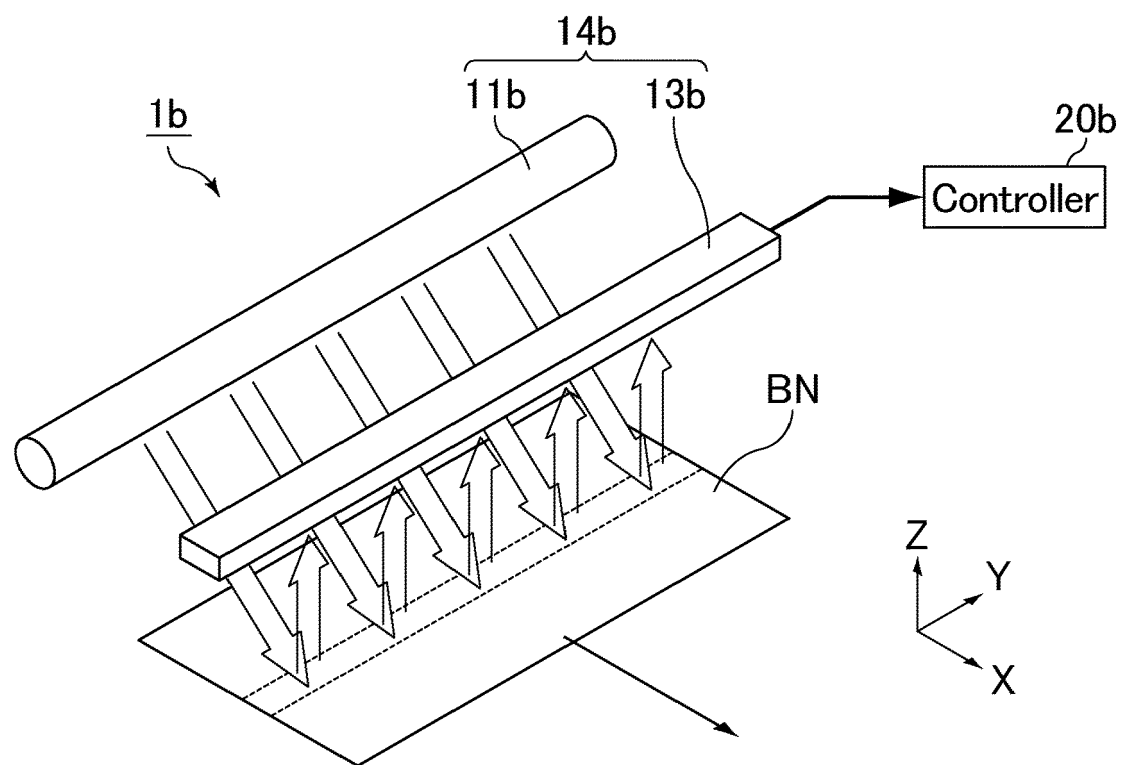


FIG.11

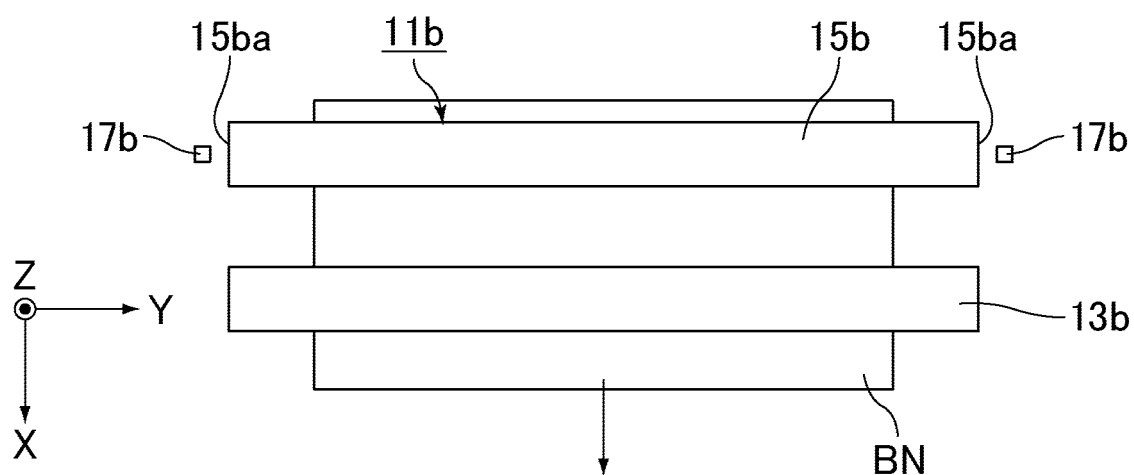


FIG.12

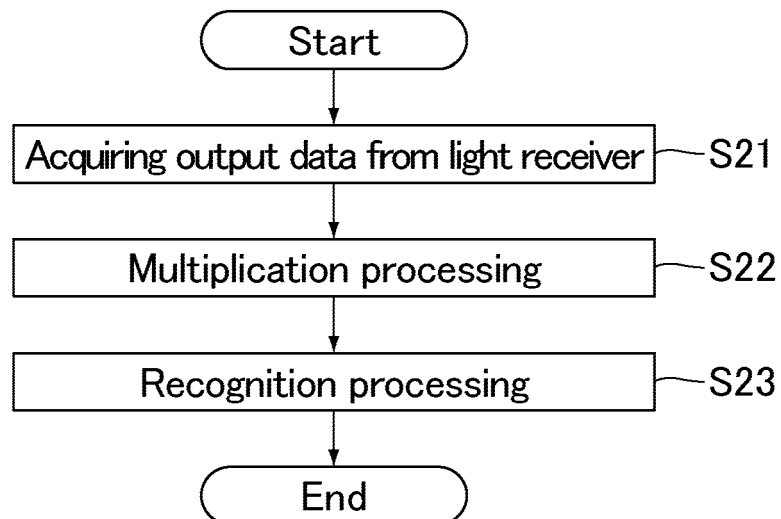


FIG.13

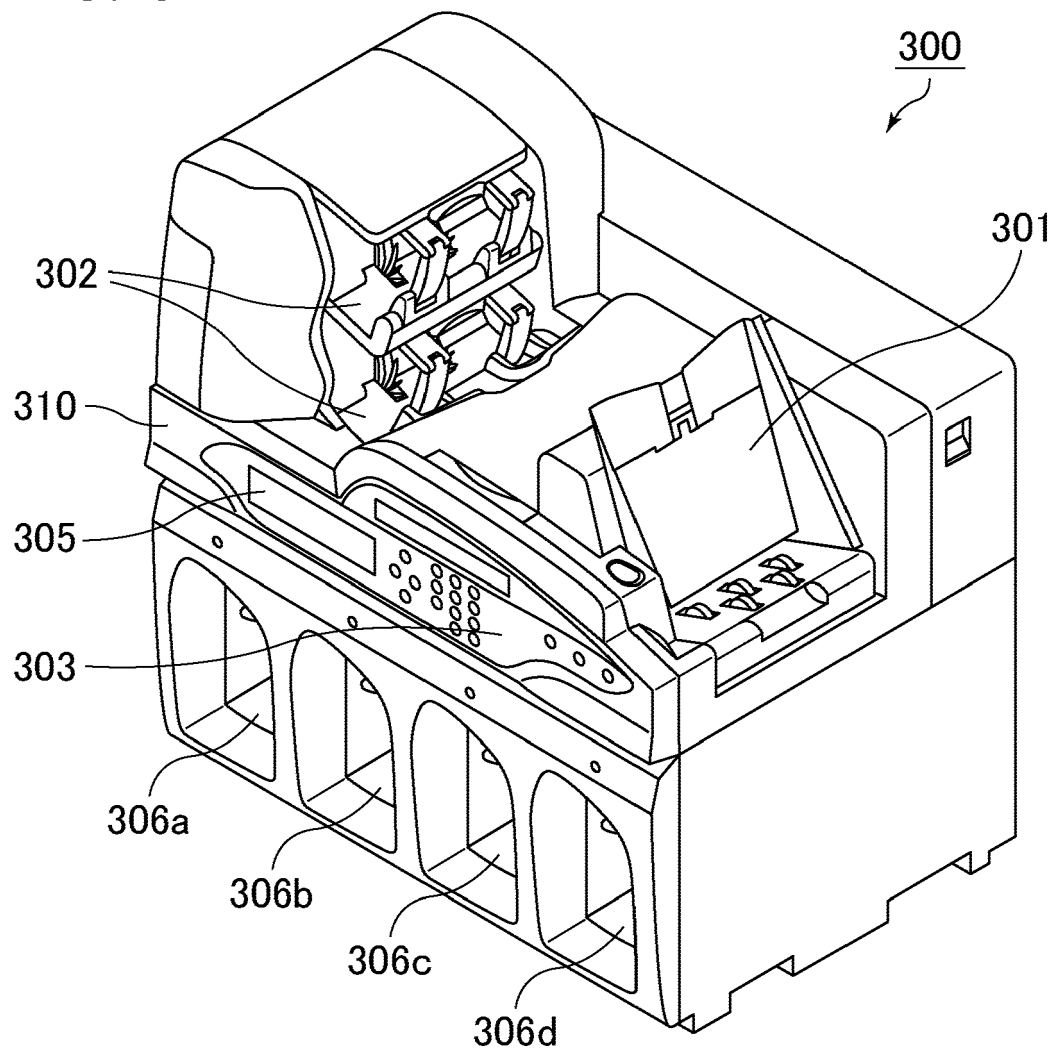


FIG.14

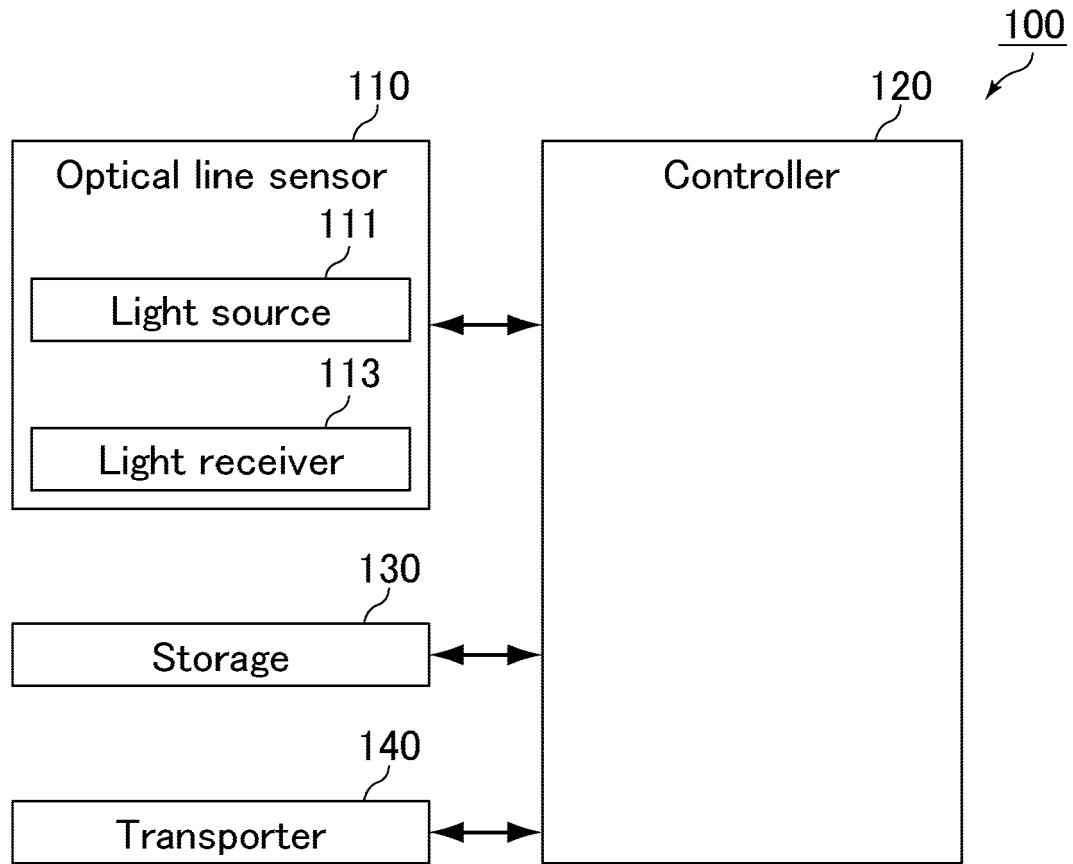
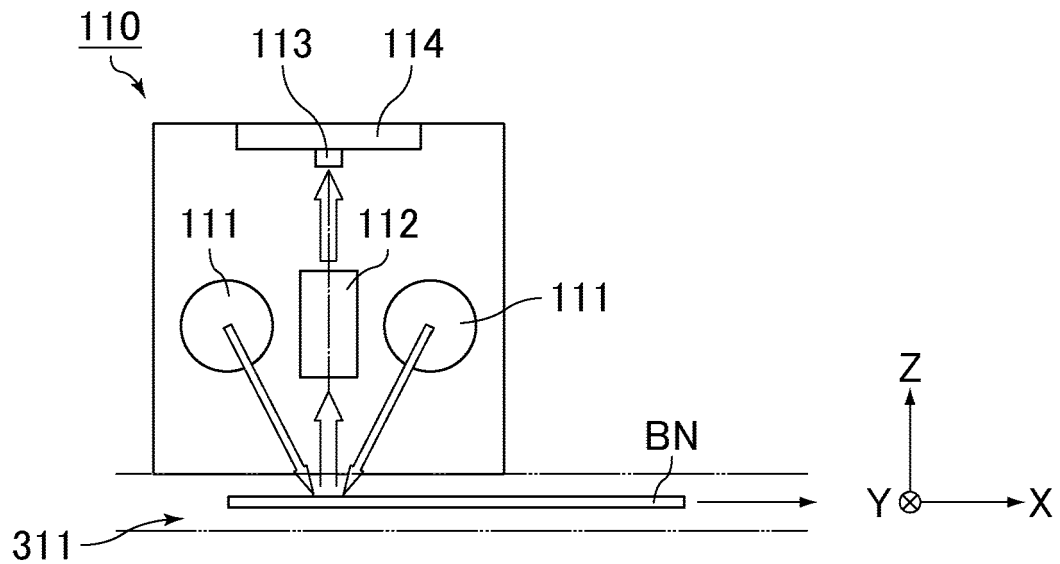


FIG.15





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