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(72) Inventors:
 • **Matsuoka, Takeshi**
Tokyo 100-8220 (JP)
 • **Takada, Yoshihiro**
Tokyo 100-8220 (JP)

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(74) Representative: **Strehl Schübel-Hopf & Partner**
Maximilianstrasse 54
80538 München (DE)

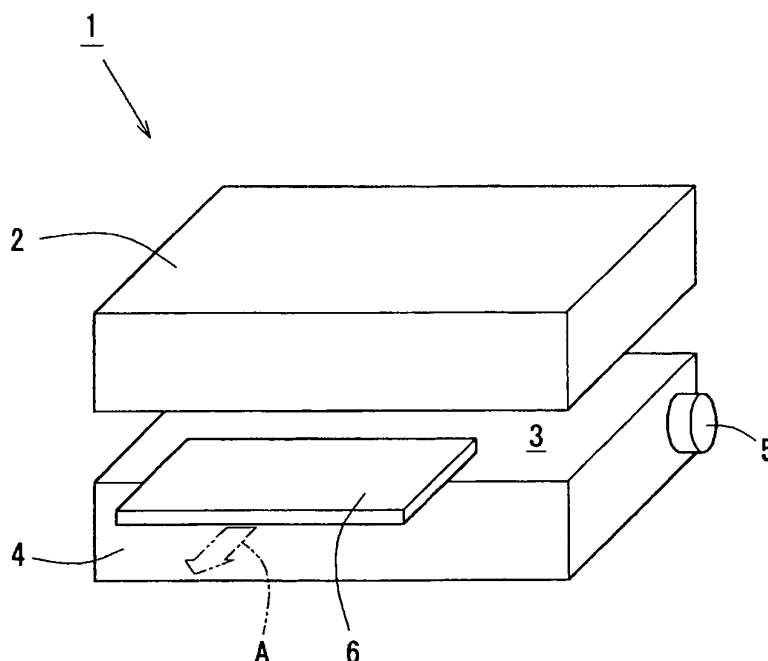
(71) Applicant: **Hitachi-Omron Terminal Solutions, Corp.**
Shinagawa-ku
Tokyo 141-0032 (JP)

(54) **Paper sheet identifying and checking apparatus**

(57) In a paper sheet identifying and checking apparatus (1) including a conveying path (3) to convey a bill (6), a line sensor (23) including a plurality of light sensor elements arranged on the conveying path in a string in a conveying width direction, and an identifying module

(35) to identify the paper sheet on the basis of a binary image (B) produced by the line sensor by reading the paper sheet, the direction of arranging the sensor elements is inclined with respect to the conveying width direction of the conveying path.

FIG.1



Description

BACKGROUND OF THE INVENTION

5 **[0001]** The present invention relates to a paper sheet identifying and checking apparatus for identifying a paper sheet, for example, a paper money (banknote) or a bill conveyed thereto, and in particular, to a paper sheet identifying and checking apparatus for producing image data of a paper sheet by use of an optical line sensor and identifying a kind and truth or falsehood of the paper sheet on the basis of the image data.

10 **[0002]** Heretofore, the bill identifying and checking device of the prior art includes an optical sensor to detect a position of a passage of a paper sheet and gradient or inclination thereof relative to a direction to convey the paper sheet. The bill identifying and checking device detects the position of the passage of the paper sheet on the basis of timing of a change in an output from the optical sensor and detects the gradient of the paper sheet on the basis of a difference in time between changes in outputs from sensor elements that is generated due to the gradient of the paper sheet.

15 **[0003]** JP-A-8-212417 describes a device conducting the detection in which an optical line sensor almost entirely covering the width of the conveying path is installed in a direction vertical to the conveying direction in which a paper sheet is conveyed in the conveying path. The device includes a rotary encoder to generate a conveyance pulse at a fixed period each time the paper sheet is slightly conveyed, a frame memory to binarize the output from the optical line sensor at timing synchronized with the conveyance pulse and to store therein the binary value resultant from the binarization, and an image processing module to digitalize the data stored in the frame memory. In the device, the conveying path is scanned in a direction perpendicular to the conveyance direction at timing synchronized with the conveyance pulse to thereby store a two-dimensional binary image of the paper sheet in the frame memory. For example, if the optical line sensor includes optical elements at a pitch or interval of one millimeter (mm) and the rotary encoder generates one pulse each time the paper sheet is conveyed one millimeter, there is obtained a binary image having a contour of a 1 mm by 1 mm square. The device execute image processing for the binary image to resultantly calculate the position and the gradient of each edge of the paper sheet.

SUMMARY OF THE INVENTION

30 **[0004]** However, in the device of this type, if the gradient of the paper sheet being conveyed is almost zero, precision in the detection of the position and the gradient of the paper sheet is lowered due to influence of a quantization error. For example, in a situation wherein the conveyance pulse has a period of one millimeter, if the gradient of the paper sheet is less than one millimeter, the edges of the paper sheet are seen as if there is no gradient in the obtained image relative to the direction vertical to the conveying direction. In this case, there is obtained one and the same result regardless of the position of the paper sheet between the conveyance pulses, leading to a maximum error of 0.5 mm.

35 **[0005]** Particularly, in the bill identifying and checking device to identify a bill, it is quite important to detect the slight difference between a true or authorized bill and the false or counterfeit bill without fail. Therefore, it is desirable to possibly prevent the deterioration in the identifying performance due to the error described above.

40 **[0006]** To improve the identifying performance, there may be employed a method in which the scanning frequency is increased by shortening the period of conveyance pulses. In this method, the detection precision is improved in the conveying direction regardless of the magnitude of the gradient of the paper sheet; moreover, the detection precision is also improved when the gradient is almost zero. For example, when a rotary encoder having a conveyance pulse period of 0.5 mm is used, the detection precision in the conveying direction is twice that when a rotary encoder having a conveyance pulse period of 1 mm is used. However, as compared with the case using a rotary encoder having a conveyance pulse period of 1 mm, there are required a higher-speed optical line sensor, a larger-capacity frame memory, and a higher-performance image processing module. Therefore, the cost of the bill identifying and checking device soars.

45 **[0007]** It is therefore an object of the present invention to provide a paper sheet identifying and checking apparatus wherein even when the gradient of the paper sheet relative to the direction vertical to the conveyance direction is almost zero, the gradient of the paper sheet can be detected with precision less than the period of conveyance pulses while keeping the cost of the device unchanged.

50 **[0008]** According to an aspect of the present invention, there is provided a paper sheet identifying and checking apparatus including a conveying path for conveying a paper sheet, a line sensor including a plurality of sensor elements arranged on the conveying path in a string in a conveying width direction indicating a direction of width of the conveying path, and an identifying module for identifying the paper sheet on the basis of image data produced by the line sensor by reading the paper sheet. The direction of arranging the sensor elements is inclined with respect to the conveying width direction of the conveying path.

55 **[0009]** Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

- 5 FIG. 1 is a perspective view of a bill identifying and checking apparatus;
 FIG. 2 is a plan view of a lower unit of the bill identifying and checking apparatus;
 FIG. 3 is a block diagram showing structure of the bill identifying and checking apparatus;
 FIG. 4 is a diagram for explaining image data in a frame memory;
 FIG. 5A is a diagram for explaining a quantization error;
 10 FIG. 5B is a diagram for explaining a quantization error; and
 FIG. 6 is a graph showing a frequency distribution of the short-edge length of a bill in the conveying direction.

DESCRIPTION OF THE EMBODIMENTS

- 15 [0011] Referring now to the drawings, description will be given of an embodiment of the present invention.
 [0012] The embodiment relates to a bill identifying and checking apparatus for conveying a bill as a paper sheet and identifying the bill. "Identifying the bill" indicates to determine the kind of bill, for example, a new thousand-yen bill, an old thousand-yen bill, or a two-thousand-yen bill in Japan and to determine whether the bill is an authorized bill or a counterfeit bill. The term "bill" implies the authorized and counterfeit bills. The bill identifying and checking apparatus is
 20 incorporated in, for example, an Automatic Teller's Machine (ATM) of a financial section of a bank to identify bills.
 [0013] First, an outline of the bill identifying and checking apparatus will be described by referring to the perspective view of the bill identifying and checking apparatus 1 shown in FIG. 1 and the plan view of the lower unit 4 of the apparatus 1 shown in FIG. 2.
 [0014] The bill identifying and checking apparatus 1 includes an upper unit 2 and a lower unit 4 installed respectively
 25 on the upper and lower sides of a conveying path 3. On an upper surface of the lower unit 4, a light projector section 23a of an optical line sensor 23 is arranged to almost entirely cover the width of a conveying width L, the projector section 23a being inclined by an angle of θ from the conveying direction (the vertical direction in FIG. 2) to the conveyance width direction (the horizontal direction in FIG. 2).
 [0015] The conveyance width direction indicates a direction vertical to the conveying direction. By inclining the line
 30 sensor 23 by an angle of θ relative to the conveyance width direction, it is possible that the bill passes the line sensor 23 in an inclined state in which the bill is inclined with respect to the line sensor 23.
 [0016] On the upper surface of the lower unit 4, a plurality of conveying rollers 22 are disposed to convey the bill and various sensors 21 other than the line sensor 23. On a lower surface of the upper unit 2, there is disposed a light receiver section, not shown, of the optical line sensor 23 to oppose the projector section 23a in the vertical direction. Therefore,
 35 like the projector section 23a, the light receiver section is also disposed in an inclined state with an angle of θ as described above.
 [0017] The conveying path is a path in which the bill 6 is conveyed in a direction indicated by an arrow A.
 [0018] The lower unit 4 is connected to various devices arranged in the ATM.
 [0019] A gear 5 links a motor in the ATM with the conveying rollers 22 of the bill identifying and checking apparatus
 40 1 to rotate the rollers 22 by driving force of the motor.
 [0020] Various sensors 21 input and output signals such as waveforms according to purposes thereof.
 [0021] The rollers 22 are rollers which rotate the bill 6 sandwiched therebetween. The rollers 22 are linked via the gear 5 with the motor of the ATM to convey the bill 6 at a fixed conveying speed.
 [0022] The optical line sensor 23 reads an image of an optical pattern.
 45 [0023] FIG. 3 shows structure of the bill identifying and checking apparatus 1 in a block diagram.
 [0024] The bill identifying and checking apparatus 1 includes conveying rollers 22, a rotary encoder 31, an optical line sensor 23, an optical line sensor driver 32, a frame memory 33, an image processing module 34 to process images, and an identifying module 35 to identify a bill.
 [0025] The conveying rollers 22 are disposed to convey the bill 6 sandwiched therebetween in the conveying direction.
 50 Four axes are disposed in the direction vertical to the conveying direction indicated by an arrow and four rollers are attached to each axis. Each conveying roller 22 is linked via the gear 5 with the motor of the ATM to convey the bill 6 at a fixed conveying speed.
 [0026] The rotary encoder 31 is attached to one of the rotary axes of the conveying rollers 22 or to one of the conveying rollers 22 to generate a conveyance pulse at a fixed period each time the bill 6 is slightly conveyed.
 55 [0027] The optical line sensor 23 includes a plurality of light projector elements arranged on the light projector section 23a in a line with an equal interval therebetween and a light receiver element array including a plurality of light sensor elements on the light receiver section in a string or line with an equal interval therebetween. The light projector elements and the light receiver element array are disposed with the conveying path 3 therebetween in a symmetric way along the

vertical direction. The light projector section 23a and the light receiver section are disposed with an inclination angle of θ relative to the direction vertical to the conveying direction, while they are substantially in parallel with each other in a plane including the light projector section 23a and the light receiver section. The line sensor 23 thus configured covers almost the entire width of the conveying path 3 and hence serves a function to capture a one-dimensional image of the conveying path through one image sensing operation. In general, the line sensor 23 is arranged in a direction vertical to the conveying direction. However, according to the present invention, the line sensor 23 is inclined by the inclination angle θ . The angle θ is larger than a skew allowance angle indicating allowance for the skew or inclination of the bill 6 conveyed through the conveying path 3.

[0028] The optical line sensor driver 32 has a function to binarize the output from the line sensor 23 at timing synchronized with the conveyance pulse of the rotary encoder 31 and to write the binary data in the frame memory 33. The driver 32 sequentially writes the one-dimensional binary data in the frame memory 33 to resultantly produces a two-dimensional binary image therein. The binary image is image data of an optical pattern of substantially the overall surface of the bill.

[0029] The frame memory 33 has a function to hold therein the two-dimensional binary image of the bill for a fixed period of time. The frame memory 33 keeps the binary image stored therein while the image processing module 342 executes its processing.

[0030] The image processing module 34 has a function to read the binary image of the bill from the frame memory 33 to calculate (estimate) a position and a gradient (angle of inclination) of each edge of the bill. To calculate the gradient of the bill, the processing module 34 serves as a gradient calculation unit. To calculate the position of the edge of the bill, the processing module 34 serves as an outer contour detecting unit. The positions and gradients of four edges of the bill calculated by the processing module 34 are fed to the identifying module 35 disposed in a subsequent to the processing module 34.

[0031] Based on the positions and gradients of four edges of the bill, the identifying module 35 determines the kind of the bill 6 and whether the bill 6 is an authorized bill or a counterfeit bill to thereby identify the bill 6.

[0032] To determine positions of the edges of the bill, the bill identifying and checking apparatus 1 thus constructed conducts operation as below.

[0033] First, when the motor of the ATM, not shown, rotates the conveying rollers 22, the rollers 22 convey the bill 6. The rotary encoder 31 attached to one of the axes of the conveying rollers 22 generates conveyance pulses. At timing of the conveyance pulses, the line sensor driver 32 binarizes the output from the line sensor 23 to produce binary data and then writes the binary data in the frame memory 33. The one-dimensional binary data is sequentially written in the frame memory 33. As a result, a two-dimensional binary image B (image data) of the bill 6 is generated in the frame memory 33 as shown in the explanatory diagram of image data of FIG. 4.

[0034] The image processing module 34 reads the binary image B of the bill 6 from the frame memory 33 to calculate the positions of four edges of the bill. Assume in the calculation that the physical coordinate value in the conveyance direction is represented by Y' and that in the conveying width direction vertical to the conveyance direction is represented by X' . For a straight line $y' = ax' + b$ in the space of coordinates (X', Y') , coefficients a and b are obtained for the four edges of the bill 6. Specifically, from the binary data items obtained for each edge, the system selects the outer-most string of points and then replaces the string of points by data items in the space of coordinates (X', Y') . The values of the coefficients a and b are obtained by applying the method of least squares to the data items. As above, the analog data is converted into digital data, and then an appropriate calculation is conducted by use of the digital data to thereby obtain the positions of the edges of the bill.

[0035] On the other hand, since the line sensor 23 is inclined as described above, the binary image B in the frame memory 33 appears as a correct rectangle on an image inclined by an angle of θ as shown in FIG. 4. If the frame memory coordinates are represented as (X, Y) , the physical coordinates (X', Y') are obtained through coordinate transformation using a determinant of expression (1) as below.

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ \sin\theta & 1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} \quad \dots (1)$$

[0036] The unit can also be converted by multiplying the right side of expression (1) by "unit of physical coordinates/unit of frame memory coordinates".

[0037] Next, description will be given of a relationship between the bill identifying and checking operation by the

identifying module 35 and the positions of the edges of the bill. In the operation to identify the bill 6 by the sensors 21 including the optical line sensor 23, if there exists a particular section of the bill 6, a relative position of the particular section is beforehand determined relative to a particular position such as a center or an angle of the bill 6. The particular section of the bill 6 is then identified on the basis of the positions of the edges of the bill 6 actually passed through the conveying path 3 and the beforehand determined relative position. For the identified section, the line sensor 23 and the sensors 21 process features of the section to resultantly identify the bill 6. That is, precision of the positions of the edges of the bill directly affects precision of the position of the section of the bill 6 to be identified. In the operation to identify the bill 6 on the basis of the particular section, the precision of the position of the section of the bill 6 greatly exerts influence upon precision to identify the bill 6.

[0038] According to the embodiment, as can be seen from FIG. 4, the lower-left corner 6a of the bill 6 is in column 6 of conveyance pulses P of the bill 6 and the lower-right corner 6b thereof is in column 2 of conveyance pulses P. That is, these corners are read at different points of timing of conveyance pulses. Therefore, the straight line (the lower edge of the bill 6) between the lower-left corner 6a and the lower-right corner 6b exists in the frame memory 33 in association with a plurality of conveyance pulses P. It is hence possible to prevent an event in which the lower-left corner 6a and the lower-right corner 6b exist on one and the same conveyance pulse P. Therefore, the position of the bill 6 can be detected with higher precision by reducing the quantization error.

[0039] Description will now be given of the quantization error appearing when the bill 6 is not inclined relative to the line sensor 23 shown in FIG. 5A and that occurring when the bill 6 is inclined relative to the line sensor 23 shown in FIG. 5B. Since the line sensor 23 is arranged in an inclined state according to the embodiment, the image is actually inclined as shown in FIG. 4. However, for easy understanding of explanation, description will be given of a case in which the line sensor 23 is disposed without inclination with respect to the conveying direction

[0040] Each pixel 40 is defined on the basis of the period of conveying pulses and the pitch of or the interval between optical elements of the line sensor 2. An outer contour of analog image 41 is an actual outer contour of the bill 6, and a digital image 42 is an area for the bill 6 recognizable in digital processing. An outer contour of digital image 43 is an outer contour of the bill 6 obtain by use of the digital image 42.

[0041] If the bill 6 is conveyed in a state of FIG. 5A without inclining the bill 6 relative to the line sensor 23, the position of the bill 6 is identified at precision equal to or less than one pixel 40 determined by the period of conveying pulses and the interval between optical elements. This leads to a large error in the operation to identify the positions of the edges of the bill 6. On the other hand, if the bill 6 is conveyed in a state of FIG. 5A by inclining the bill 6 relative to the line sensor 23, the edges of the binary image B appear in the form of steps. By drawing a regression line (obtainable using the method of least squares) for the associated pixels 40, the positions of the edges of the bill 6 can be identified at higher precision. For example, by drawing straight lines for ten pixels in a direction vertical to one step in the conveying direction, the precision in the conveying direction is ten times that of one pixel.

[0042] Description will now be given of the improvement of the precision. FIG. 6 is a graph showing a frequency distribution of the short-edge length of the bill 6 (in the conveying direction) in the bill identifying and checking apparatus 1 including the optical line sensor 23 attached in a direction vertical to the conveying direction. Specifically, FIG. 6 shows the frequency distribution when the bill 6 is inclined relative to the line sensor 23 with an inclination angle equal to or less than one degree and the frequency distribution when the bill 6 is inclined relative to the line sensor 23 with an inclination angle more than one degree. As can be seen from FIG. 6, when the gradient is large (equal to or more than one degree), the frequency distribution of the short-edge length is represented with a gentle slope centered on the mean value. However, when the gradient is small (less than one degree), the frequency distribution of the short-edge length includes two peaks. That is, the larger the gradient is, the higher the precision in the short-edge is. According to the present invention, the optical line sensor 23 is beforehand disposed in the inclined state, and hence it is secured that the bill 6 is inclined with respect to the line sensor 23 to thereby improve the precision to determine the position of the bill 6.

[0043] By disposing the line sensor 23 in the inclined state as above, the position and the gradient of the paper sheet can be detected in the conveying direction with high precision regardless of the magnitude of the inclination of the paper sheet. It is therefore possible to provide the bill identifying and checking apparatus 1 with higher identifying precision.

[0044] Since the line sensor 23 is inclined such that the angle of inclination thereof exceeds the skew allowance range of the bill identifying and checking apparatus 1, the binary image B can be produced such that the front edge and the rear edge of the paper sheet are represented in the shape of steps regardless of how the paper sheet, i.e., the bill 6 is skewed or inclined.

[0045] As a result, it is guaranteed that a stepwise image of the bill 6 is produced and the position and the gradient of the bill 6 are detected in the conveying direction with precision less than the conveying pulse. In comparison with the case in which the line sensor 23 is attached in a direction vertical to the conveying direction A (FIG. 1), the performance required for the hardware of the respective components is kept unchanged, and hence the cost of the system is not increased.

[0046] There can be provided a low-cost high-precision bill identifying and checking apparatus 1 capable of detecting the outer contour of the bill 6 with precision less than the pixel 40 which can be sensed by the line sensor 23.

[0047] As compared to reducing the interval of conveyance pulses for the line sensor 23 to read the bill 6, disposing the line sensor in the inclined state makes it possible to lower the specifications necessary for the image data processing to a greater degree, there can be provided a low-cost bill identifying and checking apparatus 1 capable of executing processing at a higher speed.

[0048] Although the pixel 40 of the binary image B is configured as a rectangle having one and the same length in the conveying direction and the conveying width direction, the present invention is not restricted by the configuration. The length of the pixel in the conveying direction may differ from that in the conveying width direction. Also in this configuration, the contour of the bill 6 can be appropriately obtained.

[0049] Although the optical line sensor 23 is inclined by an angle of θ with respect to the conveying width direction, it is also possible to configure the apparatus in which the unit of the line sensor 23 is disposed in parallel with the conveying width direction and the light projecting elements and the light receiver element array are inclined by an angle of θ with respect to the conveying width direction.

[0050] The present invention is not restricted by the configuration described above, but there can be considered many embodiments of the present invention.

[0051] According to the present invention, there can be provided a paper sheet identifying and checking apparatus in which even if the inclination of the paper sheet with respect to the direction vertical to the conveying direction is almost zero, the paper sheet can be detected in the conveying direction with precision less than the period of conveyance pulses, without increasing the cost of the apparatus.

[0052] It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the invention, the invention is not limited thereto and various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims.

Claims

1. A paper sheet identifying and checking apparatus (1), comprising:

a conveying path (3) for conveying a paper sheet (6);
a line sensor (23) including a plurality of sensor elements arranged on the conveying path in a string in a conveying width direction indicating a direction of width of the conveying path; and
identifying means (35) for identifying the paper sheet on the basis of image data produced by the line sensor by reading the paper sheet, wherein
the direction of arranging the sensor elements is inclined with respect to the conveying width direction of the conveying path.

2. A paper sheet identifying and checking apparatus according to claim 1, wherein the angle of inclination of the sensor elements of the line sensor with respect to the conveying width direction is more than a skew allowance angle allowed for the paper sheet to incline on the conveying path.

3. A paper sheet identifying and checking apparatus according to claim 1, wherein the paper sheet includes a paper sheet in a shape of a rectangle, the apparatus further comprising:

inclination angle calculating means (34, 35) for calculating an inclination angle indicating an angle of inclination of the paper sheet with respect to the conveying width; and
outer contour detecting means (34, 35) for detecting an outer contour of the paper sheet according to the inclination angle thus calculated.

4. A paper sheet identifying and checking apparatus according to claim 2, wherein the paper sheet includes a paper sheet in a shape of a rectangle, the apparatus further comprising:

inclination angle calculating means (34, 35) for calculating an inclination angle indicating an angle of inclination of the paper sheet with respect to the conveying width; and
outer contour detecting means (34, 35) for detecting an outer contour of the paper sheet according to the inclination angle thus calculated.

5. A paper sheet identifying and checking apparatus according to claim 1, wherein the line sensor is disposed to cover almost entirely the conveying width of the conveying path.

6. A paper sheet identifying and checking apparatus according to claim 2, wherein the line sensor is disposed to cover almost entirely the conveying width of the conveying path.

7. A paper sheet identifying and checking apparatus according to claim 3, wherein the line sensor is disposed to cover almost entirely the conveying width of the conveying path.

8. A paper sheet identifying and checking apparatus according to claim 1, further comprising:

a rotary encoder (31) for generating a pulse at a fixed period corresponding to a speed of conveying the paper sheet;
a frame memory (33) for obtaining image data from the line sensor at timing synchronized with the pulse and holding the image data therein; and
image processing means (34) for processing the image data held in the frame memory.

9. A paper sheet identifying and checking apparatus according to claim 2, further comprising:

a rotary encoder (31) for generating a pulse at a fixed period corresponding to a speed of conveying the paper sheet;
a frame memory (33) for obtaining image data from the line sensor at timing synchronized with the pulse and holding the image data therein; and
image processing means (34) for processing the image data held in the frame memory.

10. A paper sheet identifying and checking apparatus according to claim 3, further comprising:

a rotary encoder (31) for generating a pulse at a fixed period corresponding to a speed of conveying the paper sheet;
a frame memory (33) for obtaining image data from the line sensor at timing synchronized with the pulse and holding the image data therein; and
image processing means (34) for processing the image data held in the frame memory.

11. A paper sheet identifying and checking apparatus according to claim 5, further comprising:

a rotary encoder (31) for generating a pulse at a fixed period corresponding to a speed of conveying the paper sheet;
a frame memory (33) for obtaining image data from the line sensor at timing synchronized with the pulse and holding the image data therein; and
image processing means (34) for processing the image data held in the frame memory.

FIG.1

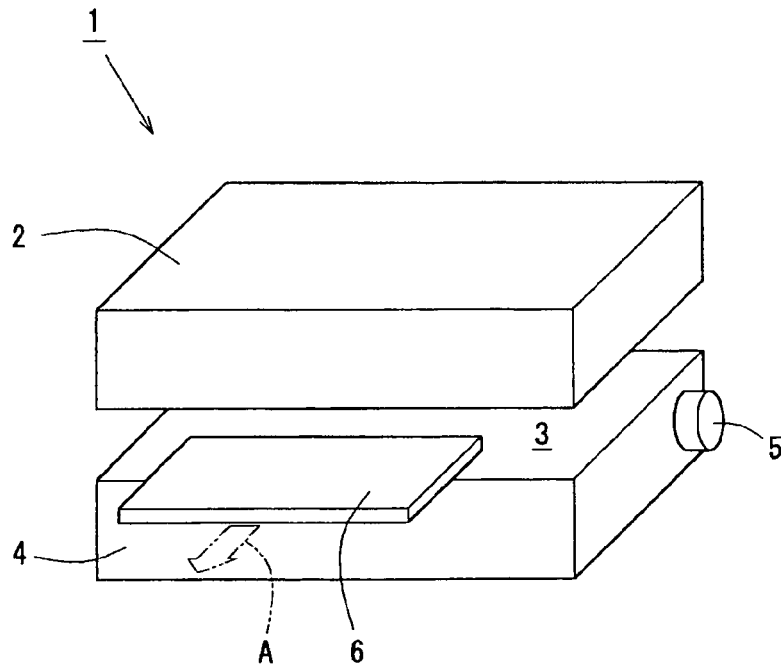


FIG.2

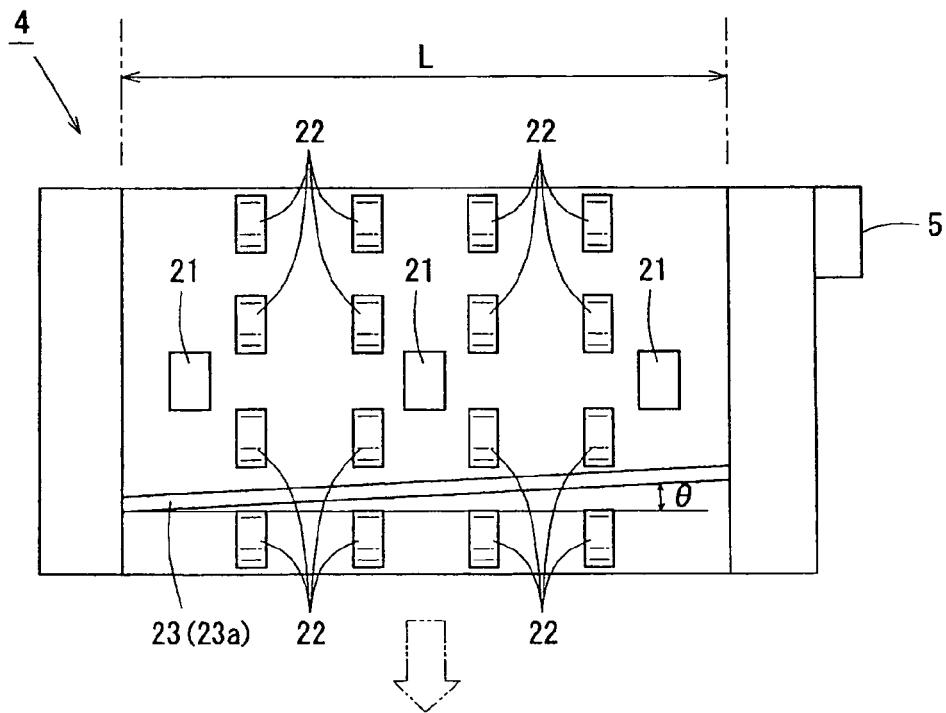


FIG.3

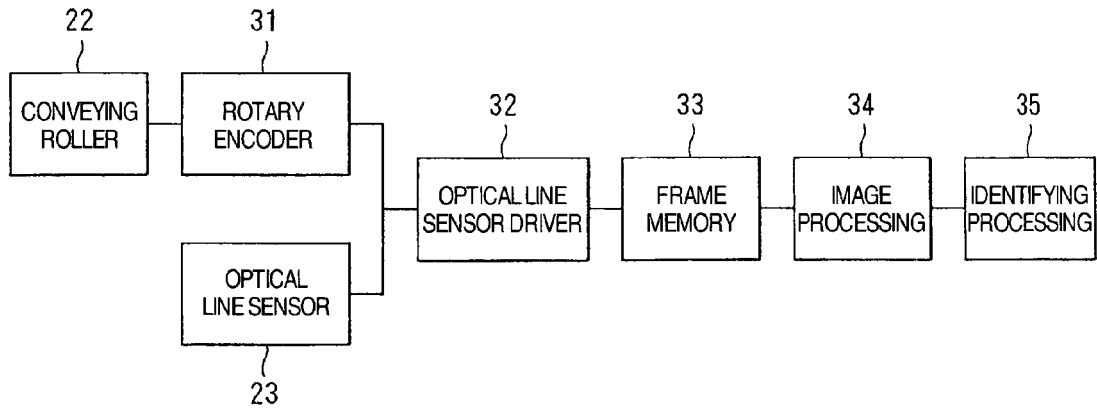


FIG.4

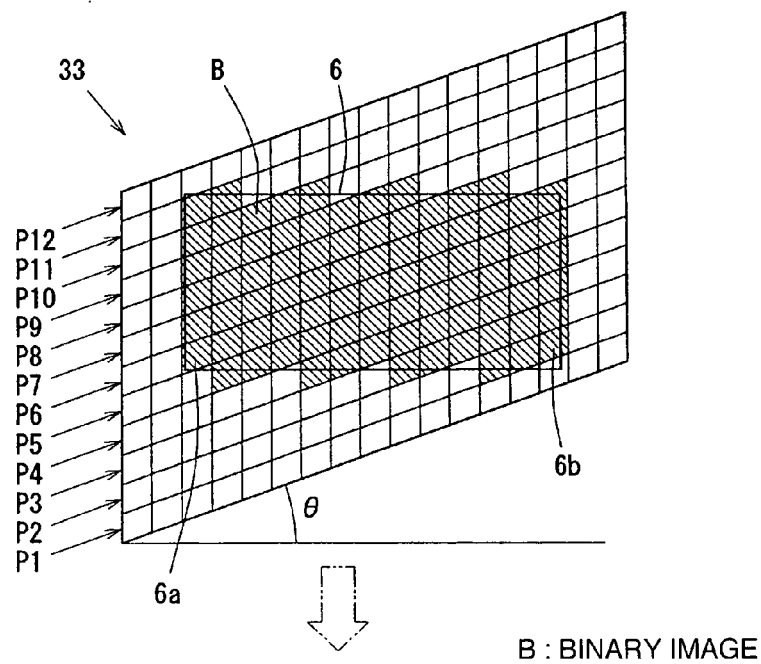
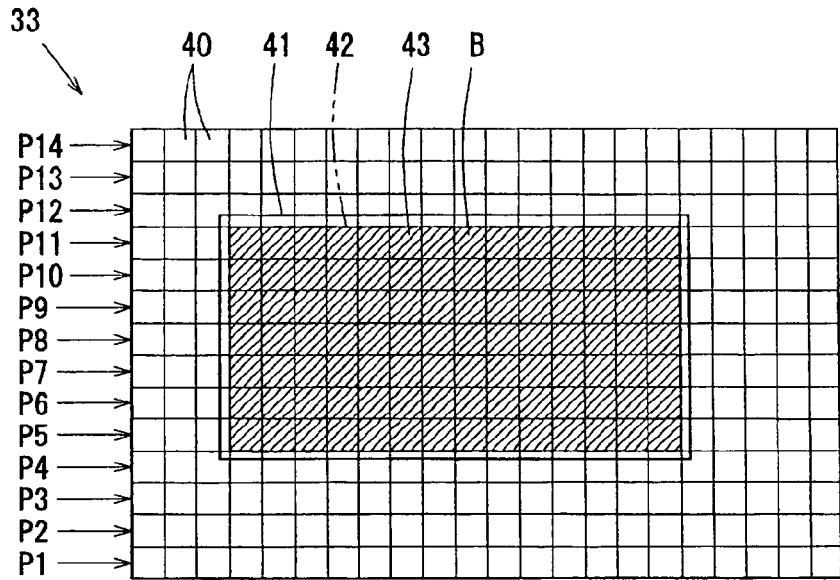
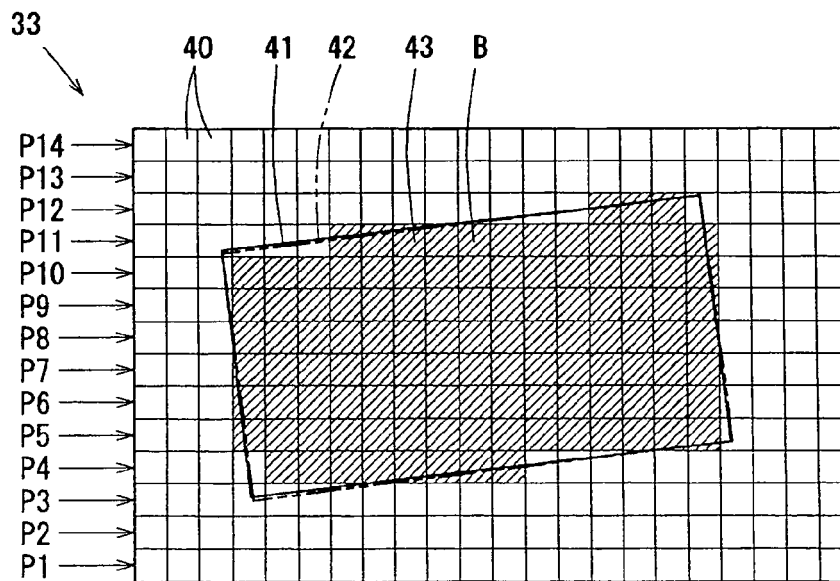


FIG.5A



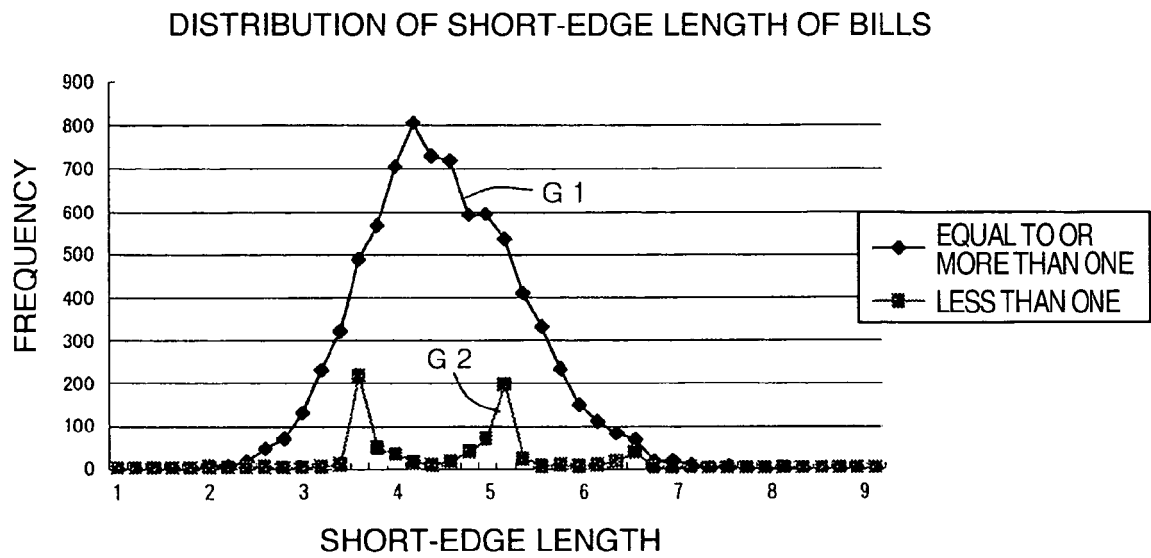
B : BINARY IMAGE

FIG.5B



B : BINARY IMAGE

FIG.6



REFERENCES CITED IN THE DESCRIPTION

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