Development of an Experimental Device of Automatic Inspection for Printed Labels and Extension to Its Prototype

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Abstract—For the automation of visual inspection for printed labels, which are coated with rubber and curl, we have developed a camera-based portable experimental device of automatic inspection in this research. By experiments, we have verified that the experimental device surely detect the failures such as the stain, the patchiness, the spread, and the chip detected by using low dimensional feature vectors unless the conveyance errors occur. Thus, we consider a necessity to develop a mechanism repressing the occurrence of the conveyance errors.

To solve the problem, we have extended the experimental device to an improved one for the automatic inspection as a prototype. From the result of the verification experiment using the prototype, we have also verified that the conveyance error hardly occurs.

Index Terms--Automatic optical inspection, Mechanical system, Pattern recognition, Real time system

I. INTRODUCTION

Recently, the automation of visual inspection is attracting attention in industry. In this research, we focus on the inspection for printed labels, especially which are coated with rubber and curl. On the label, characters or marks are usually printed, but the failure of printing occasionally occurs. Therefore, in many companies, the experts inspect them. However, it is very tough work to continue to do. It is difficult to detect tiny errors.

On the labels, since the labels curl, the shapes of printed characters and marks also curl. A low resolution and uneven lightning makes difficult to inspect [1], [2]. Therefore, constructing a camera-based inspection system for the labels should be considered.

In this research, we have developed a experimental device of automatic inspection for printed labels using a camera [3], [4]. The experimental device can detect the failure of printing automatically. The rubber-like coating makes it difficult to convey each label because the label has a tendency to cling to other label.

In the printed labels, there are several kinds of failure. Therefore, we classify them into some groups depending on the characteristics of the images of the failures. They are stain, patchiness, different pattern, displacement, spread, and chip.

In this paper, we examine the capability of the experimental device to inspect the failures such as the stain, the patchiness, the spread, and the chip detected by using low dimensional feature vectors as stated later. After that, we extend the experimental device to an improved one for the automatic inspection as a prototype. By the verification experiment of the prototype, we have also verified that the conveyance error hardly occurs.

II. SYSTEM DESCRIPTION

In this research, we have proposed the experimental device of automatic inspection as shown in Fig. 1 for the printed labels. As shown in Fig. 2, the size of the labels is 40 by 40-160 mm. The label curls because the front of the label is coated with rubber. Therefore, it is difficult to separate a label from others and convey it smoothly. The system makes it possible by using the mechanics for separating labels and a vacuum as shown in Fig. 3. The developed system consists of three parts such as a conveyance part, a capturing part, and an inspection part (laptop PC).

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feeder, the top label is taken into the system using a vacuum, is captured by a camera repeatedly until the whole image of the label is captured, and is delivered to ejection boxes, an acceptable (OK) box or an unacceptable (NG) box, depending on the inspection result.

The light used in the experimental device is examined using a box-shaped LED, a dome-shaped LED, and a ring-shaped LED as shown in Fig. 4. As a result, it turn out that the box-shaped LED is most suitable because of the uniformity of the light output and the affinity with the experimental device in shape. The box-shaped LED is set up in the experimental device as shown in Fig. 5.

C. Inspection Parts
In this part, the printed labels are inspected using the captured images in the capturing part. This is processed in the laptop PC shown in Fig. 1.

III. INSPECTION METHOD

A. Inspection Items
Several kinds of failures would occur for the printed labels. Therefore, we classify the common failures into six groups depending on the characteristics of the images of the failures as follows.

The stain. There are stains on the labels. After the binarization, this cause the increase the number of blobs, which are the isolations of printed parts.

The patchiness. Patchy printing divides the printed one character or mark into several parts. After the binarization, this also cause the increase the number of blobs, which are the isolations of printed parts.

The different pattern. The target characters, numbers, or marks are not printed, but other ones are printed there.

B. Capturing Parts
The label image is captured by using a camera with a box-shaped white light-emitting diode (LED) to provide high brightness with equation. The captured pictures are transferred to the inspection part; the number of transferred pictures depends on the length on the length of the label.
The displacement. The printed position is different to the correct position.

Fig. 9. Example of the displacement.

The spread. Spreading printing changes the shapes of printings with the increase of the area of the printed part.

Fig. 10. Example of the spread.

The chip. Chip printing also changes the shapes of printings with the decrease.

Fig. 11. Example of the chip.

B. Concept of inspection method

Before the inspection of each item stated above, printed parts and a background part are separated by binarization. After that, the inspection process is executed depending on the items, respectively, as shown in Fig. 12.

The stain and the patchiness. The inspection is executed by comparing the number of blobs, separated objects, of printed parts on the label with that of the correct printed label, where which of the correct one is obtained as templates in advance.

The different pattern. A pattern matching can be applied after registering the templates of correct printed labels with the inspection system.

The displacement. Comparing the position of the blobs with that of correct printed label, the inspection can be carried out.

The spread and the chip. Comparing the shape of the blobs with that of correct printed label, the inspection procedure is achieved.

C. Binarization

In this research, an adaptive (variable) threshold method is adopted instead of a global threshold method [5] because of the uneven lightning. In this case, we define the adaptive threshold method as the following equation:

\[
g(x, y) = \begin{cases} 
1 & \text{if } f(x, y) > \frac{1}{(2M + 1)^2} \sum_{i=-M}^{i=M} \sum_{j=-M}^{j=M} f(i, j) - N, \\
0 & \text{otherwise},
\end{cases}
\]  

(1)

where \(g(x, y)\) is the binary picture, \(f(x, y)\) is the grayscale picture, \(M\) and \(N\) are constant parameters.

D. Inspection Method for the stain, the patchiness, the spread, and the chip

In this section, the details of the inspection method for the stain, the patchiness, the spread and the chip are explained.

First, using the captured grayscale image as shown in Fig. 13 (a), the region of label is detected by the binarization using a global threshold method, eliminating the light, and the opening and closing process as shown in Fig. 13 (b). Next, by the adaptive binarization shown in (1), the printed parts and the edge of the label are separated from the background as shown in Fig. 13 (c). Using Fig. 13 (b), only the printed parts on the label are extracted as shown in Fig. 13 (d). After detecting separators, large marks as shown in Fig. 13 (e), which are used for consistency in several captured images, the stain and the patchiness are inspected by counting the number of blobs whose size is larger than a constant parameter on the label and
comparing it with that of the template as shown in Fig. 13 (f).

Using Fig. 13 (f), the spread and the chip are also inspected using the shape of each blob by neural networks [4]. In this paper, only the spread and the chip detected by using very low dimensional feature vectors are inspected by counting the number of blob and that of holes in each blob and comparing them with that of the template, respectively.

IV. VERIFICATION EXPERIMENTS

A. Targets

The labels used for the inspection ability verification experiment of the experimental device are as follows.

1. Normal labels without failures or dusts
2. Labels with the small stain (0.1 × 0.1 mm) as shown in Fig. 13 (a)
3. Labels with the patchiness of 0.3 mm in width as shown in Fig. 13 (b)
4. Labels with the spread of 0.3 mm in width at increase of the number of holes as shown in Fig. 13 (c) or at decrease of that of holes as shown in Fig. 13 (d)
5. Labels with the chip of 0.3 mm in width at decrease of the number of holes as shown in Fig. 13 (e), (f)

![Fig. 13. Four kinds of inspection objects of the stain, the patchiness, the spread, and the chip.](image)

B. Binarization

Fig. 15 shows the binarized image generated by the global and the adaptive threshold method. The thickness of characters of (a) is thin and uneven comparing (b). These show that the adaptive method is more suitable than the global method for the inspection system.

C. Inspection

The inspection experiments are carried out ten times for the normal labels and four kinds of failures as shown in Fig. 13 using ten labels each failure. At the same time, the conveyance performance of the labels under the inspection is verified.

![Fig. 14. The inspection process.](image)

![Fig. 15. Binarized images by the global threshold and the adaptive threshold.](image)
Table 1. Verification results of inspection and conveyance using the experimental device.

<table>
<thead>
<tr>
<th>Item</th>
<th>Correct</th>
<th>Incorrect</th>
<th>Conveyance error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>85 % (85/100)</td>
<td>0 % (0/100)</td>
<td>15 % (15/100)</td>
</tr>
<tr>
<td>Stain (0.1 mm)</td>
<td>84 % (84/100)</td>
<td>0 % (0/100)</td>
<td>16 % (16/100)</td>
</tr>
<tr>
<td>Patchiness (0.3 mm)</td>
<td>88 % (88/100)</td>
<td>0 % (0/100)</td>
<td>12 % (12/100)</td>
</tr>
<tr>
<td>Spread (0.3 mm)</td>
<td>83 % (83/100)</td>
<td>0 % (0/100)</td>
<td>17 % (17/100)</td>
</tr>
<tr>
<td>Chip (0.3 mm)</td>
<td>89 % (89/100)</td>
<td>0 % (0/100)</td>
<td>11 % (11/100)</td>
</tr>
</tbody>
</table>

As shown in Table 1, the verification results show that the normal labels and all kinds of test failures are inspected correctly unless the conveyance errors occur. As conveyance errors, the failure of taking a label from the feeder and a label jam in transfer were observed.

V. DEVELOPMENT OF PROTOTYPE

To solve the conveyance error mentioned in the previous section, we have developed a prototype which is improved for the conveyance performance by extending the experimental device as shown in Fig. 16. Moreover, the resolution of the camera and the uniformity of LED are also improved.

To improve the conveyance performance, the new mechanism of suppression has been developed by reducing the warpage of labels as shown in Fig. 17. Since the performance of the camera and the LED is improved, the condition of capturing image in the prototype is better than that in the experimental device. Therefore, it is confirmed that the inspection performance of the prototype is as well as or better than that of the experimental device.

As a result, it is confirmed that a conveyance error rate decreased to 0.3 % or less by the experiment using 300 labels. Moreover, it is also confirmed that the inspection time per one label is sped up to 5.8 s or less, about 2 s faster than that of the experimental device.

VI. CONCLUSION

In this research, we have developed the camera-based experimental device of automatic inspection for printed labels. The experimental device can detect the failure of printing automatically. We have classified the common failures of printing into six groups depending on the characteristics of the images. We have constructed the prototype of the automatic inspection based on the experimental device by improving the performance of conveyance and light.

By the experiments, we verified that the experimental device surely detect the failures such as the stain, the patchiness, the spread, and the chip that are detected by using the number of blobs and that of holes of each blob unless the conveyance errors occur. By the verification of the prototype, it was confirmed that a conveyance error rate decreased to below than 0.3 % using 300 labels.

REFERENCES