Research on Registration Deviation Detection of Printed Glass LED Circuit Board

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Abstract. To improve the registration accuracy, save the printing material, and optimize the printing space on printed glass circuit board for LED, the dual-cameras are introduced to capture the image of screen-printing plate. Considering the configuration of LED circuit, the dual-cameras are separately used to capture two parts of circuit image with 5mm × 4mm scale, which are from whole circuit with 200mm × 100mm scale. In this paper, the bonding pads are considered as the registration mark, the line fitting with global least square method is used to extract the image character points, and the registration deviation are calculated. According to this detection method, the registration printing experience results that the actual registration deviation (13µm in x-direction, 14µm in y-direction) satisfy the registration printing requirement of glass circuit board for LED (less than 30µm in x-direction, and less than 24µm in y-direction).

Introduction

Silver is used as the printing material in the most printed glass circuit boards that is printed by monochrome screen-printing machine in current. In this way, there is an issue that the silver bonding pad is possibly absorbed by the high temperature soldering, and peeled off from the glass substrate. To solve this issue, gold can be used as the bonding pad overprinted on the silver transmission line, because gold cannot be peeled off from sliver substrate by high temperature soldering.

To improve the registration accuracy, it’s important to determine the position and shape of the registering mark. The common registering marks, such as the cross-shape mark [1], CMYK mark [2], independent solid circle mark [3] and star-shape mark [4], require to be printed individually, and occupy the printing space. In common, there is only one single camera in the registration system, therefore, it’s difficult to large the captured image scale and improve the registration accuracy at the same time.

The Selection of Registering Mark

The screen-printing plate for printed glass circuit board is shown in fig. 1, and the registration printing plate is shown in fig. 2. In this paper, to improve the registration accuracy, the dual-cameras with a resolution of 640 × 480, are applied in the experience device. The center distance of two cameras is 170mm. These two cameras are occupied to capture the field in 5mm × 4mm on the plate. Every pixel in this image is actually corresponding to 7.8µm in x-direction, and 8.3µm in y-direction. To save the printing material and optimize the printing space, according to the character of the circuit shape, the bonding pads are selected to be the registering mark, which is shown in fig. 3. In experience, the model of LED chip is ETi-KB358A-BL. According to the datasheet, the distance between each two bonding pads should be large than 240µm. Therefore, the maximum permission registration deviation should be 30µm in x-direction, and 24µm in y-direction.
The Detection of Registration Deviation

Pre-procession for Image

Because glass is the rigid material, the substrate and the registering mark cannot be out of shape, and there are 3 steps for pre-procession [5]. And the pre-procession methods for printing screen plate and registration screen plate are same.

Step1: grizzled procession [6], as shown in fig. 3-b, which transfers 3-channal colored image into 1-channal gray image.

Step2: histogram equalization procession, as shown in fig. 3-c, which enhances the contrast by stretching contrast and increasing the pray difference between foreground and background.

Step3: binarization procession, as shown in fig. 3-d, which obtains the binary image.

Extraction of the Image Character Points

There are 3 steps to extract the image character points. The extraction methods for printing screen plate and registration screen plate are same.

Step1: For the data on the row direction in the binary image shown in fig. 5-a, calculating the average coordinate value of pixels with 0 value (black pixels), which mean the coordinate value of
the middle points for each horizontal line in binary image. Calculating the absolute error between the column coordinates of all middle points of horizontal line and their average value, according to the threshold value of permission deviation, all the points with deviation larger than threshold value can be ignored. And applying the line fitting with least square method [7], the perpendicular line can be fitted by the left points as shown in fig. 5-b.

Step2: For the data on the horizontal direction in the binary image shown in fig. 5-b, using the same method of step1, the horizontal line can be fitted as shown in fig. 5-c.

Step3: The junction points of the perpendicular line and horizontal line that are fitted in step1 and step2, are the coordinate value of character points, as shown in fig. 5-d.

![Character point extraction from printing plate](image)

![Character point extraction from registration plate](image)

**Figure 5. Diagram of character point extraction procession.**

**Deviation Value Calculating for Registration**

The coordinate value of character points mentioned above is in the image coordinate system, and the coordinate value of cameras and printing plate is in the world coordinate system. The mapping relationship between image coordinate system and world coordinate system should be determined [8], and then, the actual registration deviation can be calculated. This mapping relationship is shown in Eq. 1:

\[
\begin{bmatrix}
i \\
j \\
1
\end{bmatrix} = \mathbf{N} \begin{bmatrix}
x \\
y \\
1
\end{bmatrix}
\]  

(1)

In this equation, \(i\) and \(j\) are image coordinates, \(x\) and \(y\) are the actual physical coordinates in the relation world coordinate system. Selecting \(N(N \geq 4)\) relation points from image coordinate and world coordinate system, the homography matrix \(\mathbf{N}^* (3 \times 3)\) can be obtained. According to this homography matrix, the coordinate value of any point in image coordinate system can be transferred into the actual physical coordinate value in the world coordinate system. The coordinates of two character points captured firstly are seemed as the reference coordinates. Comparing the following coordinates value of character points, the deviation on \(x\)-direction, \(y\)-direction and rotation angle can be calculated. Then, this coordinate deviation can be provided to adjust the actual position of registration plate.

Assuming the world coordinate of two firstly captured character points are \(A(x_a, y_a)\), \(B(x_b, y_b)\), and \(A'(x'_a, y'_a)\), \(B'(x'_b, y'_b)\) for the following two character points, which is shown in fig. 6.

![Deviation calculating](image)

**Figure 6. Deviation calculating.**

The deviation in \(x\)-direction, \(y\)-direction and rotation can be determined:
The deviation on x-direction is
\[ \Delta x = \frac{\Delta x_a + \Delta x_b}{2} = \frac{|x_a - x_a'| + |x_b - x_b'|}{2} \]
(2)
The deviation on y-direction is
\[ \Delta y = \frac{\Delta y_a + \Delta y_b}{2} = \frac{|y_a - y_a'| + |y_b - y_b'|}{2} \]
(3)
The deviation on rotation is
\[ \Delta \theta = |\theta_1 - \theta_2| = \left| \arctan \frac{y_b - y_a}{x_b - x_a} - \arctan \frac{y_b' - y_a'}{x_b' - x_a'} \right| \]

Detection Experience of Registration

The registration deviation detection algorithm [9] is coded on the platform of Visual Studio 2010 and OpenCV 3.0. In the experience, the captured screen plate image [10] is shown in fig. 7.

![Figure 7. The captured screen plate image.](image)

The pixel coordinates of points A, B, C, D are A(271, 394), B(369, 394), C(271, 77), and D(369, 77) separately. The world coordinates (\(\mu m\)) are A(2113.8, 3270.2), B(2878.2, 3270.2), C(2113.8, 639.1), D(2878.2, 639.1). Then, the homography matrix is

\[
N^* = \begin{bmatrix}
0.254719 & -0.00179 & 59.3197 \\
-9.4802e^{-5} & 0.478092 & 82.8394 \\
6.4975e^{-6} & -9.4398e^{-6} & 1 \\
\end{bmatrix}
\]

This matrix means the mapping relationship between image coordinate system and world coordinate system. The dual-cameras capture two images scaled in 5\(mm\) \(\times\) 4\(mm\), in whole screen plate scaled in 200\(mm\) \(\times\) 100\(mm\). The deviation data experienced are shown in table1. Which indicates the actual average registration deviations are 13\(\mu m\) in x-direction and 14\(\mu m\) in y-direction. It’s satisfied the registration requirements of LED printed glass circuit board.

Conclusion

In this paper, using dual-cameras to capture the images of circuit, according to the shape character of LED circuit, the ponding pad images are selected as the new registration marks. Based on the experiences, the deviation of plate position is satisfied the requirements of LED printed glass circuit board.

| \(\mu m\) | (\(x_a, y_a\)) | (\(x_b, y_b\)) | (\(x_a', y_a'\)) | (\(x_b', y_b'\)) | \(\Delta x\) | \(\Delta y\) |
|---|---|---|---|---|---|---|
| 1 | (1026,3476) | (4672,827) | (1009,3466) | (4659,815) | 15 | 11 |
| 2 | (997,3410) | (4630,813) | (987,3393) | (4614,800) | 13 | 15 |
| 3 | (1011,3425) | (4611,820) | (999,3017) | (4605,808) | 9 | 10 |
| 4 | (1048,3380) | (4702,832) | (1028,3361) | (4686,823) | 18 | 14 |
| 5 | (1031,3496) | (4685,845) | (1018,3476) | (4670,827) | 14 | 19 |
| 6 | (1005,3368) | (4701,859) | (990,3361) | (4690,848) | 13 | 9 |
| 7 | (1028,3294) | (4659,871) | (1017,3287) | (4636,854) | 17 | 12 |
| \(\text{average}\) | / | / | / | / | 14 | 13 |
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