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Geometric Modeling of Illumination on the TFT-LCD Panel using Bezier Surface

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***Abstract*—In this paper, we propose a geometric modeling of illumination on the patterned image containing etching transistor. This image is captured by a commercial camera during the inspection of a TFT-LCD panel. Inspection of defect is an important process in the production of LCD panel, but the regional difference in brightness, which has a negative effect on the inspection, is due to the uneven illumination environment. In order to solve this problem, we present a geometric modeling of illumination consisting of an interpolation using the least squares method and 3D modeling using bezier surface. Our computational time, by using the sampling method, is shorter than the previous methods. Moreover, it can be further used to correct brightness in every patterned image.

***Keywords*—Bezier, defect, geometric modeling, illumination, inspection, LCD, panel.

I. Introduction

THE TFT-LCD has opened a wide market as a television and a computer monitor. This device is also used for Mobile displays like cellular phone, hand-held game player, mp3 player and so on. According to this trend, many researches are studying this field to improve the production processes for LCD panels, where, finding defects plays an important role in developing reliability. Many researches for finding defects of color filter in LCD panel have been conducted [1], [2], [3], [4], [5]. But the research for the inspection of etching transistors has hardly been progressed other than the color filter [6], [7]. Many researchers have much difficulty in finding defects due to lens distortion and uneven illumination surroundings. There are some preceding studies on recovering differently exposed photographs [8] and resolving variation in color of large-area multi-projector [9]. But these are not adaptable for LCD panel to improve the condition of uneven illumination.

Therefore, we discuss how to improve the condition of illumination on the patterned image. Periodical patterned image is the most important characteristic of LCD panel. In this paper, we present the algorithm composed of interpolation using the least squares method and 3D modeling using bezier surface. Through these methods, a geometrical modeling of uneven illumination is formed. Finally, we can improve the image by adapting the model to the original image.

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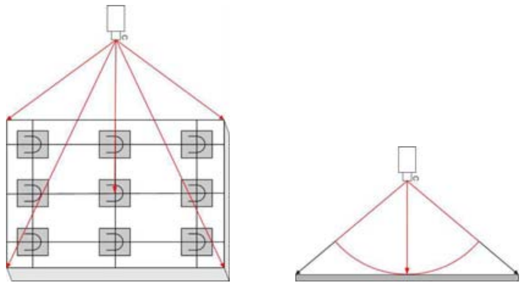


(a) (b)

Fig. 1 (a) A three dimensional view of the camera model, (b) A Sectional view of the camera model

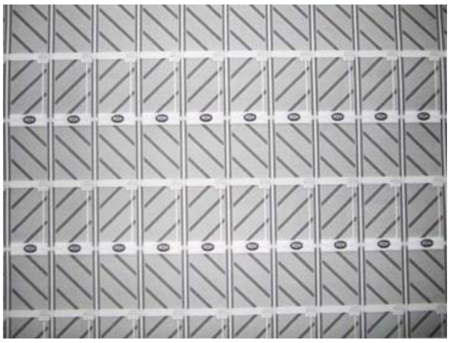
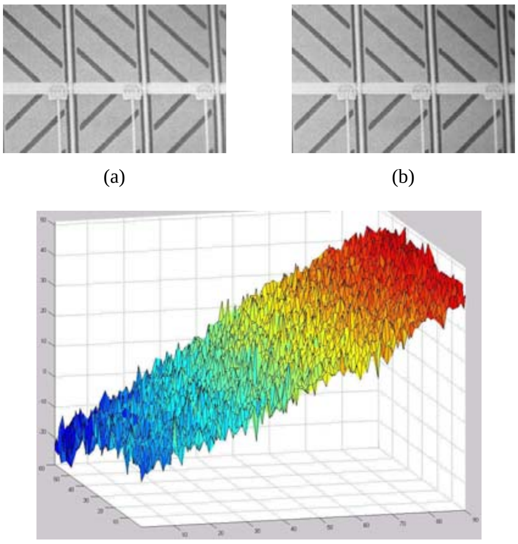


Fig. 2 The original image

The outline of this paper is as follows. Section 2 describes our problems. Section 3 proposes a newly modeled illumination, and our simulation is presented in Section 4. Finally, conclusions are drawn in the last section.

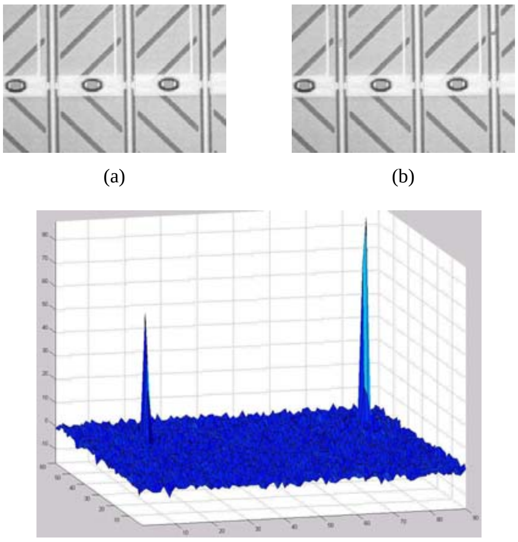
II. Problem Formulation

We used the images of arrangement about etching transistors of LCD panel to detect the defects. When obtaining the image though the camera, some problems have occurred, which are caused by a distortion of lens and the range of illumination, as illustrated in Fig. 1. Due to these effects, the image can not make a correct alignment and shows the regional difference of brightness. Especially, when the position of the camera and illumination are almost equal, the center of image is brighter than the boundary as shown in Fig. 2. In this paper, we discuss how to compensate the regional difference of brightness rather than compensating the image’s misalignment.



(c)

Fig. 3 (a) The clean image, (b) The image including illuminational gradient (c) The difference between (a) and (b)



(c)

Fig. 4 (a) The clean image (b) The image including two of defects (c) The difference between (a) and (b)

A. Difference of the Illumination

The image with an uneven illumination is compared to a clean image as shown in Fig. 3. Fig. 3(c) illustrates the difference of brightness.

B. Effect of Defects

The image, which does not include any defect, is compared to the image inserting defects shown in Fig. 4. However, there is no difference of illumination between the two.

As shown in Fig. 4(c), we can easily find the defects. But in a real situation, it is difficult due to the difference of illumination. By comparing Fig. 3(c) and Fig. 4(c), we can find the reason for this difficulty: The difference of brightness is bigger than the defect value. In other words, the defects are hidden under the difference of brightness.

III. Problem Solution

Due to the problem, described in the previous section, we propose a new algorithm which can remove the uneven illumination in the patterned image. This algorithm is progressed in four steps using the characteristics of a patterned image.

1) We obtain the outlines of 1-pixel line on the image using the least squares method.
2) We calculate the value of each point, which is designated by a sampling rate.
3) We make a model of the regional difference of brightness using bezier surface.
4) We compensate the illumination as a subtract model of the brightness from the original image.

A. Calculation of Outline

Several lines of the original image are obtained according to the red lines in Fig. 5(a). Each blue line of Fig. 5(b) and Fig. 5(c) is represented in these several lines. Each outline of these blue lines, which is represented in the red lines in Fig. 5(b) and Fig. 5(c), is calculated by using the least squares method. The least squares method runs by minimizing the summed square of residuals. The residual for the ith data point r_i is defined as the difference between the observed response value y_i and the fitted response value $\hat{y}_i$, and is identified as the error associated with the data.

$$r_i = y_i - \hat{y}_i.$$

The summed square of residuals is given by

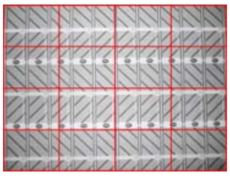
$$S = \sum_{i=1}^{n} r_i^2 = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2,$$

where n is the number of data points included in $\hat{y}_i$ and S is the sum of squares error estimate.

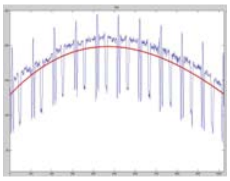
B. 3D Modeling of Illumination

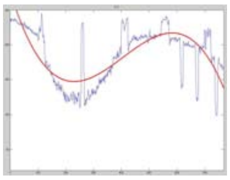
In order to show a sampling rate, we draw the red lines in Fig. 5(a). Then, we calculate the value of the every crossed point of red line in Fig. 5(a). The average of the two, one along the horizontal line and the other along the vertical line, is represented in each point as shown in Fig. 6(a). Moreover, we present a simple surface model of these points as shown in Fig. 6(b).

As we use a bezier surface, a simple surface model becomes more smooth as shown in Fig. 7. A bezier surface is defined as a parametric surface where the position of a point p as a function of the parametric coordinates u and v is given by



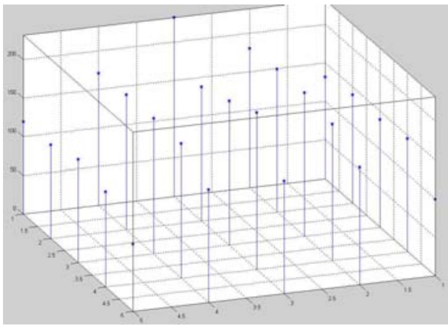
(a)



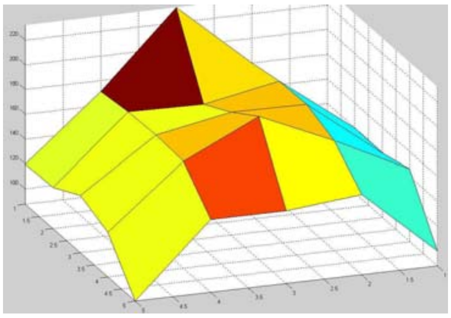


(b) (c)

Fig. 5 (a) The original image, (b),(c) The line data along the red line of (a)



(a)



(b)

Fig. 6 (a) The extracted data of the result of outline calculation (b) The simple surface model of (a)

$$p(u,v) = \sum_{i=0}^{n} \sum_{j=0}^{m} B_i^n(u) B_j^m(v) k_{i,j}$$

and, a bernstein polynomial is evaluated by

$$B_i^n(u) = \frac{n!}{i!(n-i)!} u^i (1-u)^{n-i}.$$

IV. Simulation

To compensate the uneven illumination, we subtract the model of brightness from the original image. Then, we compare our result with the result of previous research [7].

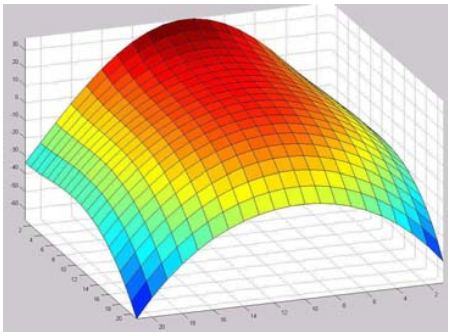


Fig. 7 The bezier surface model of the uneven illumination

In the previous research, the result is distorted and damaged when the original image is misaligned. However, in the proposed method, the regional difference of brightness is removed and the result is not damaged. An advantage of our method is that we can easily define the brightness model not only a specific shape. Moreover, we can adjust the details of mapping according to the varying sampling rate.

V. Conclusion

We proposed a geometric model of the total illumination distribution of etching transistor image. First, we obtained the outline by using the least squares method so that we can achieve the distribution of the brightness. Next, we obtained several points by sampling the data of outline. Then, we made up a 3D modeling of the brightness by using bezier surface. Finally, uneven illumination of the original image can be compensated. The proposed algorithm is much faster than the previous method and we can make up for the uneven illumination without a damage. Through this algorithm, we can adapt not only the image of LCD panel but also all of the patterned images. Also, if we develop a better method when adapting the model of illumination into the original image, then the result can improve much more.

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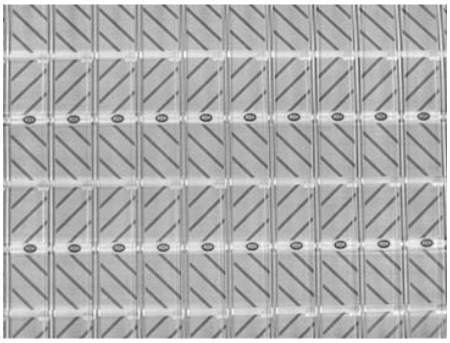
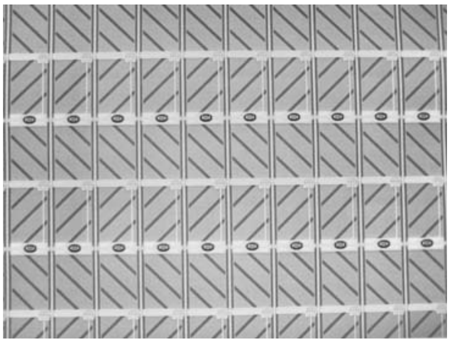


(a)



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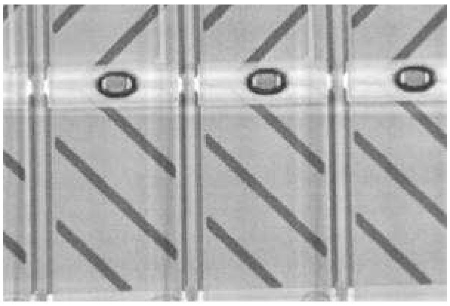
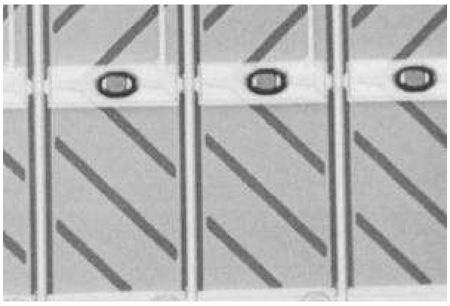


(c)



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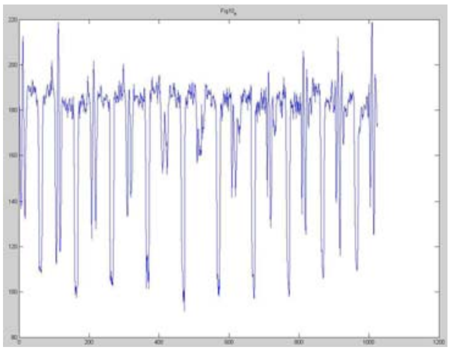
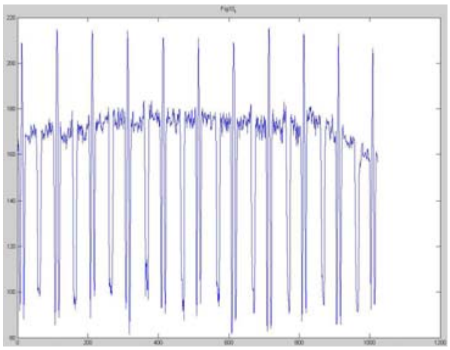


(e)



(f)

Fig. 8 (a) The simulation result of the previous algorithm, (b) The simulation result of the proposed algorithm, (c), (d) The enlarged patch of (a) and (b), (e),(f) The line data of (a) and (b)

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