Area-Mura Detection in TFT-LCD Panel*

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ABSTRACT

TFT-LCD generally has the intrinsic non-uniformity due to the variance of the backlight. The region that has the perceptible non-uniformity is defined as a defect, called area-mura. In this paper, we present a new segmentation method for detecting area-mura. We first extract candidates of area-muras using regression diagnostics and then select the real area-muras among those candidates based on the size and SEMU index, a measure of contrast based on human brightness perception. Performance of the presented method has been evaluated on those TFT-LCD panel samples provided by Samsung Electronics Co., Ltd.

Keywords : Segmentation, Regression Diagnostics, Mura, TFT-LCD, SEMU-Index.

1 INTRODUCTION

TFT-LCD panel is a display device that has been widely used in various application products. One of the problems that we face in producing TFT-LCD panels is to detect the defects on the panels, called muras. Mura is, in most cases, not easily identified so that those persons identifying muras in the industry need the experienced skill based on the related knowledge. It is thus evident for the manually identifying process by human beings to be costly and not consistent. To overcome such difficulty, an automated process using vision technique has been considered.

Depending on the shapes of mura, they may be classified into dot-mura, line-mura, and area-mura [1]. As compared to dot-mura and line-mura, area-mura is relatively difficult to be identified due to its low-contrast and no particular pattern of shape. In this paper, we thus present the technique focused on area-mura. A segmentation method for identifying area-mura suggested in this paper consists of two phases: In the first phase we extract the candidate area-muras from the TFT-LCD panel image using residual values computed from the polynomial formula approximating the panel surface. In

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the second phase we identify the real area-mura among those candidates using its size and SEMU index.

2 SEGMENTATION

Since TFT-LCD panel makes brightness using the backlight, it may have the non-uniform light brightness due to the radiance of the backlight and the distance between the backlight and the panel. The region on the panel that has considerably different brightness as compared to the rest of the panel may be defined as area-mura. To detect the area-mura, we first take the image of the given TFT-LCD panel. The image taken directly from the panel however has some brightness distortion caused by the uneven reflection from the lighting source used for taking the image. It is not then easy to figure out in such a distorted image some feature of area-mura necessary for applying the traditional segmentation methods. For example, Figure 1(a) shows the image having area-mura at the lower right corner but with brightness distortion, Figure 1(b) is the profile of this image where a curved surface (or a gradient plane) due to brightness distortion does not make the feature of area-mura clearly captured, and Figure 1(c) is the image resulting from applying the well-known Otsu’s method [2] in which the area-mura is not easily captured.

Our segmentation method for generating candidate area-muras is based on the residual values computed from the original surface image and the revised surface image obtained by removing the brightness distortion and the possible area-muras from the original image. This is based on the regression diagnostics method [3]. First, for each pixel, \( p \), on the image, we generate a polynomial, \( f_p \), approximating the original surface image except the pixel, \( p \). The complement residual value of \( p \), denoted by \( R^c_p \), is then given by the average of residual values of the rest of pixels, where the residual value, \( R_x(f_p) \), of each pixel, \( x \), is given by subtracting its intensity value on the polynomial, \( f_p \), from that on the original surface image. Those pixels whose complement residual values are greater than or equal to \( \eta R^c_{max} \), where \( R^c_{max} \)
is the maximum value of all complement residual values and \( \eta \) is the flattening rate given to be 0.2 in this work, formulate the revised surface image. Based on these pixels, we generate a polynomial, \( f_R \), approximating the revised image. Next we compute the residual value, \( R_x(f_R) \), of each pixel, \( x \), which is given by subtracting its intensity value on \( f_R \) from that on the original image. Finally we select those pixels whose residual values, \( R_x(f_R) \), are greater than or equal to \( \gamma R_{\text{max}} \) where \( R_{\text{max}} \) is the maximum value of \( R_x(f_R) \) and \( \gamma \) is threshold determining the candidate area-muras given to be 0.4 in this work. These selected pixels are assumed to formulate the candidate area-muras. Figure 2 illustrates this process: Figure 2(a) is the revised image without brightness distortion, Figure 2(b) is the profile of this image in which the feature of area-mura is clearly notified, and Figure 2(c) is the image resulting from applying the thresholding operation in which some candidate area-muras are shown.

![Figure 2](image)

3 IDENTIFICATION

To identify the real area-muras from the candidate area-muras found in the previous section, we first remove some candidate area-muras due to noise from the external sensing devices using the small-sized median filter. Next, by applying the dilation operation [4], we make all the pixels inside the same candidate area-mura have the identical intensity values. Finally, for each of candidate area-mura, we compute its size and SEMU index, whose formula is given below, the standard test level claimed by a group of TFT-LCD manufacturing industries:

\[
\text{SEMU index} = \frac{|C|}{S^{0.33} + 0.72}
\]

where \( C \) is the local contrast of a candidate area-mura and \( S \) is the size of a candidate area-mura. If the size and the SEMU index of a candidate area-mura meet the condition required by the industry, the candidate area-mura is identified.
to be the real. Figure 3 shows one example illustrating this identification process. The overall steps for segmentation and identification are summarized in Table 1.

Figure 3 : (a) Image resulting from applying the median filter, (b) Image resulting from applying the dilation operation, (c) Image having one real area-mura obtained by applying the size and SEMU index test.

4 EXPERIMENTAL RESULTS

Experiment has been performed on 31 TFT-LCD panel samples, each of which has one area-mura. The minimum size and maximum size of one area-mura were set to be 400 and 10000, respectively. For each of 31 panel samples, the SEMU index values of all candidate area-muras were computed. The SEMU index value of each real area-mura claimed by the industry was then greater than 0.5, which is shown with the gray color in Figure 4, while the average of the index values of all the other not real area-muras was less than 0.5, shown with the black color in Figure 4. Based on this result, the SEMU index threshold was set to be 0.5. From this experiment, all 31 area-muras claimed by the industry have been successfully detected but 3 candidate area-muras claimed to be not real by the industry have been identified to be real. It took less than 2 seconds, in average, to test each panel. Figure 5 shows 6 examples with their original images and final images processed.
Segmentation

1. For each pixel, \( p \), on the image, generate a polynomial, \( f_p \), approximating the original surface image except the pixel, \( p \).
2. Compute the complement residual value of \( p \), \( R^c_p \), given by the average of residual values of the rest of pixels, where the residual value, \( R_x(f_p) \), of each pixel, \( x \), is given by subtracting its intensity value on the polynomial, \( f_p \), from that on the original surface image.
3. Select those pixels whose complement residual values are greater than or equal to \( \eta R^c_{\text{max}} \), where \( R^c_{\text{max}} \) is the maximum value of all complement residual values and \( \eta \) is the flattening rate.
4. Generate a polynomial, \( f^c \), approximating the revised image based on these pixels.
5. Compute the residual value, \( R_x(f^c) \), of each pixel, \( x \), which is given by subtracting its intensity value on \( f^c \) from that on the original image.
6. Select those pixels whose residual values, \( R_x(f^c) \), are greater than or equal to \( \gamma R_{\text{max}} \), where \( R_{\text{max}} \) is the maximum value of \( R_x(f^c) \) and \( \gamma \) is threshold determining the candidate area-muras.
7. Produce the binary candidate image based on these pixels.

Identification

1. Apply the median filter method and the dilation morphology operation to the candidate image.
2. Remove those candidate area-muras not meeting the size of real area-mura.
3. Identify those candidates whose SEMU index values are greater than the given threshold to be the real.
Figure 5
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REFERENCES


