An Automated Inspection Method for the Detection of Irregularity Defects in LCD Panels

Hiroyuki YAGUCHI, Assistant professor
and
Manabu ICHINO, professor
Department of Computers and Systems Engineering
Tokyo Denki University
Hatoyama Saitama 350-0394
E-Mail: yag@k.dendai.ac.jp
JAPAN

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ABSTRACT

LCD panels have been widely used as display devices for many information facilities. From the viewpoint of quality control for LCD panels, we can categorize defective products into three categories: spot defects, line defects, and irregularity (or unevenness) defects. Point and line defects can easily be detected because the brightness of defective pixels is obviously different from other normally operating pixels. However, the detection of irregularity defects is not so easy because the natural gradation of brightness appearing in many LCD panels masks the real defects. An LCD panel is usually regarded as defective when it has a problematic local irregularity in brightness. Difficulty in detecting such an irregularity may occur when an LCD panel has a natural gradation in brightness; the difference in brightness caused by the local irregularity may often be less than that appearing in the whole of the LCD panel. For this reason, irregularity defects are currently detected by human inspectors in LCD factories.

This paper presents a method for the automated detection of irregularity defects. The predictable gradation of brightness in a LCD panel is approximated by using a smoothing spline function. Then, this gradation is removed by applying the spline function. As a result, the local irregularity in brightness is selectively emphasized. By this method, we can easily detect irregularity defects, not only in LCD panels, but also in similar objects.

1. LCD Panels and Defects

1.1 A Principle of the LCD Panel

An LCD panel is made up of liquid crystal molecules sandwiched between two polarizing filters. Liquid crystal is an intermediate material between a solid and a liquid. Figure 1 illustrates the structure of the LCD panel. The liquid crystal molecules are enclosed by two special structural boards. These boards create an ordered array of the molecules. In the absence of any voltage, the light goes through the LCD and its polarization is changed by a combination of the liquid crystal molecules and two polarizing filters. In applying a voltage to the liquid crystal molecules, the array of the molecule changes, and the LCD shuts out the light. The special structural boards contain many small transparent electrodes which control the light. Each transparent electrode is one pixel of the LCD. The LCD creates characters or figures by controlling the pixels. However, the LCD does not emit light, so we have to install a reflective board or a backing light.

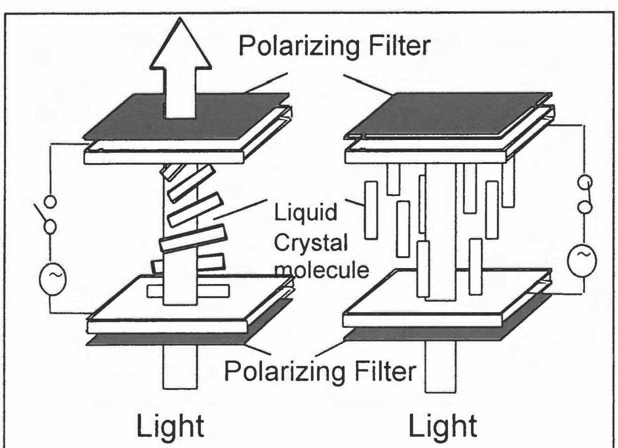

Figure 1: LCD Structure

1.2 Defect of LCD Panels

From the viewpoint of quality control for LCD panels, we can categorize 3 types of defect: spot, line, and irregularity (or unevenness) defects. A spot defect occurs when one, or a group of, LCD panel pixels fail. When a LCD does not light in a line, it is called a line defect. Point and line defects appear because some electrodes do not work. Figure 2 and Figure 3 illustrate line and spot defects.

Where there is a locally bright (or dark) spot on the LCD, we consider the LCD to have an irregularity defect. Figure 4 illustrates this. Figure 5 illustrates an irregularity defect in which the vertical axis represents brightness.

2 Method of Detecting Irregularity Defects

2.1 Why Do We Need to Detect Irregularity Defects

It is easy to detect point and line defects. The defective area has a problematic brightness value, which is clearly different from normal. Consequently, it is easy to develop an automated inspection system for these.
However, irregularity defects are not so easy to detect, because the gradation of brightness appearing in many LCD panels may not be recognized as problematic. An LCD panel is usually regarded as defective when it has an unnatural local irregularity in brightness. Difficulty in detecting such a local irregularity may occur when the LCD panel has a natural gradation in brightness. The difference of brightness appearing in the local irregularity is often less than the difference of brightness appearing in the whole of the LCD panel. For this reason, irregularity defects are detected by human inspectors.

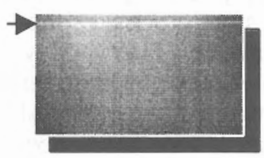

Figure 2: Line Defect

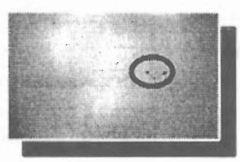

Figure 3: Spot Defect

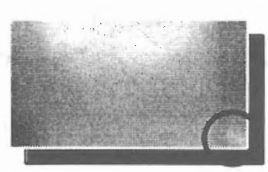

Figure 4: Irregularity Defect

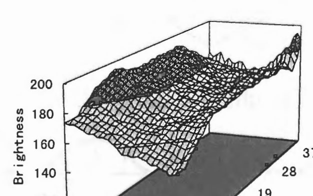

Figure 5: Irregularity Defect(Brightness)

However, the human inspection of LCD's is expensive and inaccurate. An automatic system will reduce costs and increase productivity.

2.2 Detection with the Known Method

2.2.1 Emphasis Processing

We attempted to detect an irregularly defect by using emphasis processing. Figure 6 illustrates the result of Laplacian filtering of the LCD with an irregularity defect. The natural brightness gradation of the LCD become more emphasized. As a result, it was harder to distinguish the irregularity defect than it had been on the original image. So we have designed a new system to detect irregularity defects by canceling the LCD's natural gradation of brightness.

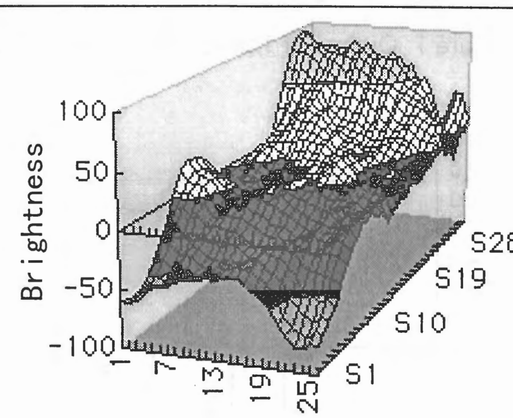

Figure 6: Result of Laplacian Filtering

2.2.2 Triangle Processing Method

TECHNOS 2000H is a system which can detect irregularity defects in LCD's by using Triangle Processing. Figure 7 is an outline of Triangle Processing. This system has a line sensor to take and process the LCD image for each line. That system sets a pixel α for the midpoint of the calculation. A "window" is a segment of a line of pixels with a fixed number of pixels and we call the center pixel α. This system adds up the brightness values of the window α and the neighboring window. The system calculates the difference of the sum of the brightness values of the $\alpha,\beta,\gamma,\delta,\ldots$ windows and the neighboring window. Next, the system selectively emphasizes only the irregular parts. However, TECHNOS 2000H has some problems. For instance, in the presence of non-linear brightness gradation it gives spurious results (Figure 8).

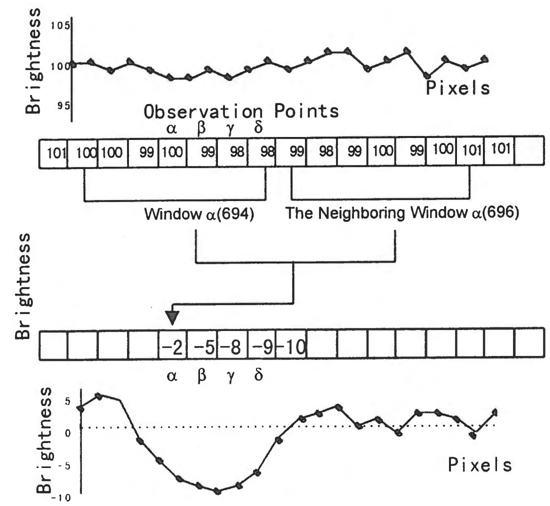

Figure 7: Outline of Triangle Processing

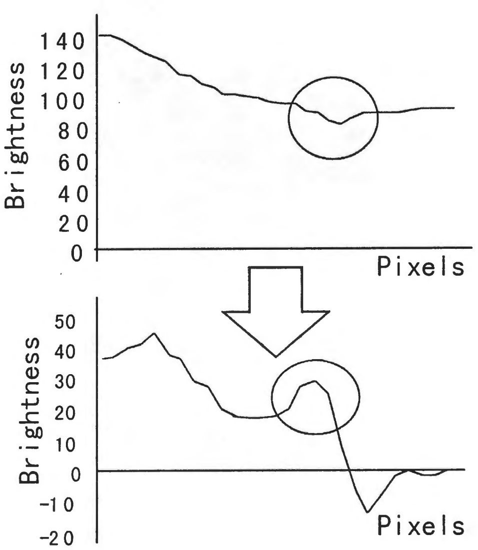

Figure 8: A Problem of Triangle Processing

2.3 Irregularity detection method by using spline function

2.3.1 Outline of Our Method

Our method will selectively emphasize an irregular part by removing the natural gradation. It calculates the real brightness value which is not influenced by the gradation of brightness in a LCD. The gradation of brightness in a LCD panel is approximated by using a smoothing spline function. Then, the gradation in brightness is removed by using the spline function and, as a result, the local irregularity in brightness is selectively emphasized.

2.3.2 Parameter of Spline Function

The smoothing spline function f(x) is calculated by minimizing σ in formula 1.

$$\sigma = \sum_{n=0}^{N-1} W_i \{f(x_i) - y_i\}^2 + g \int_a^b \{f^{(k)}(x)\}^2 dx \cdots\cdots (1)$$

Our system used the fifth polynomial function as a function *f(x)*. This formula has a smoothing parameter g. When g is small, the curve of *f(x)* becomes near to the observation point (x_i, y_i). When g is large, the curve of *f(x)* will roughly fit the observation point.

2.3.3 Process of Irregular Detection

In this paragraph, we apply our system to the example in figure 4. Our system processes the LCD image divided into individual lines. First, our system models the observation point by using a smoothing spline function. The smoothing spline function shows the gradation of brightness in this line. Next, our system calculates the difference between the smoothing spline function and the brightness value

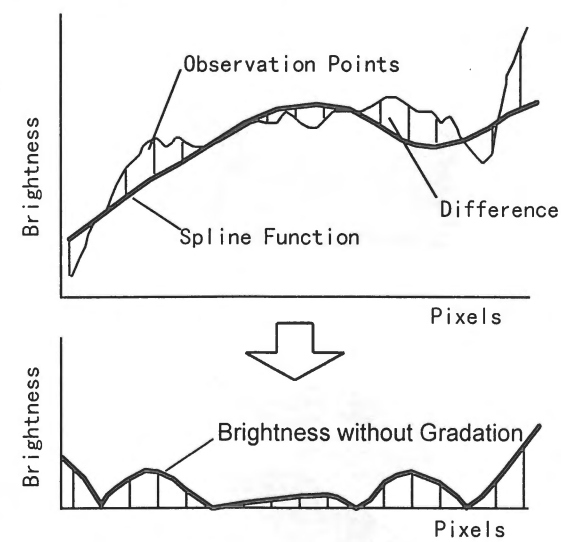

Figure 9: Outline of Our Method

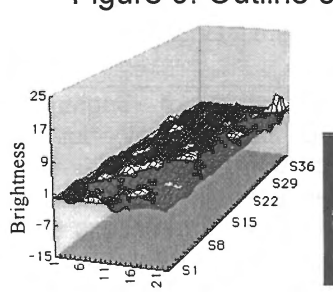

Figure 10: Result of Removing Gradation by Using Our Method

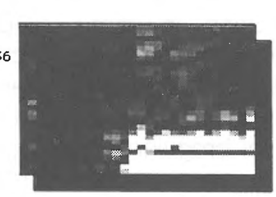

Figure 11: A Result of Our Method

of the observation point (Figure 9). Our system removes the influence of the natural gradation by this process. After that, our system smoothes and emphasizes the LCD image of each line. As a result, the local irregularity in brightness is selectively emphasized (Figure 10 and 11).

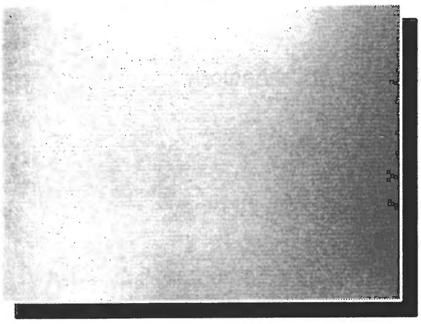

Figure 12: An Image of Normal LCD with gradation

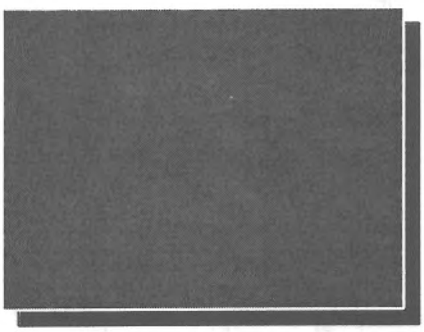

Figure 13: A Result of Our Method

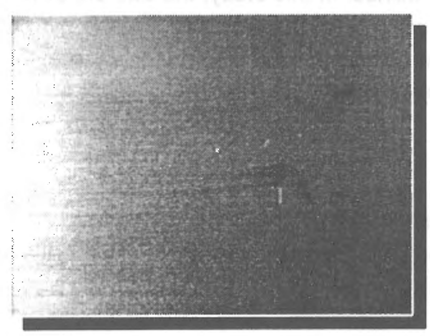

Figure 14: An Image of Plated metal sheet with irregularity Defect

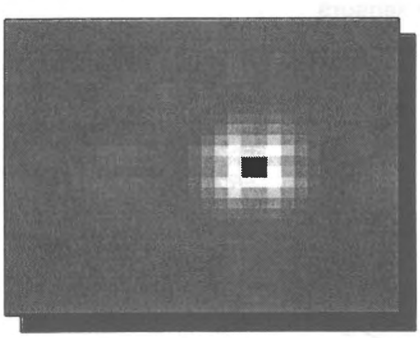

Figure 15: A Result of Our Method

3 Execution Example of Our System

3.1 An Example of Applied to LCD Panel Image

Figure 12 illustrates an LCD image which has no defects nor gradation of brightness. Figure 13 illustrates the result of our system. The result shows that our system was able to remove a gradation of brightness. Our system will provide accurate results in the inspection process.

3.2 An Example of Applied to Other Object Image

In this section, we apply our system to other objects. Figure 14 represents a plated metal sheet with an irregularity defect. Figure 15 shows the results of our system. Our system can easily detect not only irregularity defects in the LCD panels but also those appearing in other objects such as plated metal sheets.

4 Conclusion

We proposed a method of selectively emphasizing irregularity defects by using a smoothing spline function. The proposed method is not influenced by natural gradations of brightness. Our system can easily detect not only irregularity defects in LCD panels but also those in many similar situations. In other words, this method can be applied to manufacturing fields where, until now, human inspectors have been used to detect irregularity defects.

Reference

Sharp Corporation, World of LCDs, http://www.sharp.co.jp/sc/library/lcd_e/indexe.htm

Yoshiro, Y. 1996. Display Gaikankensa no Saishi Gijyutu (sono 1), Gekkan Display, 2(5), pp 69-75 (in Japanese)