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Fault detection of shadow mask by use of image data processing

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Abstract At the KACC'91 conference, we proposed a method of automatic detection of shape of the faulty holes of a shadow mask which is used in a cathode-ray tube of a color television. In this method, the image data are taken from two areas of the mask with CCD camera. Comparing the shape of holes in these two areas by use of a signal processing technique, we can find any fault in the shape of holes. This paper describes the effect of smoothing filters of effectively finding the faulty holes from the difference image data. A computer simulation and actual experiment with a shadow mask have shown that this method of fault detection is very effective for practical use.

1 Introduction

A shadow mask used in a cathode-ray tube of a color television is made from a thin iron plate in which several hundred thousands of small holes exist. These small holes are made through an etching process. In the process of making such a shadow mask, there occurs the case where some of those holes have not correct size and shape, which causes color blur on the screen of color TV. So it is an important task to detect and eliminate those faulty shadow masks.

At the KACC'91 conference, we proposed a method of automatically detecting the shape of the faulty holes by use of CCD camera and signal processing technique. In this method, two adjoining test areas from one image data of the shadow mask are taken and comparing the shape of holes in these two areas, we can detect the faults in the shadow mask. The method is described in detail as follows:

The two dimensional cross-correlation function between the data of two test areas is first calculated. And then we move one of the image data to the place where the cross-correlation function becomes the maximum.

Then we subtract one of two image data from another. The subtracted image data include the information of faulty holes.

In this paper, the effect of smoothing filters is described for finding the faulty holes from the subtracted image data.

The main role of the filter is to remove sampling errors occurring at the edge of the holes. We have examined two types of filtering; Contraction and expasnsion processing filter and Median filter.

From the results of the experiment, it is shown that Median filter processing twice is suitable for detecting faulty holes.

This method of fault detection of a shadow mask is expected to be used widely in shadow mask industries.

2 Observed image data

When the holes of a shadow mask is observed with a microscope, the shapes of the holes are converted into the pattern of black and white.

This pattern is observed with the CCD camera and converted to the image data, which are fed to a personal computer. The image data is then converted into a binary data as shown in Figure 1.

The image data are taken from two areas of the shadow mask as shown in Figure 2(a) and (b). Comparing the shape of holes in these two areas, we can find any fault in the shape of holes.

The image data of the area where the number of the pixel is assumed to be N can be shown as follows.

When the normal image data obtained from normal holes are represented as $x_n(k,l)$ where k and l are x and y variables on the screen, and the faulty image data obtained from the area containing faulty holes are represented as $x_f(k,l)$. $x_n(k,l)$ and $x_f(k,l)$ are written as follows.

$$\begin{aligned} x_n(k,l) &= x(k,l) && (1) \\ x_f(k,l) &= x(k,l) + d(k,l) && (2) \\ k,l &= 0,1,2,\cdots,N-1 \end{aligned}$$

where $d(k,l)$ represents fault.

3 Detection of fault by subtraction of the two image data

We have developed a method of fault detection by use of correlation function and the subtraction.

The crosscorrelation function of image $x_n(k,l)$ and $x_f(k,l)$ is assumed to be $R_{nf}(m,n)$.

$$\begin{aligned} R_{nf}(m,n) &= \sum_{k=0}^{N-1}\sum_{l=0}^{N-1} x_n(k,l)x_f(k+m,l+n) \\ m,n &= 0,1,2,\cdots,N-1 && (3) \end{aligned}$$

The phase that the maximum crosscorrelation function is obtained is assumed to be m' and n'. Then by moving the image $x_f(k,l)$ to (m',n') position, two images $x_n(k,l)$ and $x_f(k,l)$ almost coincide. So the difference image is obtained as follows.

$$d(k,l) = \begin{cases} \mid x_n(k,l) - x_f(k+m',l+n') \mid; \\ if\ 0 \leq (k+m'),(l+n') < N \\ 0;\ otherwise \end{cases} \quad (4)$$

The subtracted image data is shown in Figure 2(c).

Those points which exist in the surrounding part of the hole in Figure 2(c) are the points with sampling error and so they are not faults.

Therefore, it is necessary to delete those data due to sampling error.

4 Smoothing of binary image

A thick circule in the binary image data shown in Figure 2(c) is a fault, whereas the other circular points are due to sampling error and these are not faults. These sampling errors can be removed by use of a smoothing filter. The following two methods of smoothing filter were examined.

4.1 Contraction and Expansion processing

As a method of removing noise component of a binary image, Contraction and expansion processing is widely used. This processing is executed by the following two basic processings.

Contraction

$$g(k,l) = \begin{cases} 0;\ d(k,l) = 0\ or\ either\ of \\ \quad 4\ neighbor\ of\ d(k,l)\ is\ zero \\ 1;\ otherwise \end{cases} \quad (5)$$

Exapnsion

$$g(k,l) = \begin{cases} 1;\ d(k,l) = 1\ or\ either\ of \\ \quad 4\ neighbor\ of\ d(k,l)\ is\ unity \\ 0;\ otherwise \end{cases} \quad (6)$$

After the image is contracted, then the image is expanded. These processing can remove the image of small element and narrow part from the image data.

4.2 Median filtering

Smoothing a binary image by use of Median filter is carried out as follows.

$$g(k,l) = \sum_{i=-\frac{n}{2}}^{\frac{n}{2}} \sum_{j=-\frac{n}{2}}^{\frac{n}{2}} d(k+i, l+j) \qquad (7)$$

$$g(k,l) = \begin{cases} 1; & d(k,l) = 1 \text{ and } g(k,l) \geq \frac{n^2}{2} \\ 0; & otherwise \end{cases} \qquad (8)$$

At each pixel in the image, the total number of surrounding pixels having the same value as the pixel is calculated. When the object pixel is unity and there are a lot of pixels in surrounding pixels with the same value, the object pixel is adjusted to unity as effective pixel. On the other hand, the number of pixels having the same value is small, the object pixel is adjusted to zero as a noise.

Therefore, the isolated noise of a binary image can be removed with such a Median filter.

The effect of Median filter by means of equation (7), (8) is examined by simulation for following images.

The image shown in Figure 3(a) is an original image of cross line which have single width. The resultant image are shown in Figure 3(b), (c) and (d). These images are processed by Median filter once, twice and three times, respectively. From these results, the sampling errors are eliminated by Median filter used twice.

If the line's width of an original image is two or more, Median filter does not change the original image.

An original circule image and the results are shown in Figure 4(a), (b), (c) and (d).

From the above mentioned, the smoothing of images in the shadow mask testing is suitably done by means of Median filter used twice.

4.3 The result of smoothing

Consider the case where the shape of the faulty hole of a shadow mask is simple, having a large fault as shown in Figure 5(a).

Also we considered the case where the shape of the faulty holes is complex, having a lot of small faults as shown in Figure 6(a).

Since only the faulty images should be detected from such a difference binary image, it is necessary to select a suitable smoothing method.

A case of simple fault

As an example of a simple fault, the difference image data is shown in Figure 5(a), and the resultant image of smoothing by use of Median filter used twice is shown in Figure 5(b). The resultant image of the smoothing by Contraction and expansion processing is shown in Figure 5(c). We see that noises caused by sampling errors are removed completely in both methods.

A case of complex fault

A large faulty hole and a lot of slightly faulty holes exit in the difference binary image in Figure 6(a).

And the resultant image of smoothing by use of Median filter used twice is shown in Figure 6(b). The resultant image of the smoothing by Contraction and expansion processing is shown in Figure 6(c).

From these experiment, we see that the best way of smoothing in the fault detection is the use of Median filter twice.

The Contraction and expansion processing is said to be suitable to a landscape and a portrait image, but it is not suitable in the fault detection of slightly faulty binary image.

5 Conclusion

A new method is developed to detect faulty holes of a shadow mask, by use of signal processing technique.

The shape of the holes of the shadow mask are observed with the CCD camera. Two areas in one image data are chosen for checking. In order to compare these two areas, two image data are moved vertically and horizontally so as for the two-dimensional crosscorrelation function to be the maximum.

Then these two image data are subtracted to get data of faulty holes.

The effect of smoothing filter is checked for Median filter and Contraction and expansion filter.

From the result of the experiment, it is shown that Median filter used twice is better as the smoothing filter of subtracted image data.

References

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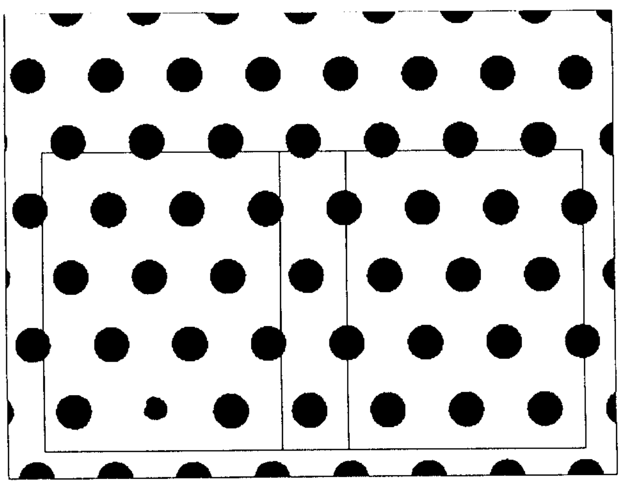

Fig.1 Observed area (include two areas to be tested)

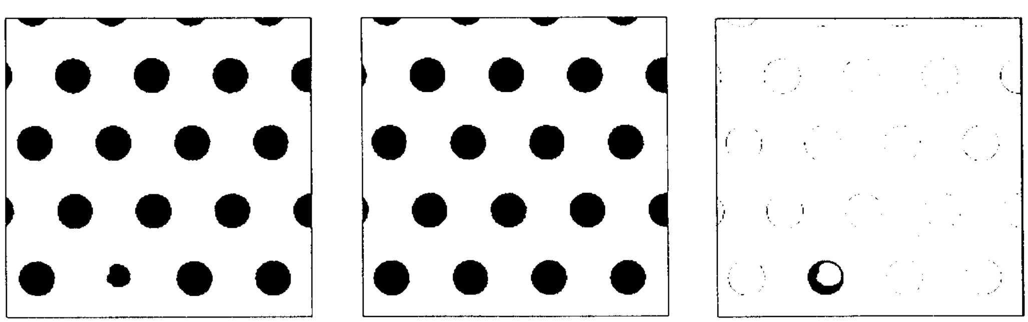

Fig.2(a) Test area 1 (b) Test area 2 (c) Difference image data

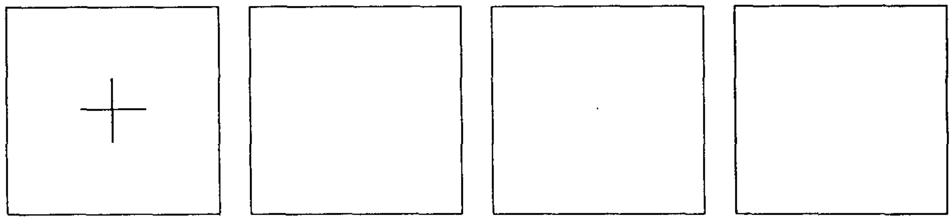

Fig.3 Cross line with single witdh

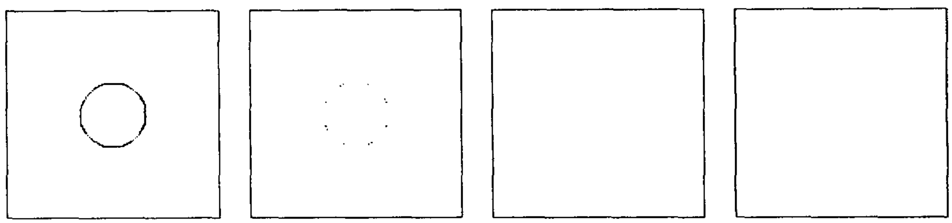

Fig.4 Circule with single width

(a) Original image (b) Result image by process once
(c) Result image by process twice (d) Result image by process three times

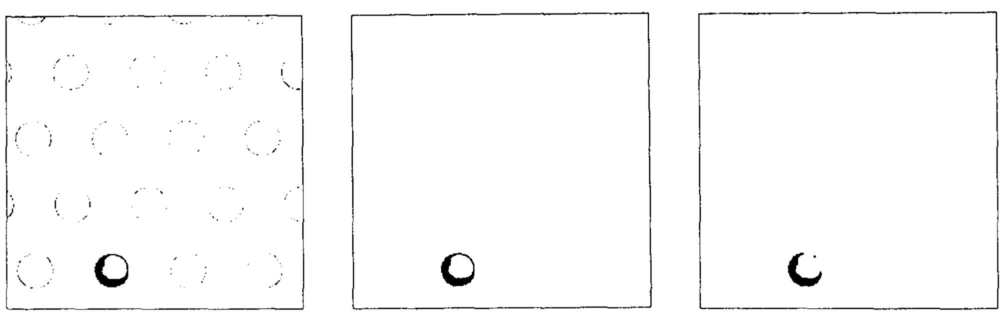

Fig.5 Simple faulty image

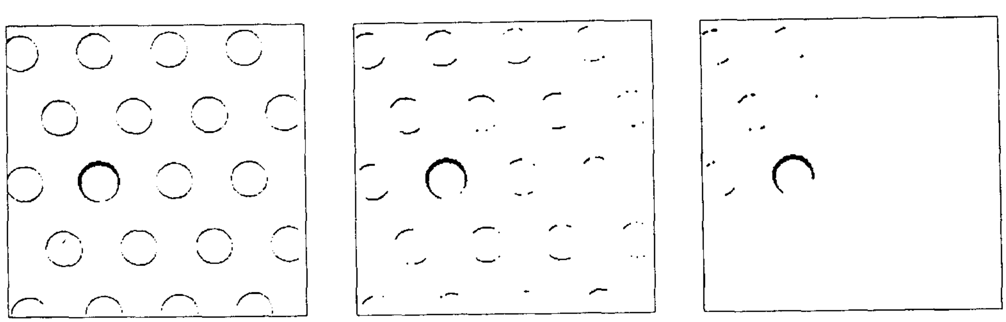

Fig.6 Complex faulty image

(a) Difference image (b) Result image by Median filter used twice
(c) Result image by Contraction and expansion