Research on SSD Countersink Defect Detection Method Based on Machine Vision

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Abstract. Defect detection of counterbore plays an important role in SSD solid state disk panel automatic detection. Its goal is to accurately find and locate the defect location. At present, the detection of counterbores mostly adopts manual detection, which has the problems of low detection speed, high false detection rate and high missed detection rate. In this paper, the defect detection algorithm of counterbore is studied. After experimental verification, the improved algorithm expansion ⊕ closed operation and Blob analysis tools are finally used for image processing to ensure the integrity of the detection effect and further improve the accuracy of SSD counterbore detection.

Keywords: Solid state drives; Countersink hole; Machine vision; Defect detection.

1. Introduction
With the development of SSD (Solid State Drives) solid state drives production industry, the requirements for the inspection of the quality of panels are becoming more and more complex. However, the commonly used manual inspection method can neither match with the modern manufacturing and processing speed nor meet the demand for quality monitoring in the production process. The SSD counterbore defect detection system based on machine vision technology, due to its non-contact detection measurement, has a wide spectral response range and higher accuracy, can work stably for a long time, improves work efficiency, and greatly saves a lot of labor resources.

2. Image Processing Based on Vision System
Image processing is an important part of machine vision system. Vision software realizes automatic detection of specific targets by processing, analyzing and identifying images. As the application of machine vision system is more and more extensive, the requirements for the image processing technology of machine vision are higher and higher. At the same time, the technology of image processing software has been developed rapidly.

The basic steps of image processing are as follows: (1) acquiring images: acquiring images through cameras, lenses and the like; (2) image preprocessing: pre-processing the image to better extract meaningful features; (3) image analysis: Analyzing the preprocessed pictures; (4) Result output: the analysis result is transmitted to the external device [1]. As shown in the schematic diagram of image processing in fig. 1.
3. Structure Diagram of SSD Counterbore Defect Detection System

As shown in fig. 2, SSD panel defect detection system consists of two parts: image acquisition and defect detection.

It consists of two processes. Image acquisition is the process of shooting the detected workpiece and sending it to PC. It mainly consists of camera, lens, backlight, etc. SSD defect detection is completed on a computer PC. The defect information in the image is detected by image processing, and feature extraction is carried out on the defect information, and then the detection result is displayed on the display screen.

The diameter of the round hole of the SSD panel counterbore is 5±0.1mm, the required detection accuracy is 0.01mm, and the horizontal length of the field of view is 8mm. In order to improve the stability of the system, we select 4 pixels corresponding to 0.01mm, and the visual system accuracy is 0.01/4=0.0025mm/ pixel, so the horizontal resolution of the camera should not be less than 8mm/(0.0025/ pixel) =3200 pixels. Only a camera with a resolution of 10 million pixels can meet the accuracy requirement, but the cost is far beyond the design scheme. Therefore, considering the problem of limited cost, the detection accuracy is reduced to 0.0075mm and the horizontal field of view of the camera is increased to 15mm. after calculation, 15mm/(0.0075/ pixel) =2000 pixels are obtained. in this subject, a camera with a pixel size of 2.2×2.2μm and a resolution of 2592×1944 pixels and a bilateral telecentric lens are selected.

The image processing software is Vision Pro, and the software interface is shown in Figure 3. Vision Pro is a set of standard machine vision algorithm software developed by Cognex Company in
the United States, including image preprocessing, image splicing, image calibration, visual positioning, measurement, result analysis and other functions.

![Vision Pro software interface diagram](image)

**Figure 3.** Vision Pro software interface diagram

4. Image Processing Algorithm

4.1. Image preprocessing algorithm

The main function of image preprocessing is image enhancement, which can better identify and analyze subsequent visual tools (size measurement, surface detection, etc.) [2]. Common image preprocessing methods include filtering, morphology, image segmentation, histogram, geometric transformation, contour extraction, color space transformation, etc. There are many kinds of pretreatment methods available. According to the specific requirements of the target to be tested, an appropriate method can be selected to produce the best image contrast. Proper pretreatment can improve the stability of the test results.

![Original defect image and gray threshold transform image](image)

**Figure 4** Original defect image and gray threshold transform image

As shown in fig. 4(a), the original defect image of SSD counterbore panel collected by the camera is converted into a black-and-white binary image through image preprocessing gray threshold transformation [3], as shown in fig. 4(b).
4.2. Morphological image processing
Corrosion and dilation are basic operations of mathematical morphology and basic theories of image processing, which can be applied to binary images:

For the set A and S of elements on \( z^2 \), use S to expand A, denoted as \( A \oplus S \), and formally defined as:

\[
A \oplus S = \{ z \mid (S)z \cap A \neq \emptyset \} \tag{3.1}
\]

Assumption: The structural element S is located at the origin of the image, and it moves on the \( z^2 \) plane. When its own origin is translated to the z point, the image of S relative to its own origin S and A have a common intersection, that is, S and A have at least 1 pixel overlapping. Then the set of all such z points is an expanded image of s to a.

Similarly, corrosion can also be formally defined as:

\[
A \ominus S = \{ z \mid (S)z \subseteq A \} \tag{3.2}
\]

Let the structural element S originally located at the origin of the image move across the \( z^2 \) plane.

Open operation: Use the structural element S to open the image A and record it as \( A \circ S \). Can be expressed as:

\[
A \circ S = (A \ominus S) \oplus S \tag{3.3}
\]

In general, the open operation smooths the outline of the image, breaks narrow connections and eliminates fine burrs \(^4\).

Closed operation: Use structure element s to perform closed operation on image A, denoted as \( A \bullet S \). Can be expressed as:

\[
A \bullet S = (A \oplus S) \ominus S \tag{3.4}
\]

Closed operation also smooths the contour, but contrary to open operation, it can usually close narrow gaps and fill small holes. Morphological image processing is a series of mathematical operations on the original image by using structural elements. Therefore, the selection of structural elements has great influence on the processing results, and the shape and parameter size of structural elements also have great influence on the processing results. Structural elements include diamond, linear, circular, square and other different shapes. Generally speaking, the shape of structural elements should be as simple as possible, because complex shapes will increase the complexity of operations and will lose some useful information. However, to ensure that the processed defect image is consistent with the original defect as much as possible, the best structural elements must be selected through repeated experiments.

4.3. Algorithm steps
In this paper, two different structural elements are designed, which are commonly used \( 1 \times 5 \) diagonal structural elements and asymmetric structural elements.
In order to obtain the ideal image processing effect, this paper attempts to combine morphological operators and obtains the ideal image processing algorithm through a large number of experiments. Including dilation $\oplus$ corrosion, dilation $\oplus$ closed operation combination operator for image processing.

Through experiments, it can be concluded that gray scale expansion alone can repair the fracture, but it will cause obvious influence on the shape and outline of the defect. However, using gray-scale closed operation alone can keep the shape and outline unchanged, but cannot completely repair the fracture. Therefore, the combination of the two morphological operators can not only repair the fracture and bridge the gap, but also ensure that the overall position and contour shape of the detected defects remain unchanged.

The specific algorithm steps are as follows:

The original image $f(x)$ is expanded with the structural element $S$, and the obtained image is $A$, that is:

$$A = f(x) \oplus S \quad (4.5)$$

Close the original image $f(x)$ with the same structure element $S$ to get the image $B$, as follows:

$$B = f(x) \bullet S \quad (4.6)$$

The expanded image and the closed image are merged to obtain the image $C$ for repairing the fracture.

$$C = A \oplus B \quad (4.7)$$

By processing the original image in the above three steps, it can be obtained that the fracture can be repaired, the discontinuity can be closed, and the overall position and contour shape of the detected defect can be kept unchanged. In this paper, the combination of the square structure element and the self-improved asymmetric structure element combined with the expansion $\oplus$ corrosion, expansion $\oplus$ closed operation of two combined algorithms were tested.

4.4. Experiment and result analysis

In order to verify the advantages of the improved structural elements and analyze the advantages and disadvantages of the two algorithms, this paper uses the square structural elements and the improved structural elements to carry out experiments on the two algorithms. The results are as follows:
The structural elements are 1×5 diagonal, and the algorithms are different for image processing.

Results analysis: fig. 6(a) and fig. 7(a) are conventional morphological algorithm expansion ⊕ corrosion, using flat structural elements diagonal type and self-improved asymmetric structural elements respectively. It can be seen that although the image has been repaired to a certain extent after the diagonal structural elements are used for processing, the tiny fracture of the image is not completely repaired and the whole image is fuzzy. By the same token, through the treatment of asymmetric structural elements, the restoration effect of the fracture of the image is better than that of the image, but the image blur and unsmooth edge cannot be avoided.

In order to make the image not only complete but also smooth in outline; In this paper, the improved algorithm expansion ⊕ closed operation is adopted, as shown in figs. 6(b) and 7(b). Diagonal type of flat structural elements and self-improved asymmetric structural elements are used to verify the results. It can be seen that after the improved algorithm and diagonal structural elements are used for image processing, the definition of the image is enhanced, but the image still has slight fracture. In order to repair the minor defects here, after treatment with asymmetric structural elements, it is obvious that the fracture is completely repaired, and the overall position of the object is unchanged and the contour becomes smooth. Therefore, this paper adopts the improved algorithm expansion ⊕ closed operation, and the structural elements are asymmetric for image processing.

4.5. Image analysis algorithm and result output

Image analysis is a visual processing tool for specific requirements in machine vision applications, mainly including: calibration, measurement, detection, character and barcode recognition, template matching, color analysis and other image tools.[5]

The image analysis algorithm in this paper is based on Blob spot finding tool under Vision Pro image processing software. Blob analysis module is used to extract the object of interest in the image. The difference between extraction method and pixel matching algorithm is: There is no need to learn...
the template, and the basis for extracting the target is that the pixel statistical features or geometric features of the target are within a certain range. The Blob analysis process is basically as follows: Firstly, the image is analyzed for several targets, which can be combined according to set conditions to form entities. Then, various characteristics of entities (including average pixel value, area, perimeter, etc.) are selectively calculated, and entities are screened according to one or more characteristic values.

![Figure 8 Unhandled defective images and pixel values.](image8)

As shown in fig. 8, the image that has not been processed by the Blob tool. In the image, not only white speckles in the aperture itself and irregular speckles in the background, but also some fine speckles are detected by Blob search tools.

Therefore, according to the actual situation, this paper uses Blob search tool to add constraint conditions to eliminate irrelevant spots in the image. the constrained image is shown in fig. 9.

![Figure 9 Blob processed defect image](image9)

Results analysis: the green selection in fig. 9 shows the defects analyzed by Blob tool.

In order to ensure the Blob tool can detect completely, it is first necessary to determine various data of detected defects, and then after filtering incorrect defect information, the image after complete detection is output [6]. However, when some SSD counterbore defects are imaged, there is external interference or other reasons that cause the image to be imaged at the crack, and the discontinuity of pixel points in the crack presents broken flocules. The cracks were repaired by theoretical analysis and experimental verification, and then the image was processed by Blob analysis tool. While ensuring the integrity of the detection effect, the accuracy of detecting SSD counterbore can be further improved.
5. Summary
The SSD counterbore defect detection system based on machine vision technology belongs to non-contact detection measurement, has extremely wide spectral response range and higher accuracy, can work stably for a long time, not only improves work efficiency, but also saves a large amount of labor resources. Through the analysis of the image processing algorithm of the SSD sink hole, the improved algorithm expansion/close operation is used in the study of this paper, and the structural element is asymmetrical for image processing, which ensures that the image can be repaired at the same time as the contour is smooth, and then Image processing is performed by Blob analysis tools to ensure the integrity of the detection effect.

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