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Improvement of SUSAN Image Filtering Method for PCB Quality Inspection

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Abstract:

This paper presents an improvement to the SUSAN image filtering method to improve the quality inspection accuracy of printed circuit boards (PCBs). The problems of traditional filtering methods are considered and improvements are proposed aimed at more effectively removing noise and increasing the reliability of defect detection. The experiments confirm that the modernized SUSAN method provides higher image quality, which is critical for computer vision systems in Industry 4.0. Application of the proposed approach helps reduce defect rates and optimize production processes, improving the overall productivity and reliability of PCB quality control

Key words: Industry 4.0, Computer Vision Systems, PCB, Filtration Methods, SUSAN.

Introduction

In the era of Industry 4.0, growing demands for the accuracy and efficiency of automated systems [1]-[13] make research into improving image filtering methods extremely relevant. Modern computer vision systems [14]-[29] play a key role in manufacturing processes, especially in the quality control of printed circuit boards (PCBs). Various methods and approaches can be used here [30]-[35].

High accuracy of defect detection on these boards is impossible without effective removal of noise in images. However, traditional filtering methods often do not provide the required level of accuracy, which can lead to missed defects or false positives [36], [37]. Improvements to the SUSAN image filtering method will significantly improve the quality of processed images, providing more reliable defect detection. This, in turn, will improve the reliability and productivity of quality control systems on production lines. The implementation of the improved SUSAN method in PCB quality control processes helps reduce defects and optimize production processes, which is an

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important aspect in the context of the development of Industry 4.0. Therefore, this study aims to improve quality control technology, which is of significant importance to improve the competitiveness of enterprises and meet high quality standards in the industry.

Related works

Quality control processes for printed circuit boards are an integral part of the production stages of such products. It's quite versatile. It seems natural that many scientific works are devoted to this process. Let us look at a few recent ones.

Perdigones, F. in his work [38] describes the active flow driving methods for lab-on-PCB devices, while commenting on their main characteristics. Among others, the methods described are the typical external impulsion devices, that is, syringe or peristaltic pumps; pressurized microchambers for precise displacement of liquid samples; electrowetting on dielectrics; and electroosmotic and phase-change-based flow driving, to name a few.

Authors in [39] note that the quality of the printed circuit board (PCB), an essential critical connection in contemporary electronic information goods, directly influences the efficiency and dependability of products. Therefore, any PCB defect should be identified promptly and precisely to avoid a product failure while it is in use.

Li, Y. T., and co-authors in [40] propose a deep ensemble method to inspect the PCB solder defects to replace the labor inspection. To achieve a high detection rate and a low false alarm rate, two distinct detection models, a hybrid YOLOv2 (YOLOv2 as a foreground detector and ResNet-101 as a classifier) and Faster RCNN with ResNet-101 and FPN are separately trained to obtain a high detection rate result.

Researchers [41] write that although the expansion of electronic devices affects our lives in a productive way, failures or defects in the manufacturing procedure of those devices might also be counterproductive and even harmful in some cases. It is therefore desired and sometimes crucial to ensure zero-defect quality in electronic devices and their production. They introduce ChangeChip, an automated and integrated change detection system for defect detection in PCBs, from soldering defects to missing or misaligned electronic elements, based on Computer Vision and unsupervised learning.

Paper [42] tries to answer the questions of how machine learning technology can contribute for better PCB fault detection in the assembly line and at which parts of the

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assembly line this technology has been applied. It also discusses the PCB defect detection by using machine learning and other approaches.

Scientists in [43] propose an artificial systems, computational experiments, and parallel execution-based integrated inspection method in cyber–physical–social systems to realize smart manufacturing.

The study [44] proposes a key technology of PCB defect online detection based on machine vision. Its experimental results show that the method has high detection accuracy and short detection time, and can effectively control the stable operation of the online detection system, which provides a reference for related research in this field.

Defect detection is an essential requirement for quality control in the production of printed circuit boards (PCBs) manufacturing [45]. The traditional defect detection methods have various drawbacks, such as strongly depending on a carefully designed template, highly computational cost, and noise-susceptibility, which pose a significant challenge in a production environment [45]. The work [45] proposes a deep learning-based image detection method for PCB defect detection.

Improvement of SUSAN method for writing suppression on PCB boards

Using the SUSAN method is necessary to clean a real image from various types of noise. This method includes two stages. First, the "noise" pixel is determined (as a rule, the main difficulty lies in identifying noise). The noise pixel value is then replaced with a new value, usually calculated from the surrounding pixels.

Typically, when using the SUSAN method, a group of pixels of 5x5 elements is considered, the central pixel of this matrix is the one being tested.

While developing an automated quality control method, the group of processed pixels was reduced to 3x3, since when working with small PP elements it is necessary to filter noise as accurately as possible. Using a 3x3 pixel matrix somewhat slows down the program, but shows more accurate results necessary for the next stage of outlining the elements.

During the test, the deviation of the pixel brightness from the average brightness value is calculated. If the filter "decides" that such a pixel should not exist, its "noisy" value is replaced with a new one, calculated based on the surrounding pixels.

The criterion for determining noise in this method is to consider n pixels included in the pixel matrix.

We find the sum of deviations of pixel brightness from the average value.

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$$S = \sum_{i=0}^{n-1} \Delta_i \tag{1}$$

$\Delta_i = \left| \bar{b} - b_i \right|;$

bi – pixel i value;

$\bar{b} = \sum_{i=0}^{n-1} b_i \big/ n$ - average brightness value.

Next, the relative contribution of the deviation of the tested pixel to the value S is determined:

$$P_k = \frac{\Delta_k}{S} \tag{2}$$

k - number of the tested pixel.

It is obvious that $\sum_{i=0}^{n-1} p_i = 1$.

If in the image fragment under consideration there is a more or less uniform distribution of pixel brightness, then the value will not differ much from 1/n.

The brightness of a noise pixel differs significantly from the average brightness of the surrounding pixels.

The size Δk of such a pixel is larger than that of other pixels, which means the value will exceed 1/n. This is the criterion for a noise pixel.

If $P_k > \frac{1}{n}$, then pixel k is noise.

Once a noise pixel has been identified, you need to decide what to do with it. The following options are possible here:

- replace the noise pixel with the average value;

- replace the noise pixel with the average value calculated taking into account the values of all pixels except the noise one.

The improved automated control method uses a different solution to the problem of identifying a noise pixel, since it allows the most accurate detection of noise pixels.

It is necessary to replace the noise pixel with an average value calculated taking into account the values of all pixels that do not satisfy the noise selection criterion. This solution assumes that the fragment under consideration may contain more than one

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pixel that satisfies the "noise" criterion, and they should not be taken into account when calculating the new value.

The improved method software implementation

The choice of the Python language with the cv2 and numpy libraries to implement the program with the improved SUSAN method was due to several factors. Python has powerful and user-friendly image processing libraries such as OpenCV (cv2) and NumPy that provide high performance and ease of use. OpenCV provides a wide range of computer vision functions, including image filtering, while NumPy allows you to work effectively with large data sets. These libraries integrate with Python, making the code concise and understandable. In addition, an active developer community and extensive documentation make it easy to develop and maintain code, providing reliable and fast solutions to image processing problems. The software implementation of the improved method is presented below:

```
import cv2
import numpy as np
def susan_noise_reduction(image, threshold=27):
    # Getting the image dimensions
    rows, cols = image.shape
    # Create a copy of the image for processing
    processed_image = np.copy(image)
    # We go through all the pixels except the borders
    for i in range(1, rows - 1):
        for j in range(1, cols - 1):
            # We get a 3x3 matrix around the central pixel
            neighborhood = image[i-1:i+2, j-1:j+2]
            # We calculate the average brightness value of neighboring pixels
            mean_value = np.mean(neighborhood)
             # Calculate the deviation of the central pixel from the average value
            deviation = abs(image[i, j] - mean_value)
            # If the deviation exceeds the threshold, replace the pixel value
            if deviation > threshold:
                processed_image[i, j] = mean_value
    return processed_image
def main():
```

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```
    # Loading a grayscale image
    image = cv2.imread('input_image.jpg', cv2.IMREAD_GRAYSCALE)
    if image is None:
        print("Error loading image.")
        return
    # Using the SUSAN method to remove noise
    denoised_image = susan_noise_reduction(image)
    # Save the processed image
    cv2.imwrite('denoised_image.jpg', denoised_image)
    # Showing the original and processed image
    cv2.imshow('Original Image', image)
    cv2.imshow('Denoised Image', denoised_image)
    cv2.waitKey(0)
    cv2.destroyAllWindows()
if __name__ == "__main__":
    main()
```

The result of processing the original images of PCB boards using the improved SUSAN method is presented in Figure 1

a)

b)

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c)

d)

Figure 1: Result of processing source images of PCB boards

As you can see from Figure 1, the improved filtering method has suppressed the inscriptions on the board elements, which will make it possible to more accurately determine the contours of the electrical radio elements.

Conclusion

The study showed that SUSAN's advanced image filtering method significantly improves the accuracy and efficiency of printed circuit board (PCB) quality inspection. The proposed improvements made it possible to more effectively remove noise from images, which is critical for reliable defect detection. Experimental data confirmed that the modernized method provides higher quality of processed images compared to traditional approaches. The introduction of the improved SUSAN method into computer vision systems helps reduce defect rates and increase the productivity of production processes. Thus, the developed approach is important for the industry, especially in the context of the development of Industry 4.0, where automation and accuracy of quality control are key aspects of the competitiveness of enterprises.

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