Visual Inspection Method of Ceramic Bottle Surface Defects Based on Niblack Optimization

Li-yuan Li¹, Xue-wu ZHANG¹,*†, Wen-tao Li¹, Xiao-qi SHAO¹, Yan XIANG² and Jin-bao SHENG²

¹College of Internet of Things Engineering, Hohai University Changzhou, China
²Nanjing Hydraulic Research Institute, China
*Corresponding author

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Abstract. In order to improve the efficiency and accuracy of the defect detection of ceramic bottle production line, a method of visual inspection of ceramic bottle surface defects based on threshold segmentation Niblack optimization algorithm is been proposed. The CLAHE interpolation image enhancement algorithm is used to improve the image contrast, and then the local threshold is obtained by calculating the local mean and standard deviation in the domain window to realize the segmentation of the defective region. Then the minimum gray value difference is introduced and whether there are defects in images are determined to the center pixel gray value range. The characteristics of the defect target are extracted, and the defect classifier is used to classify the defects according to the principle of support vector machine. The experimental results show that the optimization algorithm can realize the effective segmentation of the defect area and reduce the false detection rate by reducing the influence of background noise on the segmentation results with an accuracy rate of 90.8%.

Introduction

In the firing process of ceramic products, the defects on the surface of ceramic bottle can lead to stress concentration easily and cause damage. At present, domestic and foreign researchers have made some progress in the detection of ceramic surface defects [1, 2, 3, 4]. Guo Meng et al. [1] combined Kirsch and Canny operator to achieve the edge detection of the defect. Li Qingli et al. [2] proposed a feature color extraction method based on gray relational analysis to realize the detection of ceramic defects. Yasantha C. Samarakkrama etc [3] compared the differences of the white pixels in the edge detection images and the filled image are calculated respectively in the blocks and the reference blocks. Atul N. Shire etc [4] turned the image into a black-and-white image first, and then used the second-order edge detection to connect the edge point of the image to detect defects.

In order to improve the development of automatic detection of surface defects of ceramic vials, this paper presents a Niblack binarization optimization algorithm based on machine vision and localized threshold segmentation to realize the effective segmentation of defective surface of ceramic. In this paper, the images of six kinds of defect, such as pits, cracks, scratches, spots, pinholes and bubbles are added and segmented, and the shape, grayscale and texture feature vectors are extracted as the input vector of support vector machine (SVM) to identify different types of defects.

System Structure

The detection system of ceramic bottle surface defect which is based on machine vision consists of mechanical device and image processing, as shown in Fig. 1. The mechanical device realizes the process of transmission, sorting and acquisition of the side image of the ceramic bottle. The image processing part completes the defect detection of the ceramic bottle surface. The system mechanism
includes a conveyor belt, a photoelectric switch, an entrance flap, a CMOS camera, a rotary table and a sorting device.

![System structure diagram](image)

**Figure 1. System structure.**

**Image Processing**

**CLAHE Interpolation Image Enhancement**

Since the defective portion information is less obvious due to the reflective of ceramic surface, image enhancement is performed before the defect detection is performed. The image is processed by the contrast-limited adaptive histogram equalization (CLAHE) interpolation algorithm proposed by Zuiderveld Karel. The experimental results are shown in Fig. 2. Fig. 2 (a) (b) (c) shows the original images of ceramic bottle with no defective surface, crack surface and pit surface. Fig. 2 (d) (e) (f) shows the images that have been processed by CLAHE interpolation image enhancement. It is showed in the experimental results that the defect feature is more obvious and with higher contrast after image enhancement, which is helpful for image segmentation and feature extraction.

![Enhancement images](image)

**Figure 2. The enhancement effect of ceramic bottle with no defective surface, crack surface and pit surface (a)(b)(c)original images; (d)(e)(f)CLAHE interpolation enhancement image.**

**Improved Algorithm of Niblack Image Segmentation**

The traditional Niblack binarization algorithm defines a neighborhood window first and then calculate the local threshold by moving the neighborhood window on the gray scale. The local threshold $T$ can be obtained by calculating the local mean $m$ and standard deviation $s$ of the neighborhood window. The local threshold is calculated as shown in Eq. 1 [5],

$$T = m + k \times s = m + k \times \sqrt{\frac{1}{NP} \sum (p_i - m)^2} = m + k \times \sqrt{\frac{\sum p_i^2}{NP} - m^2}. \quad (1)$$

In Eq. 1, NP is the total number of all pixels in the neighborhood window in the gray scale image and $m$ is the local mean and $s$ is the local standard deviation, and $k$ is the constant in the interval $[0, 1]$. The algorithm results can be adjusted by adjusting the $k$ value and the size of the neighborhood window. The point of the gray value is set to 255 and it belongs to the bright spot when the center
pixel gray value \( f(x, y) > T \). And the gray value is set to 0 and defined as a dark spot when the center pixel gray value \( f(x, y) \leq T \).

In order to avoid the effect of noise on image segmentation, the Niblack binarization algorithm is improved, and the concept of minimum gray scale difference Abs is introduced. In the neighborhood window with size \( M \times N \), it is assumed that \( f(x, y) \) is the gray value of the central pixel and \( m(x, y) \) and \( d(x, y) \) represent for the local mean and the standard deviation in the neighborhood window respectively, and \( \text{StdScale} \) is the standard deviation coefficients in the input \([0, 1]\). Then the variable \( V(x, y) \) can be defined by the Eq. 2,

\[
v(x, y) = \max(\text{StdScale} 	imes d(x, y), \text{Abs}) .
\]  

(2)

The standard deviation \( d(x, y) \) measures the noise in the figure and \( \text{StdScale} \) reflects the sensitivity of the algorithm to noise. So we can get Eq. 3 and Eq. 4 from Eq. 2 and the original Niblack binarization algorithm,

\[
f(x, y) > m(x, y) + v(x, y) .
\]  

(3)

\[
f(x, y) < m(x, y) - v(x, y) .
\]  

(4)

\[
m(x, y) - v(x, y) \leq f(x, y) \leq m(x, y) + v(x, y) .
\]  

(5)

We can get the conclusions that the center pixel which satisfying Eq. 3 or Eq. 4 is considered to be in the defect existence region. And the center pixel which satisfies the Eq. 3 is a bright spot and which satisfies the Eq. 4 is a dark spot. The center pixel which satisfying the Eq. 5 is considered to be in the smooth region.

**Defect Feature Extraction and Classification Recognition**

This paper extracts 22 characteristic descriptors of the image including 11 regional shape features [6], such as the area, circumference, rectangle, compactness and Hu moment combination \( \Phi_1 \sim \Phi_7 \), and 7 grayscale feature [7], such as the maximum, minimum, contrast, gray mean, gray variance, entropy and the nonhomporal coefficient of the image, and four texture features [8], such as the contrast, the angular second moment, the inverse moment [9], and the correlation.

SVM algorithm play an important role in solving small samples, non-linear and high-dimensional problems[10]. The 22 characteristic vectors are the input of the SVM, which outputs the results of the classification recognition.

**Experiment and Analysis**

According to multiple parameters set the experimental results, we set the size of the neighborhood window \( M \times N \) as 11\( \times \)11, the minimum gray value difference as 10, and the standard deviation coefficient \( \text{StdScale} \) as 0.2.

The Niblack improved algorithm proposed in this paper is compared with the maximum interclass variance method (Otsu), iterative optimal threshold method, Sobel edge detection and Roberts edge detection algorithm [11]. The experimental results are shown in Fig. 3. The Fig. 3 (a) is the original image of the crack picture. The Fig. 3 (b) to (f) are the processing results of the four algorithms respectively. It is showed that the images processed by Otsu algorithm and iterative method can show the cracks clearly, but will result in missing image information due to noise. The images processed by Sobel operator and Roberts operator do not be affected by the intermittent curve largely, but have uncontinuous edge and the weak edges are lost. The improved algorithm can distinguish the main area of the foreground and the background from the defect image, and it can not only segment the defect well but also suppress the influence of noise on the segmentation results.
The improved algorithm is used to segment the image with different types of defects. The experimental results are shown in Fig. 4. In Fig. 4, (a) to (d) are the original defect images of different defect types. (e) to (h) are images that are enhanced by CLAHE algorithm. (i) to (l) are the images that are processed by the image segmentation algorithm proposed by the paper. The experimental results show that the improved algorithm has a good effect in segmenting many different types of defects, and the defect features are obvious.

We use Halcon platform to complete the classification process. The experiment under 22 feature dimensions selected a total of 862 defect pictures, and 40% of the defective pictures are set as training samples, and all the pictures are set as test samples. The Niblack improvement algorithm, Otsu, the optimal threshold method, Sobel and Roberts algorithm are used to segment six kinds of defective images including scrambling, fractures, pits, spots, pinholes and bubbles. The defective images after segmented are the input of SVM for classification and recognition. The classification accuracy of different algorithms is shown in Fig. 5. It is showed in the experimental results that images processed by the Niblack improvement segmentation algorithm has higher accuracy of 90.8% than other algorithms in SVM with the definite selected defect feature and classification recognition algorithm. To some extent, it can satisfy the needs of industrial production and improve the quality of production.
Summary
Aiming at improving the efficiency and accuracy of the defect detection of ceramic bottle production, an automatic method for identifying and classifying the defects on the surface of ceramic bottles is proposed. This method improves the traditional Niblack binarization image segmentation algorithm, and combines the support vector machine classification to complete the identification and classification of the defects on the surface of ceramic bottles. The experimental results show that the proposed method can reduce the interference of background noise in the image effectively, the classification accuracy of SVM is 90.8%, which can meet the efficiency and accuracy of detection on the production line.

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Reference