A Rapid Inspection Method for Encapsulating Quality of PET Bottles Based on Machine Vision

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***Abstract*—It is necessary to inspect the encapsulating quality of PET bottles automatically in the high-speed production because the defects of PET bottles could directly bring food security problems. In this paper an integral inspection method of PET bottles encapsulating quality is designed based on machine vision. The defect inspection is realized on PET bottle caps with matching localization, edge extraction and contrast detection as well as other vision algorithms. Experiments proved that three kinds of defects can be detected with the proposed method in high-speed practical production lines with a speed of 67ms/frame, and the detection false alarm rate is below 0.35%.**

Keywords-Defect Detection; PET Bottle;Encapsulation quality; Machine Vision

I. INTRODUCTION

The quality of the beverage is influenced by the encapsulation quality of the PET (polyethylene terephthalate) bottle directly. Encapsulation quality, such as no cover, high cover, crooked cover, could bring about serious food safety problems, therefore it is necessary to detect these defects in the process of production and take out the unqualified bottles from production lines. Currently, the production speed is 36000 bottles per hour. That is to say, it is too fast for manual visual to inspect in such speed. On the contrary, the machine vision detection technology has the advantages of fast speed, high precision and stable detection. For above reasons, machine vision can be applied for the inspection of appearance of PET bottle encapsulation directly [1]. Figure 1 shows various defect images of PET bottle covers grabbed with Industrial Cameras and LED Illuminations.

There are some scholars who have carried out researches on the machine vision inspection technology. Leila Yazdi utilized restricted conditions to detect the encapsulation quality of caps and bodies [2]. The results proved that machine vision inspection is feasible and the detection speed is faster. Yehu Shen put up that scratches of caps can be detected by template matching. whose false alarm rate is below 1.5% [3]. HuiMin Ma notes that false alarm rate of glass bottles can reach 2% with 8 cameras through the proposed methods like image location, prepossessing and image recognition [4]. Xiuyuan He chooses position and screening methods which combines vision location with threshold segmentation to detect the defeats of bottleneck [5]. However, his algorithm lacks of stability, because the same defect taken from different angles cannot be figured out the exactly same results. Zhengxing Zou studies the flaw detecting method of caps based on SOPC technology [6], which applies the edge extraction after threshold segmentation and region extraction. To be concrete, it uses the comparison between the information extracted from edge and template images to distinguish good caps from bad caps. Yunfeng Zheng combined with cap contour detection algorithm and support ring detection algorithm, the method could categorize the defected cap [7]. However, in the course of the experiment, strong natural light had a greater impact on the experiment results. Therefore, the stability is still not enough.

In order to solve the above problems, a method based on matching localization detection is proposed to solve the problem of rapid detection of PET bottle encapsulation quality.

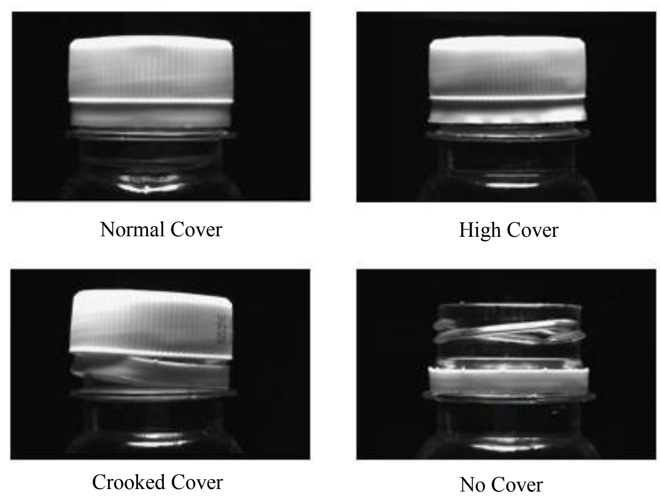

Figure 1. Defects of PET bottles

II. ALGORITHM IMPLEMENTATION

A. Overall idea of the Algorithms

Basic procedure of the algorithm is shown in Figure 2. First, the camera takes the bottle image and then locate the bottle. The presence or absence of the cap is detected by matching the region of interest (ROI)[8]. And then the edge of the ROI is extracted, and finally the high cover and crooked cover is detected. The detection algorithm is based on the Halcon library in Visual Studio 2010 development environment programming.

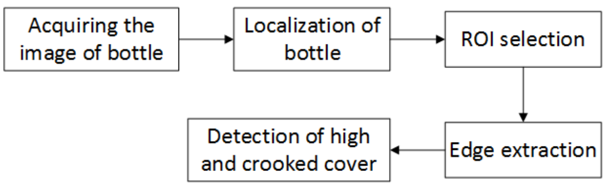

Figure 2. Flow Chart of Proposed Algorithm

B. Localization of Bottle

When the method is used detects the encapsulation quality of the bottle caps. The bottle is necessary to be located because each position of the bottle cap in the field of view is changed every time. After testing, the green rectangle is selected as the location area, as shown in Figure 3. The location area can be quickly matched to the corresponding position in the new image by normalized cross correlation match (NCC)[9]. The NCC formula is (1)

$$ncc(r,c)=\frac{1}{n}\sum_{(u,v)\in T}\frac{t(u,v)-m_t}{\sqrt{s_t^2}}\bullet\frac{f(r+u,c+v)-m_f(r,c)}{\sqrt{s_f^2(r,c)}} \quad (1)$$

where $ncc(r,c)$ is the normalized correlation number for position (r,c).The bigger the absolute value of $ncc(r,c)$ is, the more similar between template and images under testing. $t(u,v)$ denotes the gray value of position (u,v) in the template. m_t denotes the average gray value of template, s_t^2 denotes the variance of all image pixel values, $m_f(r,c)$ is the average gray value of images under testing, $s_f^2(r,c)$ is the variance of all gray values of images under testing;

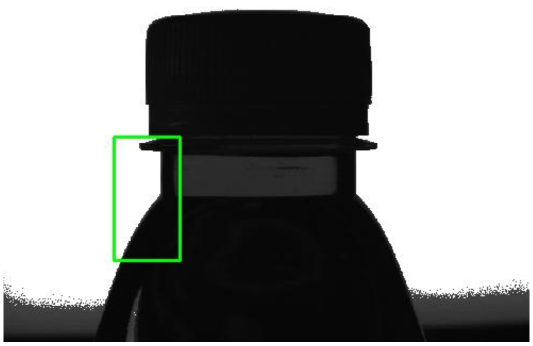

Figure 3. Selection of Positioned Area

C. ROI Selection

High cover and crooked cover are the main problems to be detected. Regions in rectangles in Figure 4 and Figure 5 are selected as detecting areas of high cover and crooked cover by observing images of defective caps. Based on the positioning area, the ROI area can be quickly found in the new image by matching.

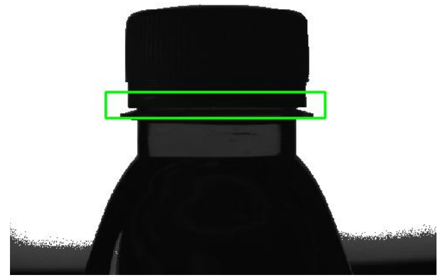

Figure 4. Detection of High Cover

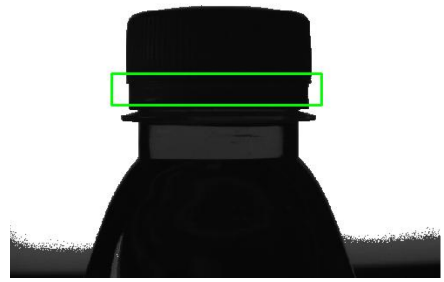

Figure 5. Detection of Crooked Cover

D. Edge Extraction

The Susan method which extracts the edge of the detection region is used by this algorithm. The information about position and direction of extracted edge and corner point are beneficial for subsequent processing. Calculation formula is as follows

$$c(\vec{r},\vec{r}_0)=\begin{cases}1 & if\ |I(\vec{r})-I(\vec{r}_0)|\le t\\ 0 & if\ |I(\vec{r})-I(\vec{r}_0)|>t\end{cases} \quad (2)$$

where $c(\vec{r},\vec{r}_0)$ denotes the discriminant function within the template that belongs to the USAN region [10] pixels. $I(\vec{r}_0), I(\vec{r})$ are corresponding gray values of images of central pixel and arbitrary pixel in template respectively. " t " is the threshold of gray level difference. If the difference value is less than or equal to threshold value t, it is regarded as USAN area. The formula is used to calculate USAN regional value is shown as follows

$$n(\vec{r}_0)=\sum_{\vec{r}}c(\vec{r},\vec{r}_0) \quad (3)$$

where $n(\vec{r}_0)$ is the value of USAN. Preliminary edge response can be acquired by threshold method after getting the value of USAN. Related formula is

$$R(\vec{r}_0)=\begin{cases}g-n(\vec{r}_0) & if\ \ n(\vec{r}_0)<g\\ 0 & otherwise\end{cases} \quad (4)$$

where g is fixed threshold, which affects the shape of detected corner point. The smaller g is, the more sharp corner point is.

E. Fast Detection of Caps encapsulation Quality

The major defects of bottles are high cover, crooked cover and no cover, which can be detected with the following methods.

1) Detection of bottles no cover

The region in rectangle in Figure 6 is selected as cap template. Setting the matched scores of NCC, which can detect the no cap situation in the new image quickly; The formula is

$$n = \begin{cases} 0 & if\ |ncc(r,c)| \le 0.8 \\ 1 & if\ |ncc(r,c)| > 0.8 \end{cases} \qquad (5)$$

where n denotes to bottles with cap or no cap; $ncc(r,c)$ denotes to the matched scores of NCC. If n equals 0, it has no cover.

Figure 6. Detection of No Cover

2) Detection of high cover

It is difficult to determine the high cover by calculating the distance between the cap and the localization region because there is a deviation in the matching process. And the support ring is fixed, this paper has taken the measurement of the distance between the cap and the support ring to determine whether the high cover is. As shown in figure 7, calculate the distance between the cover and the support ring. If the distance is more than 1.5mm, it is defined as a high cover.

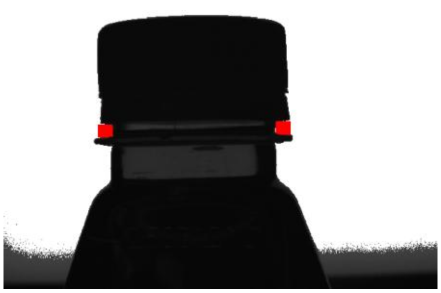

Figure 7. High Cover

3) Detection of crooked cover

Crooked cover is judged by detecting if the safety ring is deformed. Firstly, the position of the safety ring is acquired by matching localization, which is shown in the red rectangle region. Next, many parallel lines are averagely generated in rectangle with the help of measuring instruments. As shown in Figure 8, three red segments are parallel lines. The edge of the safety ring is extracted by the gray value on each line. Then, the variance of each line is calculated with

$$l_n^2 = \frac{\sum_{i=1}^{n}(l_i - \bar{l})^2}{n} \qquad (6)$$

where l_i denotes to the length of each segment; $\bar{l}$ is the given standard value; l_n^2 is the variance of difference between length. If $l_n^2 > 1$, it indicates that safety ring is deformed. In other words, the caps of bottles are crooked.

Figure 8. Crooked Cover

III. EXPERIMENT AND ANALYSIS

A. Procedures and Purposes of Experiment

The software interface design is shown in Figure 8. The PC computer is applied in this detecting system refers to industrial personal computer. Operating system is Win7 system. The system adopts Visual Studio 2010 development environment to implement the program with the combination of development of Halcon machine vision library. 2000 bottles were detected, which no cover, high cover, crooked cover and the normal cover of 500 bottles. The speed reaches 10 bottles/ second.

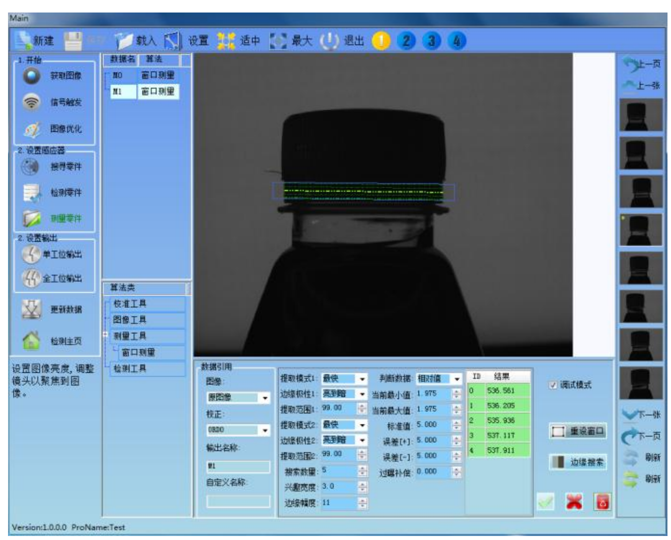

Figure 9. Software user Interface

B. *Experimental Statistics and Analysis*

Table I shows the experiment results of 2000 PET bottles with the inspection algorithm in this paper.

TABLE I. EXPERIMENTAL RESULTS OF PET BOTTLES ON THE BASIS OF DETECTION ALGORITHM

Types of Products	Number of Detection	Number of False Detection	Accuracy Rate	Comprehensive Accuracy Rate
Normal Cover	500	3	99.40%	
High Cover	500	2	99.60%	
Crooked Cover	500	2	99.60%	99.65%
No Cover	500	0	100.00%	

From the statistics in Table Ⅰ, it is can be analyzed that the accuracy rate of algorithm detection is higher. Besides, comprehensive accuracy rate is up to 99.65%. Thereinto, the accuracy rate of detection of bottles no cover reaches 100%, which meets the high-precision requirement of industrial production. Next, by comparing the methods of literature [6], literature [7] and the method presented in this paper, the following tests are carried out.

TABLE II. RESULTS OF COMPARISON TEST

	Detection Algorithms	Literature [6]	Literature [7]
Total of Detection	1000	1000	1000
Number of Missing Detection	1	5	2
Rate of Missing Detection(%)	0.10%	0.50%	0.20%
Number of False Alarm	3	12	6
Rate of False Alarm （%）	0.30%	1.20%	0.60%
Speed of Detection	67ms/frame	135ms/frame	100ms/frame

As shown in Table Ⅱ, both rates of missing and false alarm in proposed method are lower than the rates in literature [6] and literature [7]. And the speed of detection of proposed method is faster than others. The speed reaches 36000 bottles/hour in the actual production process. The algorithm detection of PET bottle caps encapsulation quality in this paper can meet the requirement of beverage manufacturer.

IV. CONCLUSION

The method of PET bottle encapsulation quality inspection in machine vision is studied in this paper. The detection of PET bottle encapsulation quality is achieved by matching localization, edge extraction and comparison test. The encapsulation quality of the bottle can be quickly and accurately detected by this method. However, the system still has the following problem: the shake of bottles would affect misjudgment rate. Therefore, Bayesian classification algorithm can be used to enhance the defect recognition rate in the future work.

REFERENCES

[1] B. W. Zhou. Vision-based intelligent inspection robot technology for health wine. Hunan University,2012.

[2] Yazdi, Leila, A. S. Prabuwono, and E. Golkar. "Feature extraction algorithm for fill level and cap inspection in bottling machine." International Conference on Pattern Analysis and Intelligent Robotics. IEEE, 2011:47-52.

[3] Y Shen, R Mo, et al. Bottle cap scratches detection with computer vision techniques. // Ninth International Conference on Natural Computation. IEEE, 2014:1314-1318.

[4] H. M. Ma, G.D. Su, JY. Wang, Z. Ni. A glass bottle defect detection system without touching. // International Conference on Machine Learning and Cybernetics, 2002. Proceedings. 2002:628-632 vol.2.

[5] X.Y. He. Research on online PET bottle defect detection based on machine vision technology. Guangdong University of Technology. 2015.

[6] Z. Zou ,Y. Xie , Q. Lin , B. Chen.. Design of PET bottle defect detection system based on SOPC. Modern Electronics Technique, 2009, 32(10):58-61.

[7] Y.F. Zhen. Design and Implementation of Vision-Based PET Bottle Packaging Quality Automatic Inspection System. Tsinghua University, 2011.

[8] Y.Yu, L.Zhang, J.F.Shi. A practical method for real-time ROI searching. Mechanical Design and Manufacturing Engineering, 2007, 36(3):72-76.

[9] B.J. Sun, D.H. Zhou. Fast matching algorithm based on NCC. Transducer and Microsystem Technologies, 2007, 26(9):104-106.

[10] G.Z. Ma, Z.L. Fang, Z Yao. Performance analysis and comparison of SUSAN edge detector. Modern electronic technology, 2007, (08): 189-191.