A GLASS BOTTLE DEFECT DETECTION SYSTEM WITHOUT TOUCHING

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Abstract:

This paper presents a new remote detection system for defect in upper portion of a glass bottle in production line. The system uses eight video cameras installed beside the production line to capture the images of the mouth, lip and neck of each bottle. Then, two computers collect and process these images to detection defects. The detection process includes two parts: one is to detect defects occurred in the mouth and lip of a glass bottle. This part uses the images captured from the top of a bottle. The other is for the defects occurred in the neck and shoulder of a bottle, by processing the images shot on the upper-side of the bottle. The processing includes image orientation, preprocessing, and image recognizing. The system sends a control signal to manufacture's mainframe once it recognizes a defect bottle, and can eject the defect bottle off the production line. The adequate test result is given to show the recognition rate system for all occurred in the upper part of a glass bottle.

Keywords:

Glass bottle; Bottle mouth defect; Bottleneck crack; Remote detection; Defect recognition

1 Introduction

Glass bottles may appear cracks, defects, gas bubbles in the manufacturing production. Online glass bottle defect detection is important for the quality of the glass bottle manufacturing production. The detection must be able to detect the defects, determine automatically if the defects in a bottle affect its appearance and using, then kick the defective ones off the production line.

The quality detection of glass bottle was performed manually. In practical, the detection is a tiring and tedious work. The effectiveness of the detection subjects is greatly affected by environment and the worker's emotion. The result of detection was not stable and reliable. The study of automation glass bottle detection catches the word's attention. Most of current systems adopt photoelectric detecting technology with touching and rolling. Such system is complicated, and the mechanical weariness is serious.

It's a developing tendency from touching and rolling detection to no touching and no rolling detection, it can decrease the affects of detection to glass bottles. Recently, some glass bottle defect detection systems without touching developed in German and France is introduced to market. These products use digital camera and aided orientation. To use them, the existing production lines must be rebuilt. This is expensive and discommodious.

We have developed a low cost but effective glass bottle upper portion defect detection system without touching and rolling. The system based on the video camera has no impact to existing production lines. The highest detecting speed can be up to 200 bottles per minutes.

2 System structure

Defects mainly lie on the upper part of a bottle, where the shape of glass is the most complicated in a bottle. The goal of our system is to detect the defects occurred in mouth and lip, and the cracks in neck.

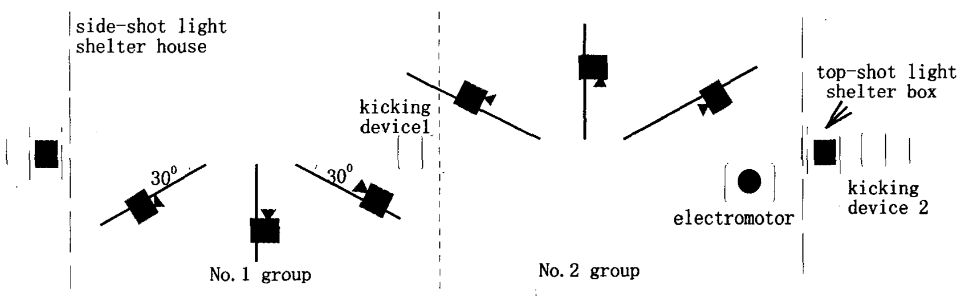


Fig.1. System assembled chart

The system shown in Fig.1 is composed of two top-shot video cameras, six side-shot video cameras in the light shelter house, two bottle-kicking devices, and a rotary electromotor

When glass bottles on the production line is passing six side-shot cameras without rolling in the light shelter house, the detection system executes detecting of bottleneck, and there is no any touch among bottles and devices.

Six side-shot video cameras are divided into two groups, which fixed on both sides of the production line in the light shelter house, each camera is apart with 60°, six cameras cover 360° around the bottleneck, and can get higher quality images of the whole bottleneck.

Two top-shot cameras are installed respectively over the starting and the end point of the detecting zone. The camera over the start belongs to the No.1 group, and the camera upon the end belongs to the No.2 group. Bottles turn 90° controlled by a motor between the start and end of the detecting production line, so the difference of image got by the two top-shot cameras is 90°. This action can eliminate the light noise affects to the top surface of bottles, what generate from the production line and the leak of the lighter shelter house.

Two computers gather the images captured by two groups of cameras respectively, then they execute image processing, analyzing, recognizing, communicating, and giving an integrated judgment in the end, they will sent a control signal to the bottle-kicking device to kick off the bad bottle from the production line if the bottle was judged as a bad bottle with defect.

System software includes three modules: system initialization module, image detection module, data fusion module shown in Fig.2.

(1) System initialization module includes demarcating video cameras, setting production line parameters and recognition parameters, and so on.

(2) Image detection module includes side-shot image recognition and top-shot image recognition. The recognition algorithm includes three parts: image orientation, defect extraction and defect recognition.

(3) Server data fusion module integrates the recognition result of two computers and shows the detection result.

This paper mainly presents the principle and algorithm of the image detection module. It is divided into two parts as side-shot image recognition and top-shot image recognition to be presented.

3 Side-shot image recognition

Video cameras are fixed upon the two sides of the production line, and shot down with 30°, the image is shown in Fig.3, we need to detect bottleneck cracks in these image, please note that crack appearing in the upper portion of bottle almost are neck crack and lip crack.

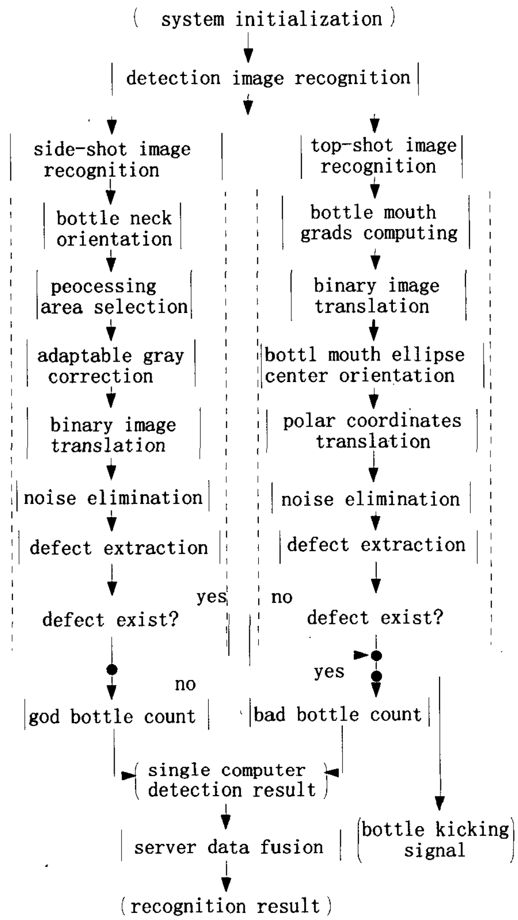
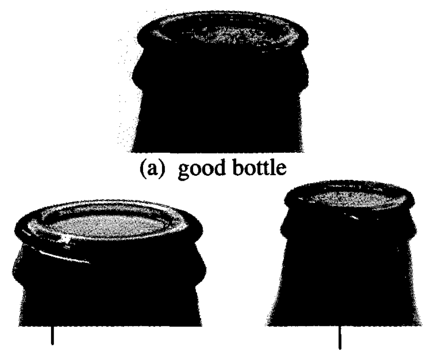


Fig.2. Detection system flow chart



(a) good bottle

(b) neck crack (c) lip crack

Fig. 3. Side-shot images

The glass bottleneck images captured from the running production-line have several features as follow: (1) The distinctness of images is not enough, and the defect is not distinct. (2) The light reflecting and refraction of glass will make complicated noise, and the noise can't be predicted. (3) There are many kinds of defects with different shape, size, etc. (4) Shape of bottleneck is changed in a little range, and so standard image doesn't exist.

We can draw a conclusion from the upper analysis that there are some disadvantageous factors for detection in the image, and strong real-time request of system asks the algorithm has very high performance.

Processing area must be selected before detection to assure real time, at the first we make a projection to horizontal direction, the top of the bottleneck can be obtained easily by binary image translation, at the second we make another projection to vertical direction, the left side and right side of the bottleneck can be obtained by translating the image into binary image, then we reduce the range from bottleneck left side to right side at a given ratio, so does the rang from top to bottom, the rectangle processing area can be determined.

3.1 Adaptive gray correction

Bottleneck image is affected by the light and reflection during shot, so the gray aberrance is inevitable, and the shade noise is uncertain. In this state, gray correction is necessary to pop out defect and reduce the affection of shade noise.

We suppose the width of neighborhood is $\pm$c and height is $\pm$r, the around of defect in the image is shielded adaptively by comparing gray values in the neighborhood. Pixels are judged as possible defect if they are higher than the average gray value $G_a(x, y)$ of the neighborhood, and need to be substituted by the minimum value $G_{\min}$ of the neighborhood. Pixels lower than the average gray value will keep their gray value, then the corrected image $G_0(x, y)$ can be got as beneath:

$$Ga(x,y) = \frac{1}{(2r-1)(2c-1)} \sum_{m=y-r}^{y+r} \sum_{n=x-c}^{x+c} G(m,n) \quad (1)$$

$$G_0(x,y) = \begin{cases} G(x,y) & G(x,y) < G_a(x,y) \\ G_{\min} & G(x,y) \ge G_a(x,y) \end{cases} \quad (2)$$

After original image subtracting the corrected image, we can get the image $G_w(x, y)$ in which defects are enhanced.

$$G_w(x,y) = G(x,y) - G_0(x,y) \quad (3)$$

3.2 Part translation to binary image

The enhanced image $G_w(x, y)$ is translated to binary image partly. Image quality of middle part is better, the lower threshold is adopted to detect defect, because there are little gray changes in this part.

There are stronger noises in the shade part on left side and right side of bottleneck, they have serious affection to defect detection, higher threshold should be adopted to detect the defects with obvious gray changes in these parts, then affection of noise can be shielded and the wrong detecting rate of good bottles can be reduced.

3.3 Defect detection

Defects are complicate and uncertain. According to appearing areas, cracks in upper portion of glass bottle can be separated to lip crack, neck crack, shoulder crack, etc. According to the shape, cracks also can be separated to transversal crack, inclined crack, vertical crack, large crack, etc.

The main feature of crack is line feature. The method of defect detection is continuous area detection, it scans in the binary image line by line, gray values of pixels in one continue area are set as 128 except black background in processing area. Pixels with 128 gray-value in one continue area may be defect or noise, so we count the number of them and judge according these conditions:

(1) Set judging parameters: width of bottle, top, bottom, left and right of processing rectangle area.

(2) pixels$\geq$k$\times$width; k<1

(3) LineNumber $_{\text{bottom-top+1}} \geq 4$;

(4) RowNumber $_{\text{right-left+1}} \geq 2$。

To distinguish defect and noise, we need to do more judgment using the position and defect style, such as coherence and continuity of inclined crack [4].

The processing result is shown in Fig.4, the left one shows original image, the right one shows the processing rectangle area and the white line style horizontal crack on the neck of bottle. The crack is obviously appeared and correctly recognized.

Fig.4. neck crack and processed image

In defect detecting, mould seam likely generates error detection, we still need to distinguish the mould seam from the defects the more time [5]. The mould seam is long in vertical direction, its width is narrow, and there are only one mould seam in the processing area shown in Fig.5. The pixels only satisfied with these features will be judge as true defect.

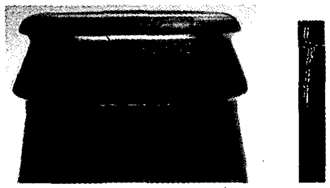


Fig.5 mould seam and the detection result

The approach includes four steps: first doing gray correction, next translating corrected image to binary image with lower threshold, then doing the horizontal direction filtering, finally judging if there is long and regular vertical line [6], it's mould seam if the result is true.

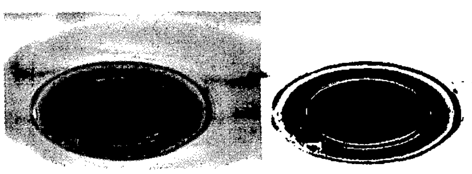
4 Top-shot image recognition

Two top-shot video cameras are fixed right upon the production line, the bottle mouth surface images are single-field images for the real-time request [7], so the shape of bottle mouth in the single-field image is ellipse shown in Fig.6 and difficult to recognizing. Top-shot image recognition include orientating, polar coordinates translating, surface defect detecting.

4.1 Center orientation

At first, the left boundary and right boundary of bottle mouth in the top-shot image are determined by horizontal direction gray histogram, and the up boundary and down boundary are determined by the vertical direction gray histogram.

Second, Roberts template is used to get the grads image, then the grads image is translated to binary image shown in Fig.6 (2).



(1) original image (2) binary image

Fig.6. Top-shot bottle mouth image

In the end, we orientate the center position by the maximal probability principle.

(1) To the binary image, line scan from up to down, there is a left point $x_{\min}$ and a right point $x_{\max}$ in a line, they can determine a midpoint x_{center} between $x_{\min}$ and $x_{\max}$. After scanning whole image we can get a set of $x_{centeri}$, they compose a track of centers x-coordinate, i is the line number.

$$x_{centeri} = x_{\min i} + (x_{\max i} - x_{\min i})/2 \qquad (4)$$

(2) To the binary image, row scans from left to right, so there is a left point $y_{\min}$ and a right point $y_{\max}$ in a row, they can determine a midpoint y_{center} between $y_{\min}$ and $y_{\max}$. After scanning whole image we can get a set of $y_{centerj}$, they compose a track of centers y-coordinate, j is the row number.

$$y_{centerj} = y_{\min j} + (y_{\max j} - y_{\min j})/2 \qquad (5)$$

(3) To count the times of all $x_{centeri}$ and $y_{centeri}$ appeared, we can get the maximal probably center point coordinates (x_{center}, y_{center}) , it is the center point of bottle mouth.

4.2 Polar coordinates translation

The recognition of bottle mouth surface defect may take as the ellipticity check of bottle mouth image. The ellipses have different distortion when there exist defects on the bottle mouth surface, the good bottle mouth's standard ellipse is turned to horizontal line in polar coordinates, and defect is turned to anomalous curve.

We translate the mouth image in polar coordinates, In Eq.6, a is the long axis of ellipse, and b is the short axis of ellipse, the points on the ellipse are

$$\begin{cases} x = a\sin\theta \\ y = b\cos\theta \end{cases} \qquad (6)$$

Fig.7 is the bottle mouth image in polar coordinates corresponding Fig.6 (2), the white points are the light edge points.

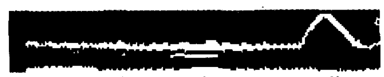


Fig.7. Mouth image in polar coordinates

The difficult arc recognition is turned to simple line recognition in polar coordinates, the defect recognition become easy.

4.3 Defect detection

Bottle mouth surface defect detection includes two steps: eliminating normal horizontal line and recognizing the defects.

(1) Horizontal line elimination: a horizontal template line with image width long and three pixels width is used to scan the polar coordinates image from up to down, $N_{whitepoints}$ is the white points number on the template line, if

$$N_{whitepoints} > \frac{1}{10} width_{image} \qquad (7)$$

These white points are taken as on the normal horizontal line, so they are substitute by the black points shown in

Fig.8, the normal horizontal lines in the image is eliminated clearly, and only the defects are reserved.

Fig.8. Mouth image after line elimination

(2) Defect recognition: a rectangle with 40×40 pixels is used to scan the whole bottle mouth image after line elimination line by line from left bottom corner to right top corner. We think defect existing if the number of white points exceeds 40; the recognizing result is shown in Fig.9.

Fig.9. Mouth defect recognizing result

5 Detection result and analysis

The glass bottle upper portion defect detection system was installed in a production line, eight video cameras and two computers worked together, we have got a high online detecting speed of 200 bottles per minutes, and the detection results are shown in Tab. 1

Table 1. Detection results

Bottle type	**bottle samples**	*1) R eco g-* **nized**	**misdetection rate**
Neck transver -sal crack	62	61	1.6%
Neck inclined crack	20	19	5%
Mouth surface defect	20	20	0%
Bad bottle	**102**	**100**	**1.96%**
Good bottle	**100**	**98**	**2 %**

The defects were grouped to neck latitude crack, neck inclined crack, and mouth/lip surface defect. Misdetection includes over-detection, meaning recognize a good bottle as defect; and under-detection, meaning fail to recognize a defect bottle. As shown in Table 1, during our test run, over-detection rate is 2%. Under-detection rate is 1.96%.

Adjusting detection thresholds can reduce either over-detection or under-detection rate. The two rates are contradictory. The more critical threshold is set, the less under-detection but more over-detection will occur, and vice versa.

The results show that this detection system has better integrated detection performance to cracks on the bottle's neck and bottle mouth's surface defects, It is fit for the current bottle making production lines.

References

[1] Newsletter. Quality control and inspection. http://www.ttnt.de/download/qci3.pdf, 2000.

[2] J. Mulliner, G. Folkins. Making measurements with vision. http://www.eetasia.com/articles, National Instruments, 2002.

[3] C. Firmin, D. Hamad, J.G. Postaire. Fault detection by a Gaussian neural network with rejects options in glass bottle production. SPIE Proceedings Vol. 2785, pp.152-162, 1996.

[4] D. Behar, J. Cheung, Ludwik Kurz. Contrast Techniques for Line Detection in a Correlated Noise Environment. IEEE Transactions on Image Processing, T-IP (6), pp. 625-641. 1997.

[5] Y. Li, T. W. Liao, Weld defect detection based on gaussian curve. Proceedings of the 28th Southeastern Symposium on System Theory (SSST '96), 1996.

[6] V. Kamat-Sadekar, S. Ganesan. Complete description of multiple line segments using the Hough transform. Image and Vision Computing, vol. 12: pp.597-613, 1998.

[7] COGNEX. Machine vision sensors. Summer 2002. http://www.cognex.com/pdf/insight, 2002.