A fast and robust visual detection method for glass bottle body with binary template matching

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Abstract: As multiple glass bottle bodies appear in the same one image from a view, the high precision and speed localization of the bottle body is difficult for the traditional visual detection methods. To overcome the problem, the imaging system is first briefly presented. And a new visual detection framework, named BTMfast, for glass bottle body with binary template matching is proposed. First, the input image is down-sampled to reduce the computational complexity. The subimages containing body region are obtained according to the position priors. Then, the neck or body of a bottle is taken as the template, then the template image and each sumimage is segmented with OTSU segmentation algorithm. Thirdly, the central line of the body in the original image can be obtained by the binary template matching. Finally, the top boundary of the bottle mouth is enhanced by a filtering operation with a new kernel. And the mouth position is obtained by segmenting the filtered image and column scanning. We create two datasets for evaluating the performance of our method. Compared with many approaches on the two datasets, our method can achieve the optimal result. The localization error is about 1.5, the consumed time is about 4.3 ms.

Key Words: Visual detection, template matching, localization, glass bottle body

1 Introduction

Glass bottles are widely used as packaging containers for beverages and foods, especially in the beer packaging industry [1]. The body of the glass bottle may be broken, contaminated in the transportation and production process. The use of glass bottles with defects on bottle body may endanger consumers'lives health, and damage the image of enterprises. Hence, the quality of the bottle body must be strictly checked before using. In the process of quality inspection of the glass bottle based on machine vision, it is a necessary process to locate body area. Because the position of the bottle body is not fixed [2, 10, 11] in images due to the transmission mechanism vibration and the high-speed motion of the glass bottle. To date, many research literatures about the bottle body localization have been reported. Duan et al. (neck edge histogram filtering, NEHF) [2] first obtains the coordinates of the left and right edge points of the bottleneck by progressive scan. Only an edge point pair is obtained for each line, where the edges of the left and right region are obtained using different filtering kernels. Then, the average value of the abscissa of each edge pair is calculated. Finally, the central line of the bottle body is obtained by the histogram of the average values. Zheng et al (gray projection pole, GPP) [11] obtained the grayscale projection gradient curve of the whole bottle in the vertical direction. The extreme values most closed to the left and right endpoint are respectively considered as the left and right boundaries of the bottle body. The method is simple and fast in execution, but when multiple bodies appear in the image, the position of the bottle body cannot be detected accurately. To overcome the problem, and further speed-up, Huang et al. (neck edge barycenter, NEB) [10] took the barycenter in horizontal direction of bottleneck edge points as the central of the bottle body. Ma et al. (neck edge histogram, NEH) [3] combined the edge points with histogram to guarantee positioning accuracy. The last two methods, only the bottleneck region is used for localization. So they have high speed and robust to overlapping interference of the bottle body. But, they are also susceptible to interference of the defect area, and multiple bottle areas, as shown in Fig .1. As a traditional object detection method, template matching is widely used in various fields, such as: texture detection for glass bottle bottom [1], tacked Substrates Counting [4], Face detection [6], Pulmonary Nodules in Helical CT Image [5], Optic Disc Detection in ophthalmic image [8]. We proposes a bottle positioning method, called BTMfast[1], using binary template matching to achieve fast and accurate positioning of the bottle body. There are three contribution in this paper: .

(1) A localization method for glass bottle body with binary matching template is proposed, and the positioning error is smaller than those of conventional methods.

(2) Accelerate the proposed method by downsampling, which greatly reduces computational complexity and simultaneously ensures the positioning accuracy.

(3) A new filtering kernel is used to outstand the top boundary region of the bottle mouth to obtain the bottle mouth position.

The rest of the paper is structured as follows: The second Section briefly introduces the imaging system designed by us and analyzes the properties of the acquired images. The details of the proposed method is given in third Section. The fourth Section shows the experimental results, and the last Section gives a conclusion.

2 System architecture and image property

The imaging system is mainly composed of a planar light source (1), reflectors (2), (3) (4) (6) (7) and a camera (5), and so on. To acquire the body region as many as possible, where

This work was supported in part by the National Science Foundation of China under Grant 61733004 and Grant 61573134, in part by the Hunan Key Project of Research and Development Plan under Grant 2017XK2102, Grant 2018GK2022, and Grant 2018JJ3079,

[1]The codes of our method and experimental data are available: http://www.escience.cn/people/zhouxianen/index.html or https://github.com/zhouxianen/BTMfast

Fig. 1: Many bodies appear in the bottle body subimage from the same view. The left and right regions respectively marked by the blue dotted lines and red solid lines are two body subimages from two different perspectives of observation.

the tested bottle (8) is on conveyor belt (9), we designed an imaging system consisting of five mirrors, the structures and real photograph are shown in Fig. 2 (a), (b) and (c). The two different view body subimages are collected to the same mirror (4) by two symmetric reflected light paths: (1)− >(2)− >(3)− >(4) and (1)− >(6)− >(7)− >(4). Finally, the image of the bottle is aquired by the plane array camera (5) facing the mirror (4), as shown in Fig. 1 (d), which is a gray scale with a resolution of 1296×966. The grayscales of the body region are obviously lower those background because those light rays directed at the bottle body are reflected and refracted. Moreover, to avoid interference from natural light and lighting light. The camera is closed in a box (10) with black inner surface, as shown in Fig. 2 (c).

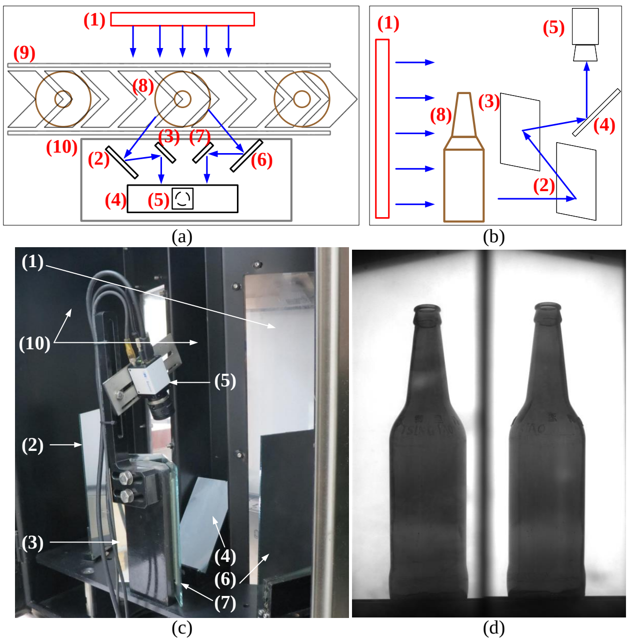

Fig. 2: Imaging system and the acquired image of the bottle body. (a), (b) and (c) are the top view, side view and the real photograph of the imaging system, respectively. (d) the acquired image of the glass bottle body.

3 The proposed method

To localization the bottle body in high-speed and high-precision, we take the neck or body region of a bottle as the template, propose a new localization method called (fast binary template matching, BNTMfast) based binary template matching for glass bottle body. To distinguish the different templates according to the name of the called names, the neck and body templates methods are named fast neck binary template matching (BNTMfast) and fast body binary template matching (BBTMfast), respectively. The proposed method consists of three parts: 1) downsampling and segmentation, 2) binary template matching, and 3) obtaining the mouth position. The flowchart of BNTMfast is given in Fig. 3. For BBTMfast, all procedures except that the input template is a entire body image are same with BNTMfast.

3.1 Downsampling and segmentation

The speed of the glass bottle packaging production line is generally 48,000-72,000 bottles per hour, i.e., the consumed time for each bottle is less than 72 milliseconds (ms). In other words, the visual inspection applications of glass bottles are strict with the real-time requirement. While the original scale input image and template are directly used for matching. The calculation of the algorithm is too large to meet the requirements of high-speed detection in practical application. Hence, we down-sample the input image to get the low-resolution image. Assuming that the original image scale is Ssrc and the zoom scale is r, where 0≤ r ≤ 1, and the image scale after the down-sampling is $S_{down} = r * S_{src}$. Second, the subimages of body in the resized image are abstracted according to position priors, as shown if Fig. 2 (c1) and (c2). It is obvious that only the black body area and high grayscales background regions are preserved. Finally, the two subimages and template image are separately segmented by threshold segmentation. Considering the obvious contrast between background and bottle area in bottle image, the OTSU adaptive threshold segmentation algorithm [7] can meet the requirements of this method.

3.2 Binary template matching

Template matching is a technique for finding the most similar part of an image with a given template. Template matching algorithms are usually used for gray images. Considering the thickness of different bottle bodies may be different due to the limits of manufacturing process. The locate results may be not good, if we use the same one template. It is encouraging to note that only the structure information of bottle body and template is useful for bottle locate application. Therefore, we employ binary template matching to locate bottle body. Many similarity measures, such as Rogers and Tanmoto, Dice, Yule, Correlation and so on, can be selected for binary matching [9]. Correlation is used in this paper. Assuming that the body subimage and template image are denoted by $I_{sub}(x, y)$ and $T(i, j)$. The correlation coefficient map $I_{ccp}(x, y)$ is calculated by formula (1). Here, $\overline{I}sub(x, y)$ and $\overline{T}$ respectively represent the ratio of the number of non-zero pixels in the current processing area of the subimage to the product of the length and width of the template, and the ratio of the number of non-zero pixels in the template to the product of the length and width of the

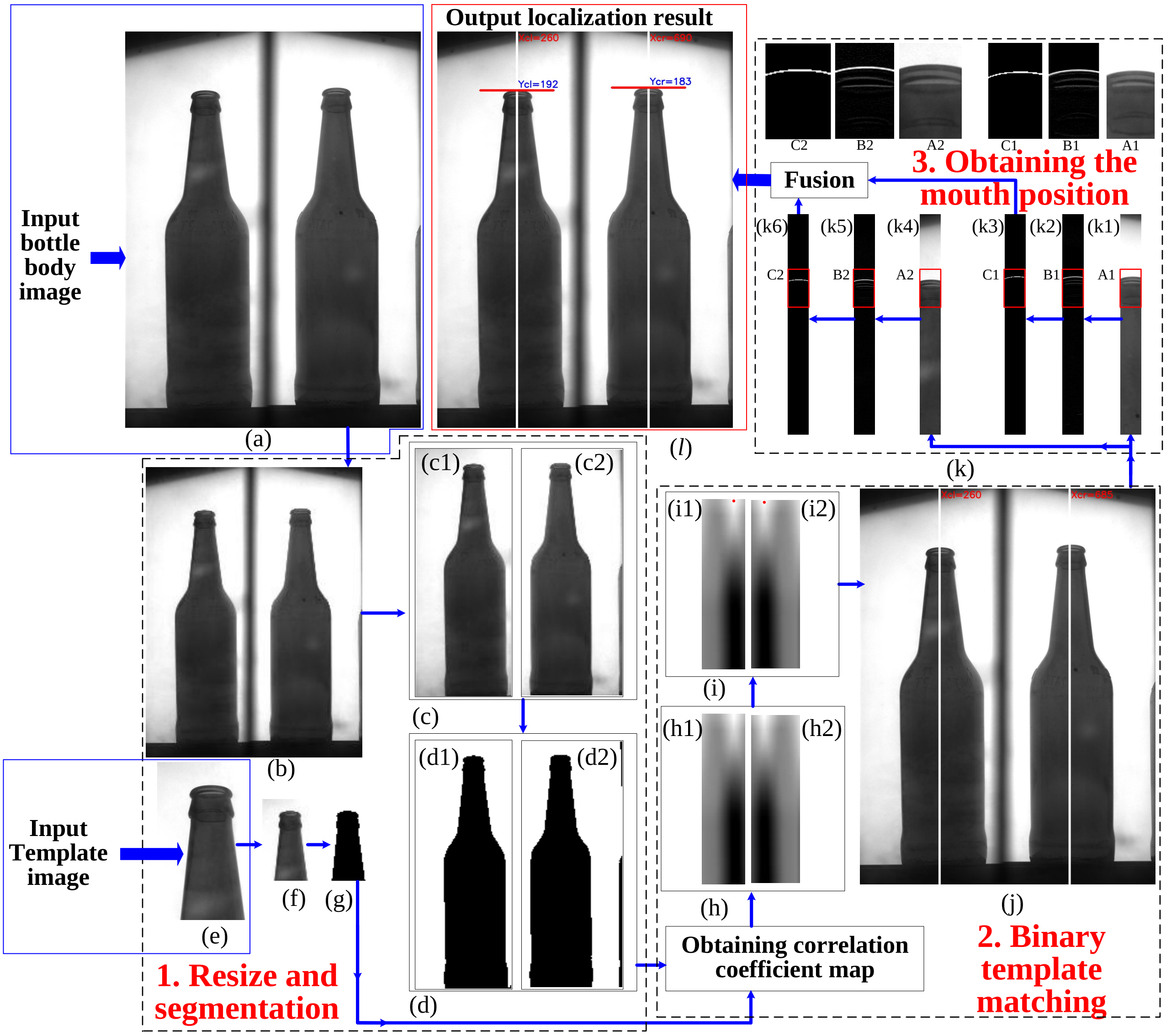

Fig. 3: The flowchart of our proposed localization method. (a) The input image of the glass bottle body. (b) The low resolution image of the input tested bottle. (c) The subimages of the left and right region in the resized image. (d) The segmentation result of the subimages of the resized iamge. (e) The input template image of the neck region from a glass bottle. (f) The low resolution image of the template image. (g) The segmentation result of the template image. (h) The correlation coefficient map for measuring the similarity between the template and resized image. (i) The maximal values in the correlation maps. The optimal matching positions are marked by red circle points. (j) The central line of bottle body. (k) The pipeline of obtaining the bottle mouth position. The six images on the texts "A1","B1","C1", "A2","B2" and "C2" are respectively the enlarged figures of red rectangle regions named A1, B1, C1, A2, B2 and C2. (l) The final localization of our proposed method.

$$I_{ccm}(x,y) = \frac{\sum_{i=1}^{T_h}\sum_{j=1}^{T_w}(I_{sub}(i+x,j+y)-\overline{I}_{sub}(x,y))(T(i,j)-\overline{T})}{\sqrt{\sum_{i=1}^{T_h}\sum_{j=1}^{T_w}(I_{sub}(i+x,j+y)-\overline{I}_{sub}(x,y))^2\sum_{i=1}^{T_h}\sum_{j=1}^{T_w}(T(i,j)-\overline{T})^2}} \tag{1}$$

template, the corresponding defines are

$$\overline{T} = \frac{1}{T_h T_w}\sum_{i=1}^{T_h}\sum_{j=1}^{T_w}T(i,j) \tag{2}$$

$$\overline{I}_{sub}(x,y) = \frac{1}{T_h T_w}\sum_{i=1}^{T_h}\sum_{j=1}^{T_w}I_{sub}(x+i,y+j) \tag{3}$$

For the two subimages of the bottle body, as shown in Fig. 3 (c1) and (c2), the correlation coefficient maps are computed according to the formula (1), as shown in 3 (h1) and (h2), respectively. The more similar the area in the subimage to the template, the greater the gray value the corresponding region in the correlation coefficient map. Hence, the central line x_{cl_res} in the resized image can be obtained by peak detection. And the central line in the original input image is prone to be computed by $x_{cl\_src} = x_{cl\_res}/r$ because r is known, as shown the white lines in 3 (j).

3.3 Obtaining the bottle mouth position

Traditional bottle positioning methods usually only acquire the bottle center line of bottle body. This paper simultaneously realizes the position acquisition of the central line of the bottle body and the top boundary of the bottle mouth. Firstly, the rectangular sub-images, $I_{rec}(x, y)$, containing the central regions of the bottle mouth are obtained. The gradient map of the image is calculated by formula (4).

The gray values of the top boundary of the bottle mouth are obvious saliency compared with other regions, as shown the regions B1 and B2 in Fig. 2 (k2) and (k5). The global threshold segmentation method are used to segment the sumimages. Considering that there is no other boundary between the first line and the boundary area of the bottle body in the segmented binary image, the Y coordinates of the edge points are obtained by scanning the segmented image column by column from top to bottom. The minimum value of the obtained Y coordinates is taken as the upper boundary Y_b of the bottle mouth. Finally, the detection results of the center of gravity of the bottle body and the boundary of the bottle mouth are obtained, as shown in Figure (l).

4 Experiment

To evaluate the performance of our method, we create two datasets. The first dataset contains 15 bottle body images, where majority of these images are standard. The second dataset includes 25 images, and many multiple bottle body appear in the same view subimage are common, as shown in Fig. 1. For the two datasets, the central line of the bottle body X_m and the upper boundary of the bottle mouth Y_m are manually calibrated. The consumed time T_{cs} (ms) and positioning errors of are taken as the quantitative evaluation, where the latter is defined as

$$E_x = |x_{cl} - X_m| \tag{5}$$

Where the execution time refers to the time consumed between the acquisition of the bottle image and the final output of the positioning result. All the test experiments in this section are carried out on a computer equipped with an Intel(R) Core(TM) i5-4210U (1.7-2.4 GHz) and 6 GB of memory.

In the following, tests are conducted on our two datasets. First, to verify the advantages and disadvantages of our method and traditional bottle body positioning methods, compared with four traditional methods, including NEHF [3], GPP [2], NEH [4] and NEB [1]. Then, to verify the advantages and disadvantages of those methods with the template matching method based on gray value and the template matching methods without downsampling acceleration processing, and to evaluate the advantages and disadvantages of template matching using bottleneck and whole bottle body as templates, we compare BNTMfast and BBTMfast with some similar combinations. All these template-matching-based methods are named as gray bottleneck template matching (GBTM), gray bottleneck template matching method (GNTM), binary bottleneck template matching (BBTM), binary bottleneck template matching (BNTM). The scaling scale r = 0.2. The results of localization error and some visual results of the template-matching-based methods are shown in Table 1 and Fig. 4, respectively.

Table 1: The comparison of the positioning error. All methods based on template matching are implemented using C++. Others are programed by MATLAB. The optimal results are marked by the bold fonts.

	Dataset1		Datasets2	
Method	E_x	T_{cs}(ms)	E_x	T_{cs}(ms)
BNTMfast	**1.5**	4.3	**1.7**	3.4
BBTMfast	**1.5**	**4.0**	**1.7**	**3.3**
BBTM	3.5	99.9	3.3	101.0
BNTM	2.5	88.1	2.4	92.4
GBTM	123.8	98.5	61.0	86.0
GNTM	42.9	95.3	32.6	124.4
NEHF[3]	4.0	220.8	13.0	115.1
GPP [2]	7.3	30.2	30.6	15.4
NEH [4]	8.0	162.0	50.9	124.9
NEB [1]	11.4	14.8	42.6	8.8

It is obvious that our methods BNTMfast and BBTMfast achieve the optimal results compared with any other methods. For the fast template matching methods BNTMfast and BBTMfast, Whether using bottle body or bottleneck as template, the positioning accuracy and execution time are almost the same, which obviously superior to other methods. Compared with BBTM and BNTM, the execution time of our method BNTMfast has been improved by nearly 25 times, and the positioning accuracy has also been improved to a certain extent. Because the shape and structure information of template image and matched image is the most useful for the bottle body locate application. In this paper, we use binary template matching, while for downsampling binary image, the reduction of resolution has almost no effect on the contour structure characteristics of the bottle body subimage and template image. The template matching methods GBTM, GNTM in gray image is ineffective and unsuitable for bottle body locate application. The robustnesses of other traditional methods are not good, as multiple bottle body appear in the same view subimage, the positioning error would increase particularly obvious.

5 Conclusion

The imaging system for glass bottle body inspection has been briefly introduced in this paper. And a new fast and robust visual detection algorithm using binary template matching has been presented in detail. In our method, the neck or body region of the glass bottle is taken as the template. The binary image of the dowmsampling body image is taken as the input of template matching. Two datasets including 40 images captured by our designed vision system are created to evaluating the performance. Many localization methods are compared with our method. experimental results demonstrate that our method can achieve the best performance than the comparison approaches. The speed of our method is increased by more than 20 times compared with those of the corresponding methods without speed-up strategy. The localization error is about 1.5, the consumed time is about 4.3 ms. The proposed method can meet the requirements of high-speed and high-precision inspection in glass bottle packaging production line. Moreover, it can be applied to the detection and location of other rigid objects.

$$I_{gra}(x,y) = 3I_{res}(x,y) - I_{res}(x-1,y+1) - I_{res}(x,y+1) - I_{res}(x+1,y+1) \tag{4}$$

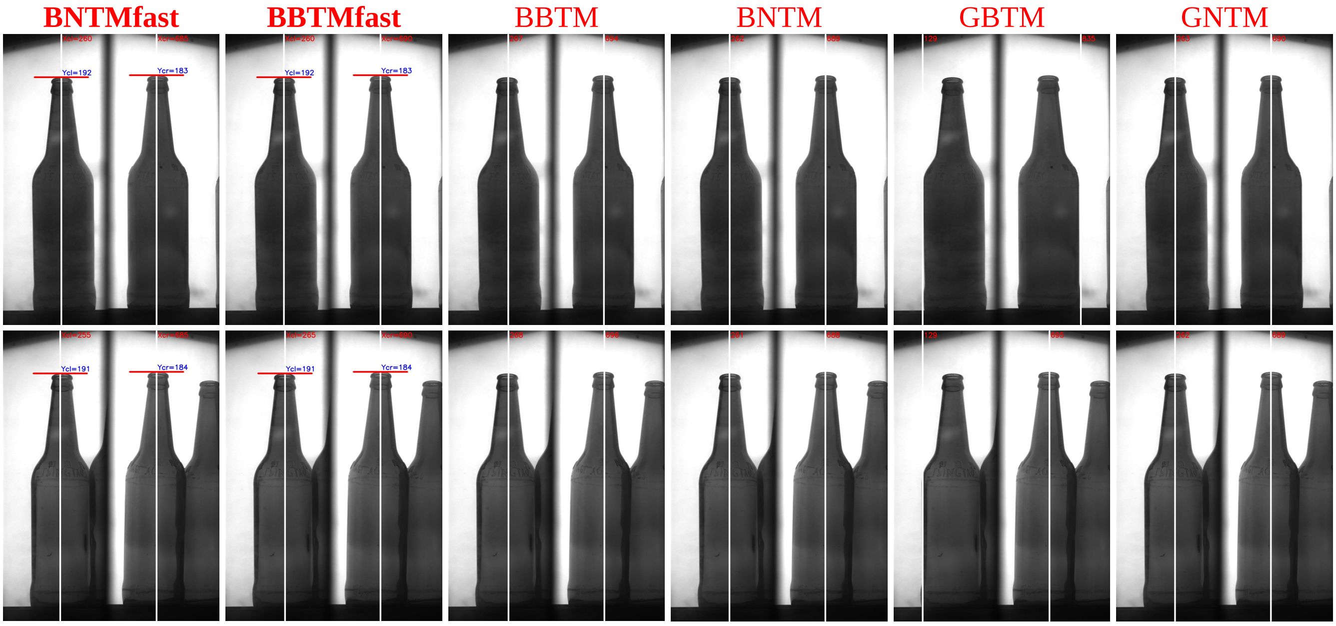

Fig. 4: Some visual results of the template-matching-based methods. The first and second rows are the locate results for two different images obtained by our system.

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