A non-contact real-time measurement of lamp dimension based on machine vision*

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(Received 26 December 2014)

In order to realize the online measurement of lamp dimension, the bulb image dimension measurement based on vision (BIDMV) is proposed. The image of lamp is obtained by camera. After image processing, such as Otsu algorithm, median filter, ellipse fitting and envelope rectangle fitting, the dimension of lamp can be calculated. Based on this method, a non-contact real-time measurement system of the lamp's dimension is developed. The precision of the proposed method is 0.07 mm, and it can satisfy the tolerance of the National Standard GB15766.1-2008. The experiment results show that the proposed method has a faster measuring speed and a higher precision compared with other measurement methods.

Document code: A **Article ID:** 1673-1905(2015)02-0145-4

DOI 10.1007/s11801-015-4238-4

The measurements of the lamp's key parameters include the contact measurements[1] and the non-contact measurements[2]. Yao et al[3] built an resin lens defect classification system based on machine vision technology. Hu et al[4] designed an algorithm for large scale space angle measurement based on linear structured light and machine vision. Sun et al[5] presented a non-contact and high-precision method based on the process of a digital image to measure the diameter of a shaft. Hamzeloo et al[6] proposed a method to estimate the size distribution of particles in crushing circuit of a copper concentrator by using image processing and neural network techniques. Mebatsion et al[7] developed an automatic separation procedure of touching objects based on their curvature values by using machine vision. Those methods are all based on machine vision application, but the machine vision has not been used to measure the dimension of lamp.

In the contact measurements, the lamp is placed in a holder for measuring, so the bulb housing may be damaged by the holder. And those measurements are offline with low precision. In some manufactures, the lamp is still detected by human eyes, which is time consuming and inaccurate. In this paper, in order to measure the essential dimensions of filament lamp efficiently and accurately, the bulb image dimension measurement based on vision (BIDMV) is proposed based on the previous work in our laboratory[8,9]. And based on this method, a non-contact real-time detection system for measuring the dimension of lamp is developed. Compared with the contact method, the proposed method can detect lamps online, and it can get more information from the image. Compared with the methods by human eyes, the proposed method is faster and has higher precision.

The system for measuring the dimension of filament lamp is shown in Fig.1. The system mainly consists of the CCD camera, the conveyor belt, the low-angle light sources and the back light source.

The light source is important for machine vision. The suitable light should enhance the visibility of object's certain features, and suppress the noise interference. Back light illumination is used to enhance the feature of filament and to reduce the bulb housing reflection. The back light source should be put as close as possible to the conveyor belt for getting a clear image. Low-angle light illumination is used to reduce the cap reflection and to

* This work has been supported by the National Natural Science Foundation of China (Nos.60808020 and 61078041), the National Science and Technology Support (No.2014BAH03F01), the Tianjin Research Program of Application Foundation and Advanced Technology (No.10JCYBJC07200), and the Technology Program of Tianjin Municipal Education Commission (No.20130324).

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make the pin visible.

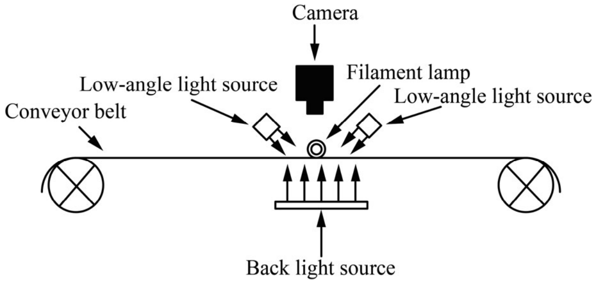


Fig.1 Schematic diagram of the non-contact real-time detection system

The visibilities of filament and pin are both enhanced by using low-angle light and back light, as shown in Fig.2(a). But as shown in Fig.2(b), only the feature of pin is visible by using natural light. Obviously, the image in Fig.2(a) is easier to process than the image in Fig.2(b).

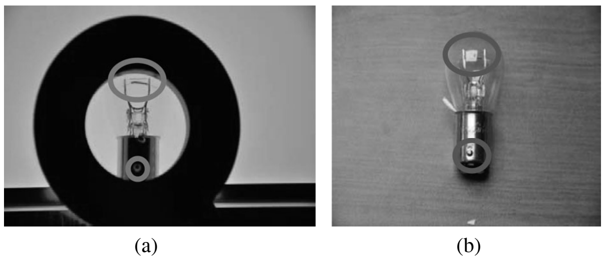


Fig.2 (a) Image in low-angle light source and back light source; (b) Image in natural light

The region of interest (ROI) is specified to improve the image processing speed, and ROI in the obtained image is shown in Fig.3.

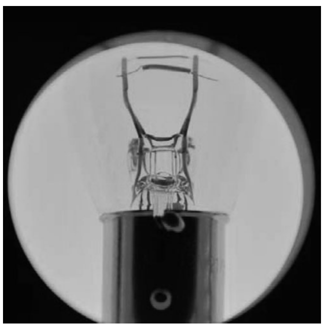


Fig.3 ROI in the obtained image

An improved Otsu algorithm[10,11] is used to automatically perform the clustering-based image thresholding. Assume that the gray level of an image is L. The number of pixels at level i is denoted by n_i, and the total number of pixels is shown as $N=\sum_{i=1}^{L} n_i$. The probability at level i is given by $P_i=\frac{n_i}{N}$.

The image can be divided into two classes by the threshold t as follows

$$\mu_0=\frac{\mu(t)}{\sum_{i=0}^{t} P_i}, \tag{1}$$

$$\mu_1=\frac{\mu_T(t)}{1-\sum_{i=0}^{t} P_i}, \tag{2}$$

where

$$\mu(t)=\sum_{i=0}^{t} i\cdot P_i,\quad \mu_T(t)=\sum_{i=t+1}^{L} i\cdot P_i . \tag{3}$$

The between-class variance is

$$\sigma^2=\sum_{i=0}^{t} P_i\cdot[\mu_0-\mu(t)-\mu_T(t)]^2+$$

$$\sum_{i=t+1}^{L} P_i\cdot[\mu_1-\mu(t)-\mu_T(t)]^2 . \tag{4}$$

The threshold t is the gray value which maximizes the between-class variance, and can be expressed as

$$t=\max_{1<t<L}[\sigma^2(t)] . \tag{5}$$

After Otsu processing, the filament and the pin are separated from the background, but there are still some noise, as shown in Fig.4(a). In order to remove noise, the median filter is used, and the resulted image is shown in Fig.4(b). The median filter is effective at removing noise and preserving edges. The two-dimensional median filtered output signal is given by

$$g(x,y)=\mathrm{med}\{f(x-k,y-l),(k,l\in W)\}, \tag{6}$$

where the pixel value at location (x, y) is given by $g(x, y)$ before image processing, the pixel value is given by $f(x-k, y-l)$ after using median filter, and W is the filtering window whose size is $n\times n$ and it is formed by partitioning of image[12].

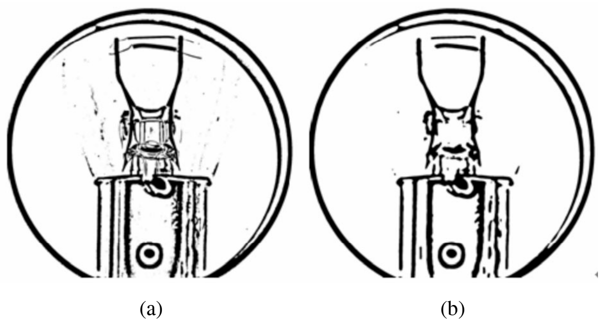


Fig.4 (a) Image after processing with the Otsu algorithm; (b) Image after using median filter

Contours are extracted before ellipse fitting, and the image of contours is shown in Fig.5.

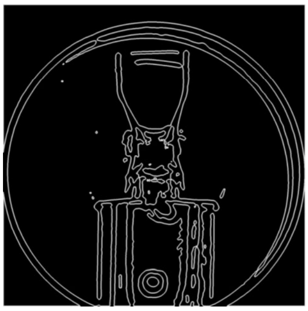


Fig.5 The image of contours

In order to get the pin, the ellipse fitting is used. In analytic geometry, the ellipse can be defined by

$$Ax^2+Bxy+Cy^2+Dx+Ey+F=0\ , \tag{7}$$

and

$$\frac{(x-x_0)^2}{a^2}+\frac{(y-y_0)^2}{b^2}=1\ , \tag{8}$$

where (x_0, y_0) is the center of the ellipse.

The least-squares method is used in ellipse fitting. Suppose that the ellipse is described by Eq.(8). To avoid the null solution, the parameters of ellipse are restricted[13]. The constraint is shown as

$$A+C=1\ . \tag{9}$$

The parameters of ellipse can be calculated by Eqs.(8) and (9) using the least-squares method, that is to say, find the minimum solution of the function as

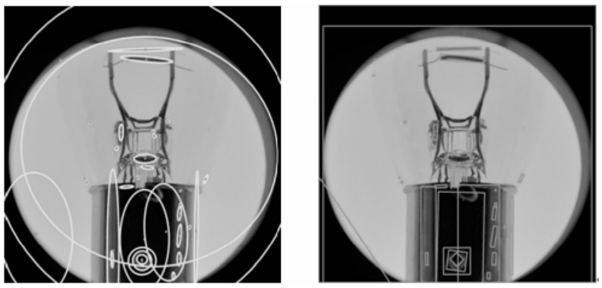
$$f(A,B,C,D,E,F)=$$

$$\sum_{i=1}^{n}(Ax_i^2+Bx_iy_i+Cy_i^2+Dx_i+Ey_i+F)^2\ . \tag{10}$$

By the extreme value theorem, if $f(A, B, C, D, E, F)$ is minimum, we can obtain

$$\frac{\partial f}{\partial A}=\frac{\partial f}{\partial B}=\frac{\partial f}{\partial C}=\frac{\partial f}{\partial D}=\frac{\partial f}{\partial E}=\frac{\partial f}{\partial F}=0\ . \tag{11}$$

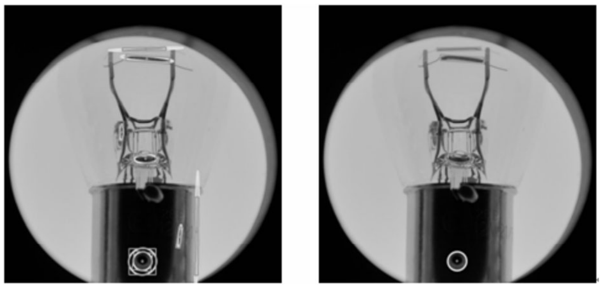
A linear system of equations can be got through Eq.(11). By solving the linear system of equations and Eq.(9), the coefficients of Eq.(7) can be calculated. Then the coordinates of the ellipse's center can be calculated. The image after ellipse fitting is shown in Fig.6(a).



(a) (b)

Fig.6 (a) Image after ellipse fitting; (b) Image after envelope rectangle fitting

In order to get the filament, the envelope rectangle fitting is used, and the image after envelope rectangle fitting is shown in Fig.6(b). The image after envelope rectangle fitting and ellipse fitting is shown in Fig.7(a). There are many unrelated ellipses and rectangles. By setting an appropriate threshold, the filament and the pin are kept, and the other ellipses and rectangles are filtered, as shown in Fig.7(b).



(a) (b)

Fig.7 (a) Image after envelope rectangle fitting and ellipse fitting; (b) Image after threshold

The used lamp is P21/5W, which is offered by Baoding Life Automotive Lighting Group Co., Ltd.. In the National Standard GB15766.1-2008, the tolerance of P21/5W is 0.3 mm. The calibration results are shown in Tab.1. The errors for ten times of experiment are shown in Fig.8. Using the standard deviation formula of $\sigma=\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\mu)^2}$, it can be calculated that σ is 0.07 mm.

Tab.1 Calibration results

Time	1	2	3	4	5	6	7	8	9	10	σ
Pixel	479.811	479.811	479.264	479.658	481.545	479.966	478.985	481.685	481.141	481.368	—
Result (mm)	31.721	31.421	31.685	31.711	31.826	31.732	31.667	31.845	31.809	31.824	0.07

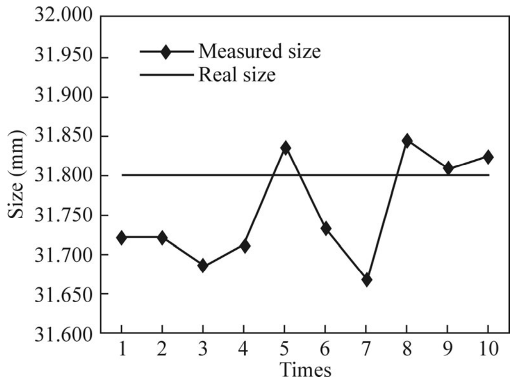


Fig.8 Measurement errors for ten times of experiment

A non-contact real-time detection system for measuring filament lamp quality is developed based on the proposed BIDMV method. Some image processing is used to find the filament and the pin in the system. Otsu algorithm is used to automatically perform clustering-based image thresholding. The median filter is used to remove noise. Then the ellipse fitting and the envelope rectangle fitting are applied to extract the pin and the filament. Finally, the dimension between filament and pin can be calculated. Because there is no holder in the proposed non-contact method, the damage of the bulb is avoided. The used CCD camera in this detection system is more efficient and precise than the measurement by human eyes. The proposed method has a faster measuring speed. By using the conveyor belt, the measurement is automatic.

Acknowledgement

Thanks for the support from National Natural Science Foundation Committee and Tianjin Research Program of Application Foundation and Advanced Technology. This research is also supported by the Tianjin Key Laboratory of Advanced Electrical Engineering and Energy Technology.

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