Shell Casing Size Measurement Method Based on Improved Hough Transform

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Abstract: In order to improve the accuracy and efficiency of the measurement of the Shell Case size, a measurement system based on machine vision is introduced. Through the preprocessing, threshold segmentation algorithm and edge detection of the shell case image. Correlated size measurement of lines and circles in contour using binary search method and Hough transform. The experiment of detecting four sizes of 100 qualified shells shows that the system can realize the rapid and accurate detection of shell casings, and can be used to assess their quality performance. It effectively improves the detection efficiency and further improves the automation level of detection, which has a good application prospect.

Keywords: Machine Recognition, Hough Transform, Dichotomy Method, Shell Case

1 Introduction

In the production process of shell casing, inevitable to produce unqualified products, so it is necessary to measure and evaluate its shape and size[1]. At present, the size detection of shell casing mainly stays in the hand-operated stage, which is inefficient and the results are related to artificial experience and easy to cause error-detecting. With the wide application of machine vision measurement technology, non-contact detection methods have begun to use digital image processing technology to digitize the measured object to calculate the relevant dimensional parameters.

The artillery shell size is measured using machine vision has the advantages of non-contact and high precision, but it also exist the problems of false detection and time-consuming. In order to improve the efficiency and accuracy of measurement, this system uses Hough transform to measure the dimensions of straight lines and circles in the shell image. This method has strong anti-interference ability, but has high time and space complexity[2].

This paper proposes a visual recognition system based on Fast Hough transform detection with binary search. After processing and enhancing the image information of the captured image, the visual recognition system identifies the contour linears of the shell case, and then uses the binary search method to search the Hough threshold multiple times to form an iteration until the threshold that meets the requirements is tracked[3], and the relevant lines and circles are identified, so as to obtain the relevant size information of the shell case and realize the non-contact precision detection of the shell[4].

2 Measurement Scheme

Shell size measurement system is mainly composed of the measured module, Image acquisition Module and processing module. The system diagram is shown in Fig.1. This system assembles the shell casing in the detection station (The shell position is shown in

Fig.1), orientations the camera directly above the detection station and the side position for image acquisition, and transmits the image to the processing system, identifies and calculates the size, and evaluates each size to measure the quality of the shell casing.

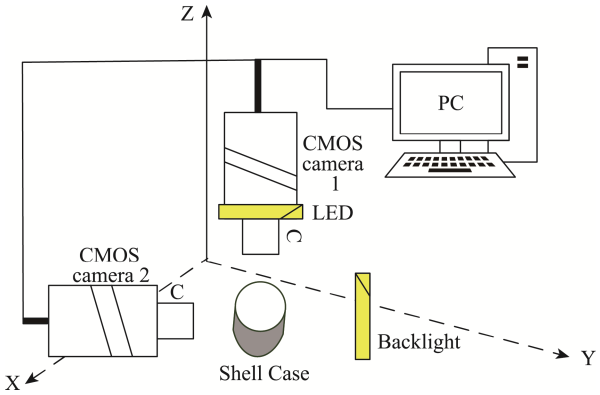


Fig.1 Vision Measurement System

The measured module is a regular size shell, the major contents of the detection are A1 (Diameter), A2 (Wall thickness), A4 (Full length) and L1 (Length). The image acquisition module is composed of LED and CMOS sensor. The ring LED above provides different angle illumination to solve the problem of diagonal illumination shadow[5]. The lateral background light source effectively highlights the geometric features of the shell shape, so that the edge contour is clearly visible, presenting a clear black and white image.

To improve the real-time performance of the measurement system, this system uses CMOS sensors to obtain clear and identifiable images and transmits the images to the processing module[6]. Processing module is a computer system, which completes image processing to obtain the measurement results and the final results displayed on the computer screen and save to determine whether the shell is qualified.

3 Image Preprocessing and Edge Detection

In the actual detection, due to the influence of equipment and detection environment, the shell case image will be disturbed and produce noise during the acquisition and transmission process. At the same time, the image background and light intensity will also affect the image quality[7]. Therefore, before the shell shape detection, it is necessary to preprocess the image to reduce the image redundancy information, enhance the shell shape contour information, and improve the efficiency of subsequent image processing algorithms. Shell is shown in Fig.2.

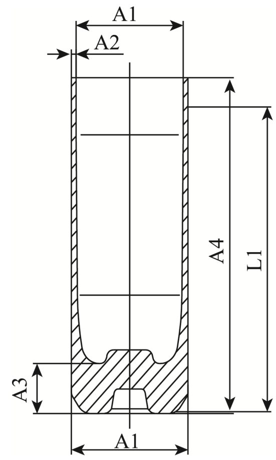


Fig.2 Schematic Diagram of Shell

3.1 Image Preprocessing

Affected by the ion of light and the dark current of the diode, the images collected by CMOS sensors are usually mixed with point noise and shot noise. In order to eliminate noise interference and improve image signal-to-noise ratio without losing image details, the system uses median filtering to remove noise to improve image quality. Median filtering is a nonlinear smoothing filter based on sorting statistical theory[8]. The basic idea is to replace the gray value of the pixel with the median gray value of the pixel neighborhood, thereby eliminating isolated noise points. The order of the filtering matrix must be odd. For the selection of the order, too high will lead to the loss of edge features, and too low will affect the filtering effect. This paper selects the odd order that is smaller and nearest than the edge pixel of the image valid information, because there are gradient decreasing pixels around the line. The results show that this can remove noise while retaining the maximum effective information. Filtered image as show bellow:

$$g(x,y) = med\{f(x-k, y-l), (k,l \in W)\} \quad (1)$$

In the formula, $f(x,y)$ is the original image; W is a two-dimensional template.

Because the gray level transformation of the shell image is not obvious, the low contrast makes the image not clear enough. In order to highlight the image features and increase the difference between the background and the background[9], this paper uses histogram equalization to expand the image gray value range and enhance the image contrast.

The grayscale histogram is transformed as follows, $G(p)$ represents the input histogram, and the input grayscale range is$[p_0, p_k]$; $H(q)$ represents the output histogram, and the gray brightness range is $[q_0, q_k]$:

$$\sum_{i=0}^{k} H(q_i) = \sum_{i=0}^{k} G(p_i) \quad (2)$$

Then the probability density function for $H(q)$ of size $N*N$ is:

$$f = \frac{N^2}{q_i - q_0} \quad (3)$$

Substituting Equation (3) into Equation (2), we can get:

$$N^2 \int_{q_0}^{q} \frac{1}{q_K - q_0} ds = \frac{N^2(q-q_0)}{q_K - q_0} = \int_{p_0}^{p} G(s) ds \quad (4)$$

The transformation function of image histogram equalization:

$$q = \frac{q_K - q_0}{N^2} \int_{p_0}^{p} G(s) ds + q_0 \quad (5)$$

In this system, only the image captured by camera 1 needs to use the image enhancement algorithm, as shown in Fig.3 for the use of histogram equalization after image comparison, can see that the balanced image contrast is significant.

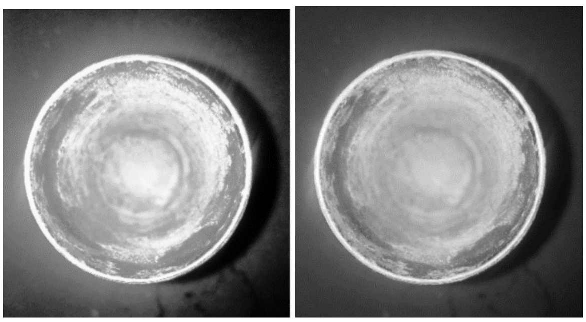


Fig.3 Comparison of Image Enhancement Results

3.2 Image Segmentation

Using binarization can distinguish the detected target from the background in the image. The basic binarization can only obtain the required binary image under certain conditions. When the light changes, the image quality will change accordingly. In this paper, the maximum inter-class variance method (Otsu) that is adaptive image threshold segmentation method for binary image processing after pretreatment. Ostu uses the weighted sum of the probability density functions of two or more normal distributions to construct the image histogram[10]. The gray value at the minimum probability between the maximum values of the normal distribution is taken as the threshold, that is, the variance of the target and the background corresponding to each threshold is calculated. Finally, the threshold of the minimum variance between the classes is set as the optimal threshold to separate the image[11]. A represents the target area, B represents the background area, the variance between classes is as follows:

$$\sigma^2(T) = W_A(\mu_A(T) - \mu_0)^2 + W_B(\mu_B(T) - \mu_0)^2 \quad (6)$$

In the formula, w_A and w_B represent the probability of A and B after threshold T division:

$$w_A = \sum_{i=0}^{T} P_i,\ w_B = 1 - w_A \quad (7)$$

μ_A, $\mu_B$represents gray mean:

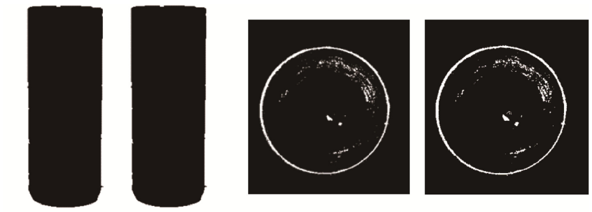
$$\mu_A(T) = \frac{\sum_{i=0}^{T} i \cdot p_i}{w_0} \quad (8)$$

$$\mu_B(T) = \frac{\sum_{i=T+1}^{L-1} i \cdot p_i}{w_1} \quad (9)$$

The binary method can automatically obtain the appropriate threshold for binarization by calculation, which is more practical in engineering. Fig.4 and Fig.5 show the comparison of images after basic binarization and Ostu binarization when the shooting light changes. It can be seen that Ostu has stronger adaptability and better effect.

a Side View of Shell Case b Top View of Shell Case

Fig.4 Basic Binary Image Comparison



a Side View of Shell Case b Top View of Shell Case

Fig.5 Ostu Binary Image Comparison

Edge is a combination of pixels with obvious changes in image gray level, which can describe the contour of the target and obtain its shape, size and other information. When identifying the shell size information, it is necessary to detect its edge information[12-13]. In this paper, double threshold non-maximum suppression Canny operator is used to extract the image edge contour. This operator is an optimal edge detection operator, reflected in not losing the important edge, the actual edge and detection edge position deviation minimum and can reduce the multi-response to a single edge response.

Firstly, the input image $f(x,y)$ is smoothed by two-dimensional Gaussian smoothing operator $G(x,y)$ to remove noise. The smoothed image is expressed as follows, where (x,y) is the image coordinate and б is the standard deviation of the probability distribution:

$$I(x,y) = G(x,y) * f(x,y) \tag{10}$$

$$G(x,y) = e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{11}$$

The image is convoluted with the operator G_n, G_n is the first derivative of G along the n direction:

$$G_n = \frac{\partial G}{\partial \bar{n}} = \bar{\boldsymbol{n}}\boldsymbol{\nabla G} \tag{12}$$

Edge normal vector $\bar{\boldsymbol{n}}$:

$$\bar{\boldsymbol{n}} = \frac{\nabla(G*f)}{|\nabla(G*f)|} \tag{13}$$

The edge is located at the local maximum of the convolution of G_n with the image f in the $\bar{n}$ direction:

$$\frac{\partial}{\partial \bar{n}} G_n * f = 0 \tag{14}$$

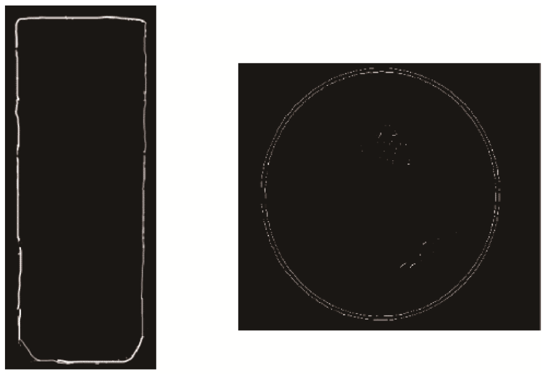
Substituting G_n into the above formula can obtain:

$$\frac{\partial^2}{\partial \bar{n}^2} G * f = 0 \tag{15}$$

The above formula can find the local maximum value in the direction perpendicular to the edge; this operator is also called non-maximum suppression. The strength of the edge:

$$|G_n * f| = |\boldsymbol{\nabla}(G * f)| \tag{16}$$

Finally, the double threshold lag threshold processing is used to eliminate false information, that is, the high and low thresholds are set, and the point z greater than the high threshold is marked as a strong edge point ; set the point less than the low threshold to 0. Finally, a pixel between the size thresholds is connected to a pixel previously marked as an edge point (If the pixel is not connected to a strong edge point, set to 0). After the canny operator processing, the whole edge distribution image can be obtained. The shell image processed by the above method is shown in fig.6 below:



a Side View b Top view

Fig.6 Edge Distribution image

4 Dimension Information Acquisition

The shell image can use Hough transform to obtain the pixel size of straight line and circle size. Hough transform is a transformation from image space to polar coordinate space. It is one of the key methods to identify and detect geometric shapes in image processing.

4.1 Hough Transform

Hough transform can detect straight lines and curves, and transform the image from the rectangular coordinate system to the parameter coordinate system. The descriptor of the same information in the parameter coordinates focuses on one point, and the possibility of forming a geometric shape is cumulatively judged by setting an accumulated array[14]. To solve the problem of an infinite vertical line slope K, the line equation $\rho(\theta)$ needs to be formalized in polar space as follows:

$$\rho(\theta)=x\cos\theta+y\sin\theta,\ 0\leqslant\theta\leqslant\Pi \tag{17}$$

In the above formula:

$$\rho=\sqrt{x^2+y^2},\ \theta=arctan(y/x) \tag{18}$$

ρ represents the distance from the straight line to the origin, and θ represents the angle from the x-axis to the vertical line. Through the same cumulative value, the possibility of feature points forming a straight line can be judged.

The expected circle equation for the center C(x_c, y_c) and the radius circle R can be expressed as follows in polar coordinates:

$$\begin{cases} x_c = x - R\cos\theta \\ y_c = y - R\sin\theta \end{cases} \tag{19}$$

For each circle in the rectangular coordinate system, the same point (x_c, y_c, R) can be determined. In the $\rho-\theta$ theta plane, we constantly accumulate to find the maximum point, determine the cumulative threshold, and judge whether the circle exists.

4.2 Improved Hough Transform Based on Binary Search

The traditional Hough line transform takes a long time and occupies a large memory space, and cannot confirm the cumulative value of the line that conforms to the actual situation of the project, that is, the threshold[15]. Therefore, in order to avoid the problems of false detection of straight lines, not missing qualified straight line information and low efficiency, this paper proposes a Hough detection method based on binary search to determine the cumulative threshold to identify the shell size.

Known Hough line recognition can be obtained straight line three important straight line parameters: polar radius ρ polar angle θ and line number lineSize. The Hough line recognition algorithm designed by this system is as follows:

Set the cumulative threshold range $(\mathrm{T_{Min}}—\mathrm{T_{Max}})$, the number of lines range $(L_{Min}—L_{Max})$ and the number of cycles to take the detection threshold:

$$\mathrm{Thold}=(\mathrm{T_{Max}}—\mathrm{T_{Min}})/2 \tag{20}$$

Hough detection is performed to determine whether the line position meets the line number requirement. If it meets, the line information is returned. If it does not meet, the Hough threshold is updated. In the process of updating, the intermediate factor is introduced to search quickly based on the dichotomy search idea:

When line_size$>L_{Max}$,

$$\mathrm{Thold}=\mathrm{T_{Max}}+(\mathrm{T_{Max}}-\mathrm{Thold})/2 \tag{21}$$

When line_size$<L_{Min}$,

$$\mathrm{Thold}=\mathrm{Thold}-(Thold-\mathrm{T_{Min}})/2 \tag{22}$$

Determine the number of lines, repeat the update detection threshold until lineSize ϵ $[L_{Min}—L_{Max}]$.

Return the line information obtained by the detection, and judge the number of threshold updates to avoid falling into a dead cycle. Set the angle deviation ε and length deviation ξ to classify and screen the straight lines. For the identified i, j straight lines, it satisfies:

$$\begin{cases} |\theta_i-\theta_j|\leqslant\varepsilon \\ |\rho_i-\rho_j|\leqslant\xi \end{cases} \tag{23}$$

The i, j line is taken as two grayscale change lines of the same line. The following illustration shows the top enlarged view of the traditional Hough line recognition design with two large difference thresholds and improved cartridge case recognition results:

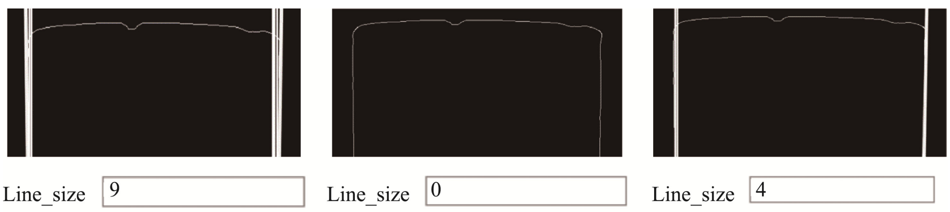


Fig.7 Hough Line Recognition

According to the number of circles, the Hough circle threshold is searched by dichotomy. At the same time, in order to speed up the detection of circles, the radius range of circles is set. The recognition results are as follows:

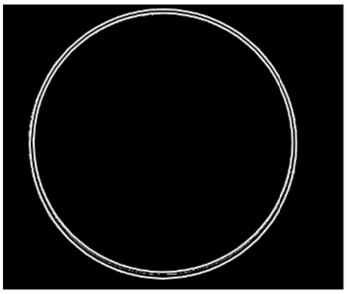


Fig.8 Hough Circle Recognition

4.3 Size Calculation

The size of the shell can be obtained by processing and calculating the identified straight lines and circles. In order to eliminate the possible error effects, it is necessary to filter out the misidentified lines and circles and then solve them[16].

Determine the distance of the parallel lines in the same group to remove the misidentified lines, and calculate the average polar radius and polar angle of the remaining parallel lines. First, the average polar diameter of the same group of parallel lines is calculated, and then the deviation between each line and the average polar diameter is judged.

(1) A point in the polar coordinate of Hough transform is the parameter of the straight line ρ and θ, then the distance L_d between the two straight lines is A1:

$$\mathrm{A1} = |\rho_1 - \rho_2| \tag{24}$$

(2) Determine the number of parallel groups and their vertical relationship, parallel group number >=2 vertical judgment ;

(3) Calculate the vertical line intersection. Assuming that the polar coordinate equation of the vertical line is expressed as follows ;

$$\begin{bmatrix} R_1 \\ R_2 \end{bmatrix} = \begin{bmatrix} cos\,\theta_1 & sin\,\theta_1 \\ cos\,\theta_2 & sin\,\theta_2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \tag{25}$$

Intersection coordinates(x_i, y_i) can be obtained, where:

$$x_i=(R_1 sin\theta_2 - sin\theta_1 R_2)/(\cos\theta_1 sin\theta_2 - \sin\theta_1 cos\theta_2) \tag{26}$$

$$y_i=(R_2 cos\theta_2 - cos\theta_2 R_1)/(\cos\theta_1 sin\theta_2 - \sin\theta_1 cos\theta_2) \tag{27}$$

(4) According to the identified center error to determine whether the identification is accurate, and then calculate the shell wall thickness A2 according to R;

(5) The actual physical size is calculated by the pixel size obtained by the measurement system:

$$Physicalsize=(Pixelsize*Viewdimension)/Distinguishability \tag{28}$$

(6) Finally, the calculated size is checked to determine the performance index of the cartridge case.

5 Experimental Result and Analysis

In order to verify the effect of the algorithm, this paper uses Visual Studio software and C# language programming to configure the EmguCV visual library object limit light detector image record for verification. In the VS software windows form design interface design of this project validation, including image processing parameters, control buttons and results display and other information. In order to verify the accuracy of the measurement, the No.1 shell casing is measured, and the measured size can be compared with the actual size as shown in Tables 1 and 2 below:

Table 1 Comparative Test Data

Position of Measurement	True Size (mm)	Measurement (mm)	Error (mm)
Full Bullet Length	111.4650	111.4575	0.0125
Length of Shell Case	109.3500	109.3471	0.0029
Shell Diameter	40.2100	40.2070	0.0230
Wall Thickness	1.0500	1.0583	0.0083

Table 2 Repeated Experimental Data

No.	Full Bullet (mm)	Shell Case (mm)	Shell Diameter (mm)	Wall Thickness (mm)
1	111.4675	109.3471	40.2045	1.0583
2	111.4541	109.3429	40.2060	1.0570
3	111.4564	109.3457	40.2087	1.0570
4	111.4568	109.3496	40.2083	1.0570
5	111.4570	109.3456	40.2048	1.0584
6	111.4581	109.3471	40.2067	1.0584
7	111.4538	109.3458	40.2034	1.0585
8	111.4557	109.3463	40.2065	1.0570
9	111.4529	109.3479	40.2076	1.0570
10	111.4547	109.3446	40.2049	1.0570
Maximum Error	0.0109	0.0071	0.0066	0.0085

The system measures 10 shells to test the stability of the system. The results are shown in Table 2. It can be seen that the visual measurement system has good stability.

From the above table, the maximum recognition error is 0.0109 mm, and the error rate is less than 1%, which can effectively meet the system recognition requirements.

6 Conclusion

Aiming at the performance of the test quadrant shell, this paper analyzes how to identify the test points according to the image features. By combining image filtering, enhancement, threshold segmentation and other technologies, a fast Hough line detection algorithm combining line number and dichotomy search is proposed. The experimental results show that the method can quickly measure the size values of the shell, which proves the effectiveness and accuracy of the algorithm in recognition.

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