The study of eccentric bunghole self-positioning system based on computer vision technology

Wei Yuan[1*], Jianqi Zhang[2]

[1]*XianDian Universityr, Shannxi Xi'an 710071, China*

[2]*Weinan Normal University Shannxi Weinan 714099*

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Abstract

This paper on the basis of deeply understanding the domestic automatic filling equipment's, develops an eccentric bunghole self-positioning system based on computer vision technology, through full automatic camera calibration and improved Hoff conversion algorithm to obtain the coordinate information of circle centre of eccentric fillers, thus controls the operation of driving stepper motor, realizes the automatic positioning of sprue guns to eccentric bunghole. The experiment proves the operation accuracy of this system is high, the speed is fast, the algorithm is efficient, stable, and a high practical value.

Keywords: computer vision technology, eccentric bunghole, automatic positioning, camera calibration, Hoff transformation algorithm

1 Introduction

Automatic filling machinery plays a very important role in modern industry automatic production, which is widely used in production fields such as petroleum, chemical engineering, medical treatment, beverage and so on [1]. However, when the filler of containers is eccentric entrance, the application of full automatic filling technology suffered serious restrict, at present the filling machinery of most enterprises adapts semi-automatic method, namely manual positioning barrel entrance filling. This becomes great dangerous operation sequence to the fillings of poisonous liquids with strong infiltration capacity such as sodium cyanide, hydrofluoric acid and so on. [2]. This paper on the basis of deeply investigating the current situation at home and abroad developing the eccentric bunghole self-positioning system based on computer vision technology, successfully solved the difficult self-positional problems which random distributed in circumference direction of eccentric entrances of filling lines, which cam guarantee the personal security of toxic liquid filling workers, can improve the mechanization and automation level of filling works, and with a good practicability [3].

2 The Eccentric Bunghole Self-Positioning System Based on Computer Vision Technology

This paper studies the eccentric bunghole self-positioning system based on computer vision technology is showed as Figure 1. The detected barrels are sent to filling station through transmission sequences, after computer obtains oil drum arrival information through optoelectronic switch, the industrial CCD vidicon installed above the oil drum can collect image information and send the images to image capture card in time. Image capture card processes digital decoding, A/D conversion to input signals, and through PIC bus sending the digital image data to computer memories to save. Computer makes analysis to the collected oil drum image information to calculate the centre positional coordinate in the images of top surface and send the information to electric control system, through line interpolation method, with the filler entrance of electric control system aims at oil drum spile to finish the automatic positioning of fillers. Finally the system control direct current machine stretches the fillers into spile through pinion and rack drive to realize automatic filling. Figure 2 lists the working process block diagram of eccentric bunghole self-positioning system based on computer vision.

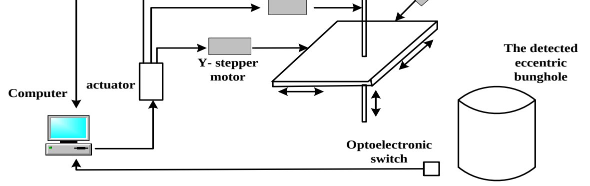


FIGURE 1 The simple diagram of eccentric bunghole self-positioning system based on computer vision

* ***Corresponding author*** e-mail:wnyuanwei@163.com

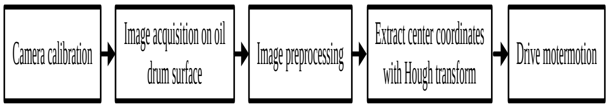


FIGURE 2 The working process block diagram of eccentric bunghole self-positioning system based on computer vision

2.1 CAMERA CALIBRATION [4] [5] [6]

The designed camera calibration of this paper does not need any artificial participation and all the calibration processes are completed automatically in order to adapt the automation-filling request of oil drum. The process includes six steps such as making threshold segmentation, parameter circular array mark, enter automatic withdrawal of parameter circular array and the vidicon parameter calculation based on least square fit to target images, which is showed as Figure 3.

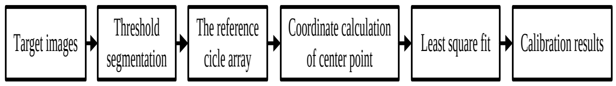
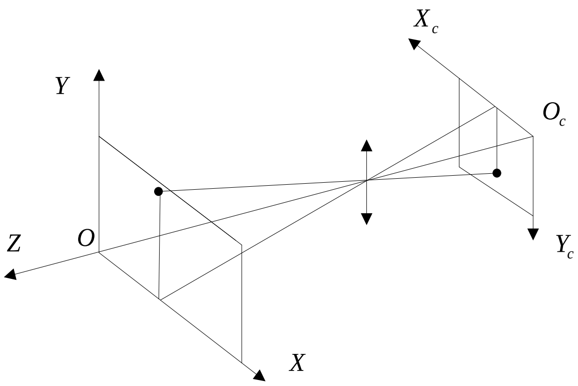


FIGURE 3 Vidicon calibration process diagram

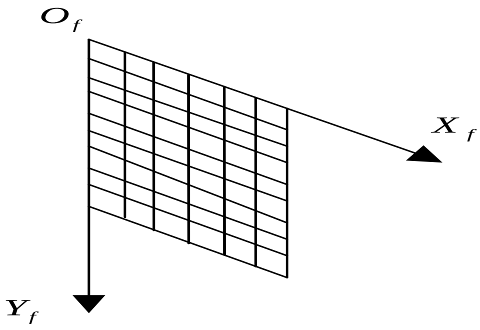
2.2 COORDINATE SYSTEM IN CAMERA CALIBRATION

As it shows in Figure 4, the coordinate system in camera calibration has the following three layer's coordinate systems:

1. World coordinates of scene coordinates, the general three-dimensional scenes of (XYZ) are expressed by this coordinate system.
2. Camera coordinates. $\left(X_c O Y_c\right)$ takes the focal length centre of microspore vidicon as the origin, takes the three-dimensional rectangular coordinate system of vidicon optical axis established on the basis of Z axle, namely the camera CCD plane coordinate system.
3. Pixel coordinates. $\left(X_f O_f Y_f\right)$ also called frame saving coordinate system of computer image (fix on the images), which is the rectangular plane coordinate system in pixels, its origins locates on the top left corner of images.



(a) World coordinate and camera coordinate



(b) Pixel coordinates

FIGURE 4 The three-layer coordinate system during vidicon imaging progress

(1)The Calibration Method of This Paper

Placing the showed target location of Figure 5 into the plane XOY of world coordinate system which showed as Figure 4(a),suppose the centre point coordinate of any reference circle is (X,Y), the imaging coordinate of this point within camera CCD plane coordinate system is $\left(X_c, Y_c\right)$. In image pixel coordinate supposed as $\left(X_f, Y_f\right)$, any point P(X,Y) in target with the coordinate in projection point $P_c\left(X_c, Y_c\right)$ should meet:

$$\begin{cases} X_c = KX \\ Y_c = KY \end{cases}. \tag{1}$$

K is proportional action factor in the algorithm.

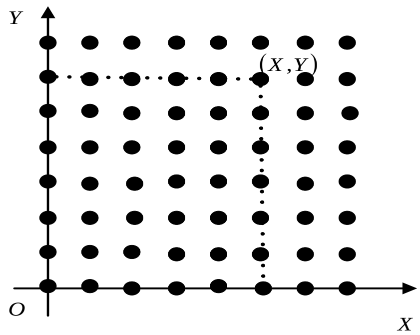


FIGURE 5 Calibration target

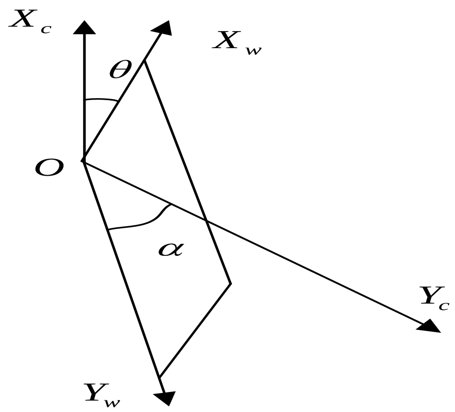


FIGURE 6 Rotation and decentration of camera coordinate system

Considering the factors such as camera optical axis out of plumb and CCD installation inaccuracy will lead to the rotation error and decentration error in CCD plane, which need to make conversion and correction to CCD plane. Suppose the CCD plane coordinate system after conversion and correction is X_wOY_w (see also to Figure 6), and then the rotation, decentration error of CCD plane can use the following formulas to correct:

$$\begin{bmatrix} X_w \\ Y_w \end{bmatrix}^T = \begin{bmatrix} X_c \\ Y_c \end{bmatrix}^T \begin{bmatrix} 1 & 0 \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{bmatrix} \quad (2).$$

λ_x, λ_y in the formula means the horizontal equivalent and vertical equivalent, which respectively on behalf of the actual value of unit pixel in image plane $\left(X_f O_f Y_f\right)$ countdown to world coordinate system XYZ on horizontal equivalent and vertical equivalent?

Simultaneous formula (1), (2) to obtain:

$$\begin{cases} X_f = A_0 + A_1 X + A_2 Y \\ Y_f = B_0 + B_1 X + B_2 Y \end{cases}, \quad (3)$$

A_0, B_0 in the formula is the relative transform constant on horizontal equivalent and vertical equivalent.

$$\begin{cases} A_1 = \dfrac{\cos\alpha}{\lambda_x} \\ A_2 = -\dfrac{\sin(\alpha+\theta)}{\lambda_x} \\ B_1 = \dfrac{\sin\alpha}{\lambda_y} \\ B_2 = \dfrac{\cos(\alpha+\theta)}{\lambda_y} \end{cases}. \quad (4)$$

In the formula, if $A_1, A_2, \mathrm{B}_1, \mathrm{B}_2$ is known, then we can get:

$$\sin\alpha = \sqrt{\frac{A_1^2 B_1^2 - A_2^2 B_1^2}{A_1^2 B_2^2 - A_2^2 B_1^2}}, \quad \lambda_x = \left|\frac{\cos\alpha}{A_1}\right|, \quad \lambda_y = \left|\frac{\sin\alpha}{B_1}\right|. \quad (5)$$

Suppose the coordinate measuring value of any centre of reference circle in target is $\left(X_i, Y_i\right), i = 0,1,2,...,n$, the corresponding coordinate in the image coordinate system is $\left(X_{fi}, y_{fi}\right), i = 0,1,2,...,n$, with the least square fitting method we can obtain the coefficient $A_0, A_1, A_2, B_0, B_1, B_2$ in formula (3).

Suppose $P = \left[A_0\ A_1\ A_2\ B_0\ B_1\ B_2\right]^T$, (6)

$$Q_i = \begin{bmatrix} 1 & X_i & Y_i & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & X_i & Y_i \end{bmatrix}, \quad (7)$$

$$Q = \left[Q_1\, Q_2\, Q_3 \ldots Q_n\right]^T, \quad (8)$$

$$R_i = \left[X_{fi}\, Y_{fi}\right]^T, \quad (9)$$

$$R = \left[R_1\, R_2\, R_3 \ldots R_n\right]^T. \quad (10)$$

The n in the formula is the centre number of target reference, which participates in the least square calculation, according to formula (3):

$$QP = R. \quad (11)$$

Substituting $\left(X_i, Y_i\right)$, $\left(X_{fi}, Y_{fi}\right)$ sequence into (11) formula, with the least square calculation we can obtain:

$$P = \left(Q^T Q\right)^{-1} Q^T R. \quad (12)$$

From the above analysis we can know the parameter fitting method based on the least square can proceed as following steps:

1. Measuring the coordinate $\left(X_i, Y_i\right)$ of each centre of target reference circle array in world coordinate system.
2. Adapting image processing method to measure the corresponding coordinate of $\left(X_i, Y_i\right)$ in image coordinate system is $\left(X_{fi}, Y_{fi}\right)$,
3. According to 1., 2. results to build matrix R and Q;
4. Getting column vector P, thus determines $A_0, A_1, A_2, B_0, B_1, B_2$;
5. After obtaining $A_0, A_1, A_2, B_0, B_1, B_2$,then according to the image information $\left(X_f, \mathrm{Y}_f\right)$ of measured objects within algorithm (2-86) to recognize the target object information (X, Y) in environment.

2.3 IMAGE CAPTURE AND PROCESSING [7]

When capture cards are at work, sends the collected data to memory. Through Read Form Mem() function can display the image data which saved in memory, through the time testing of system shows that when image capture cards are at work, collection to memory is about 500ms,the collection directly to screen will not more than 40ms.In order to accelerate collection speed, system sends the images which collected by image capture cards to VGA display card and displayed through screen, then invoking ReadDisp Window() function to read the image data and save the image from screen, and then store to specified memory buffers, the image processing progress is showed as Figure 7:

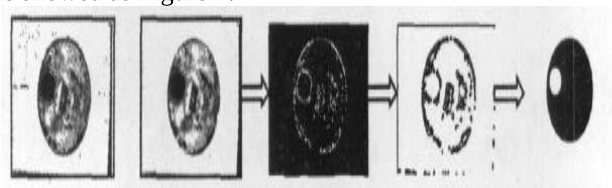


FIGURE 7 Figure collection and processing

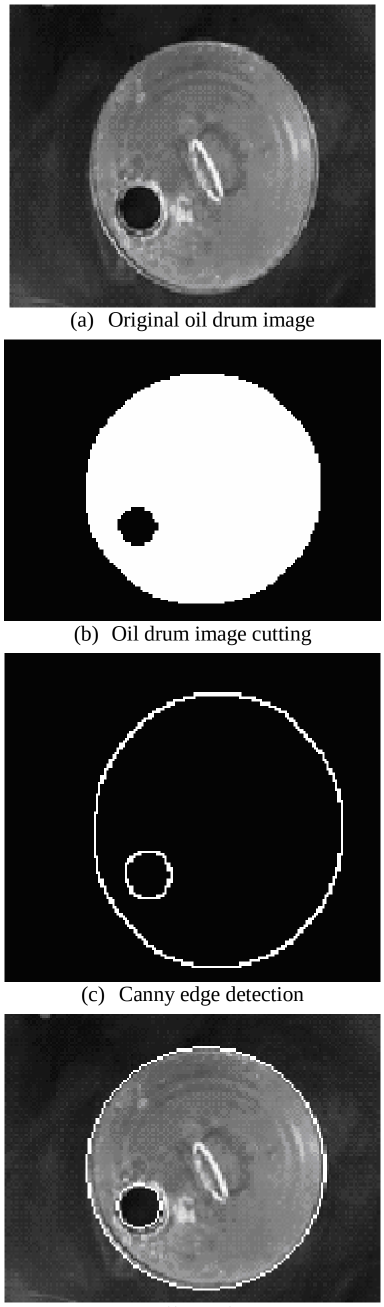
2.4 DETERMINES THE CENTER COORDINATE POSITION OF ECCENTRIC BUNGHOLE WITH HOFF TRANSFORM ALGORITHM

The calculation of Hoff transform is very complex, which includes great number of squares, evolution operations. With the value range of r constantly enlarged in circular testing application, the size of three-dimensional group in parameter space increases proportionally, which needs to consume lots of computer memories and the efficiency becomes low. Therefore, this paper summarizes the subjects and proposes a new circular Hoff transform algorithm, and the basic steps are showed as follows:

1. Getting the binary edge image through canny edge testing;
2. Defining accumulator space of transform position, its size is in line with the size of binary edge image;
3. Looking for next edge point, with this pixel as the central confirming （2 k+ 1)×(2k+1) windows, and establishes coordinate system xoy in this edge point;
4. Counting the number of edge points in windows, if the number of point equals to (2k +1) goes to 5., otherwise to 3.;
5. Looking for endpoint A, B;
6. Verifying whether A, B, O these three points are collineation, if collineation goes to 3., otherwise calculates the perpendicular bisector function of segment AB;
7. Using the mutual positional relationship between origin O and segment AB to determine circular bending direction, namely the accumulation direction of centre in parameter position, and accumulates to this direction in parameter position.
8. Inspecting whether finishing the scanning of overall image, if not finish, then goes to 3., if finish goes to 9.;
9. When all the edge point detection finished, finding the maximum of accumulator results in parameter position, the corresponding accumulator coordinate of this value is the central coordinate of detected circles.

This Hoff transform algorithm can wipe off straight edge and noise point, refuse the meaningless accumulated information through using circular edge outline information, compared with traditional Hoff transform algorithm, its computational effort is small, the operation speed is fast, and occupied computer memory is low.

When uses this algorithm to determine bunghole central position, mainly needs to go through image acquisition, image cutting, edge detection and Hoff transform these four steps, which is showed as Figure 8. After excluding cover centre of oil drum, then can according to image coordinate value $\left(X_f, Y_f\right)$ and camera calibration coefficient we can obtain the world coordinate value (X, Y) in the central of eccentric bunghole.



(a) Original oil drum image

(b) Oil drum image cutting

(c) Canny edge detection

(d) Fast Hoff transform results

FIGURE 8 The central extraction process of eccentric bunghole

2.5 MOTOR DRIVE SYSTEM OF MARCHING TYPE DESIGN

After vision system detecting the central coordination information of eccentric bunghole, we need to send the bunghole central coordination to the above of fillers with computer and realize automatic self- positioning fillings.

This paper designs the marching type drive system with the core of L297.L298, the circuitous philosophy is showed as Figure 9.

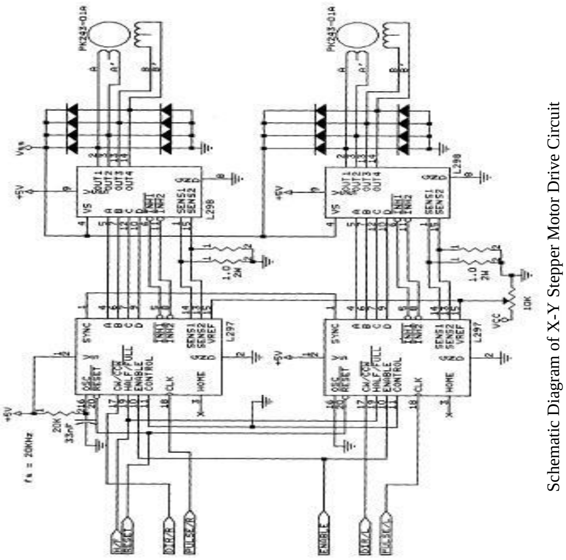


FIGURE 9 Circuitous philosophy figure of X-Y marching type drive

The core of stepping motor controller chip circuit L297 is pulse distributor, adapts plastic packaging form of 20 feet dual in-line type, usually with +5V to supply power. There are two PWM choppers in L297 for controlling winding current to realize constant current cut wave, thus obtained a better torque-frequency features, which applies to the control of bipolar two phases stepping motor or unipolarity four-phase stepping motor.L297 only need to receiver direction (forward / rollback), model(half step/basic step pitch), clock (step-by-step impulse) these three input signals from upper computer, which produces three kinds of phase sequence signals corresponding to three different working manners: half step method (four phase and eight step); single-phase incentive method (single phase and four step); double-phase incentive method (two phase and two step). The initial state of L297 is ABCD=0101.

L298 is double-H bridge high voltage large current power integrated circuit, it receives standard logic electrical level signals, which can use for the electric loading such as driving relay, coil, continuous current motor and stepping motor and so on.

The system consists of L297 and L298 drives two-phase stepping motors, the highest voltage is 46V, each phase current reaches to 2A.

The parallel end of computer sends clock signal, positive and negative turning signal, working pattern signal, enable signal and control signal. The steering of CW/CCW control motor is opposite when evaluates 1 or 0.CLOCK is stepping impulse signal input end, on falling edge of each impulse, electrical machine generates a stepping. HALF/FULL is half step or basic step pitch mode setting, 1 is half step mode, and 0 is basic step pitch. If HALF/FULL evaluates low level, when impulse distributors are in odd number state, then is two-phase incentive mode; when impulse distributors are in even number state, then is single-phase incentive mode. When CONTROL chopper control is 0, controls INH1 and INH2, when is 1, controls ABCD.ENABLE enables input, when is 0, INH1, INH2, A, B, C and D all is 0.RESET input, when is 0, pulse distributors return to initial state. In circuit, the two resistances in fifteen feet of L297 used for adjusting the reference voltage of chopper circuit, which is compared to the feedback potential size through pin 13.14 to confirm whether to process chopper control, thus achieved to control the current peak of machine winding and the aim to protect stepping motor.

2.6 OPERATION EFFECT MONITORING OF SYSTEM

For adjustment, eccentric bunghole automatic positioning system sets up manual functions, X axis, Y axis both can realize inching. Bunghole circular image coordinate and world coordinate can be displayed real-time. The chose steeping angles of electrical machines α is 0.91°, which adapts belt drive, the diameter of gear pitch is 12.59mm, and pulse equivalent of stepping motor is 0.1mm.

The positional accuracy of computer vision eccentric bunghole automatic positioning system is the sum of eccentric bunghole circle recognition error 0.06mm and filling gun moving error 0.1mm,its value is 0.16mm.

Every time detects an eccentric bunghole ,the runtime of positioning system is the sum of eccentric bunghole circle recognition time and the time of machine control stepping motor drive aligns to eccentric bunghole circular, which is about 6.5 seconds.

Operating effect shows this the positional accuracy of this computer vision eccentric bunghole automatic positioning system is superior, running speed is fast, and realized conveniently and speedily, which has a practical importance to improve bottling equipment industry.

3 Conclusion

In order to solve the accurate positioning problem of eccentric bunghole during stepping bunghole filling, this paper develops an eccentric bunghole self-positioning system based on computer vision technology. At first makes a brief expound to system working process and working principle, then aims to the working process of this automatic self-positioning system to make analysis and explanation one by one: the vidicon calibration adapted by this paper dispense with artificial participation, all the calibration progress are completed automatically, including target image, threshold cutting, reference circle array mark, automatic withdrawal of reference circle array mark and the vidicon parameter calculation based on the least square fitting these six steps, finally proposes a new Hoff transform algorithm. This algorithm uses circle edge outline information features directly deletes straight edge and noise point, as well as refuses accumulate meaningless image information. Compared with traditional Hoff transform, its accumulation parameter domain is two-dimensional array, the computational effort is low, operation speed is high and can save computer memory usage effectively; then this paper designs stepping motor drive system with the core of L297, L298, after this system receiving the eccentric bunghole information coordinate sent by computer, drive syringe removes to the upward side of filler, thus realizes automatic positioning filling. Finally, obtains the self-positioning system of computer vision eccentric bunghole has the advantages of high positional accuracy and fast operational speed, which has a widely practical significance and application value.

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Authors

Wei Yuan, born in 1973, Shaanxi Province of China

Current position, grades: PhD Candidate, associate professor
University studies: Bachelor of science degree was earned in major of the application of electronic technology, Shaanxi Normal University in July, 1997; master of engineering's degree was earned in major of science and technology, Xidian University in April, 2007.
Scientific interest: infrared image system simulation and evaluation

Jianqi Zhang, born in 1960, Shaanxi Province of China

Current position, grades: professor, PhD candidate supervisor
University studies: Bachelor of engineering's degree was earned in major of physics, Xidian University in 1982; master's degree was earned in major of physical and electronic components in Xidian University in 1987; PHD degree was earned in major of microelectronics science and technology, Xi'an Jiaotong University in 1998.
Scientific interest: photoelectric imaging system simulation and evaluation