The study on robot eviscerating technology and visceral contour recognition based on image processing for poultry

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Abstract. In this study, robot eviscerating technology was used in the poultry slaughter industry. The poultry viscera were grabbed by the manipulation with the guidance of machine vision technology. A machine-vision-based method of locating the viscera of poultry carcasses was described. The threshold segmentation method, sobel operator and image operations were used to segment the images of poultry viscera. Subsequently, the visceral contour was extracted and its position was detected for common poultry such as Three-Yellow Chicken. The identification rates of this visceral contour recognition system were 95.3%, suggesting that the proposed image recognition algorithm could achieve the accuracy required for poultry visceral contour detection. Therefore, the traditional artificial poultry eviscerating would be replaced by robot eviscerating technology, and the new technology exhibited higher automation program and better eviscerated effect, the location prediction of viscera and the positioning of the machine vision system could be designed, the new technical means were provided for subsequent research on the conveyor chain of poultry eviscerated.

1. Introduction

With the improvement of economic development and people’s living standard, the structure adjustment and upgrading in the traditional industry had become the consensus of industry development. The development of poultry meat processing was rapid, poultry slaughtering equipment demand was huge. In the traditional poultry slaughtering production line, most of the process were completed by manual work, such as hanging, sorting, eviscerating, decoupling, sorting, segmentation, etc. Because artificial labor were intensive, and work environment was very bad, workers tend to be infected poultry diseases, it obviously could not meet for long time operation[1,2,3,4]. Compared with the traditional artificial eviscerated operations, the machine vision technology was applied to automatic poultry eviscerated robot system, and it had a high quality, high speed, high intelligence and other irreplaceable advantages. According to the current market demand and related technology research, the combination of machine vision and industrial production, not only improved the product quality and reliability, but also ensured the efficiency of industrial production, it was of great significance.

In recent years, the raw materials increased and the processing enterprise labor cost due to the poultry breeding, food safety was acknowledged and quality accidents had the huge impact, the introducing advanced technology such as machine vision, robot and so on, which were introduced into traditional poultry slaughtering industry, could improve the automation of production, ensure the safety of poultry processing health, improve the production efficiency, and reduce labor intensity, it had become the development trend for a modern poultry processing enterprises and automatic slaughtering equipment pressing needs[5,6].
In this study, the parallel robot technology was applied to automatic poultry eviscerated robot system, automatic poultry eviscerated system was set up based on parallel robot, and effectively solved the slow artificial eviscerating efficiency and the problem of large labor intensity.

2. Materials and methods

2.1 The process for eviscerating poultry
The process for poultry eviscerating was one of the key links in poultry slaughtering and processing, it was strict in operation process in order to ensure the integrity of the viscera, improve economic value of the products, and avoid the hidden trouble caused secondary meat pollution because of the viscera damage. Artificial auxiliary line for eviscerating usually consisted of six to eight process, according to the difference of the production capacity, each working procedure performed by 1 to 3 people, the operator was very dense, and the maximum production capacity in the poultry slaughtering and processing line which used by artificial auxiliary line was 3000/ hour, and it was unstable in product quality[7,8,9,10]. Figure 1 was poultry hanging conveyor chain, figure 2 was the artificial auxiliary line. However, the biggest processing capacity of automated processing equipment production line could reach 8000-12000 / hour, and it was stable, health and safety. In all poultry slaughtering operations, the process that the internal organs were taken out from the carcass became the bottleneck which blocked poultry slaughtering processing in the large-scale production and product quality.

Automatic eviscerated processing for poultry was one of the key technologies, it realized the standardization and scale of poultry processing, reduced the production cost, improved the meat quality and health and safety[11,12]. The structure and working principle of all multiple devices in the processing system for eviscerating poultry were basically similar, the control unit adopt spatial cams mechanism (cylindrical cam or conical cam), the same structural cam manipulators multiply as executive component were around circumferential direction, execution units revolve about the cam by hanging conveyor system, and the control execution parts which was controlled by the process of turning the cams completed the corresponding operations. The mechanical structure and function of each device were different, which completed rotary cutting, shearing, harvest (to pick/clip) gut and lungs, inside and outside clean and wash, and other functions. When the poultry viscera was took out, poultry were hanged on the suspension conveying line for the viscera processing. The eviscerated processing technology of the key working procedure had anal cutting, open the chest cutting, eviscerating poultry and lung absorption.

2.1.1 Anal cutting
The hanging poultry carcass moved in the conveyor chain which actuated by the conveying device, a rotating cutter on avian body anus fixed before cutting[13]. The key point in the process was the reasonable design of spatial cam mechanism and cam manipulator of gear transmission mechanism, etc, it had made complete rotating knife down and rotary cutting motion to fix the poultry anus. The structure design of the cam manipulator was also the difficult point in the process.

2.1.2 Open the chest cutting
After the poultry hanging on the conveyor chain entered the breast opening machine, the breast opening knife entered into the chest of the poultry along the incision, the blade swung along the central axis, clung to the sternum, and cut down the sternum center to facilitate internal operations. The key point was the reasonable design to cam manipulator which was composed of cam mechanism and the four bar linkage, to complete radial telescopic movement and swinging along one axis[14]. In the research , the shape of the cutter was also another major task.
2.1.3 Eviscerating poultry
At present, for the present investigation, two types of eviscerating poultry were used in the eviscerating poultry equipment, the cylindrical cam structure and conical cam structure, but this study used the end of the actuator to mimics the eviscerated operations by parallel robot system[15]. Poultry hanging conveyor chain entered the work scope of eviscerated robot to eviscerate for poultry by using intermittent movement.

2.1.4 Lung absorption
When the poultry were eviscerated, most of the internal organs of poultry including heart, liver, gut, wordy, gizzard were took out, the lung sat between the back of the skeleton, and other internal organs were relatively independent, suction lung machine was used to take internal organs homework including lung and hemorrhage left, The key technology of poultry eviscerating was processing station control vacuum pump valve to complete lung operation.

2.1.5 Cleaning inside and outside
Because visceral injury and pollutants might be caused when the poultry were eviscerated, it was necessary to clean the poultry carcasses both inside and outside[16,17]. Key technologies were start-stop with location control flow, the technology had similarities with vacuum lung operation.

2.2 Intelligent robot system for eviscerating poultry
At present, on the poultry slaughtering production line, poultry processing was largely manual, it increased labor costs and management costs, also increased the risk of secondary pollution[18,19]. Considering poultry slaughtering industry development present situation and the actual demand, robot system was constructed based on machine vision, robot, motion control, advanced technologies such as automatic poultry eviscerated, as shown in figure 3. Robot system was mainly composed of PC and motion controller, parallel robot, manipulator and machine vision system based on industrial camera. LG - DELTA series robot was the four degrees of freedom parallel robot, the motors were installed on the fixed support, the inertia of the robot motion platform was small, very quick action and high repeat precision, top speed was 5 m/s, repetitive positioning accuracy was ± 0.05 mm. Robot end executor was the manipulator.

The camera in the system was CR - GEN3 - M640x Genie series camera which met GigE Vision standard, and it was dedicated to digital camera products offered by machine Vision field. Its development platform could support both CCD and CMOS imaging sensor chip. The camera resolution was 640 ×480, pixel size was 7.4 microns.

Robot control system consisted of upper and lower machine. Industrial camera was used in the upper industrial PC, and it gathered the poultry images on the conveyor chain to the industrial control
computer, machine vision algorithm was used in the system to locate and track for poultry viscera center, the parallel robot manipulator was moved to eviscerate poultry carcass through a motion controller. The whole process was divided into four parts: image preprocessing, target extraction and center identification, fetching manipulator.

1) Image preprocessing: the image information was collected and denoised to eliminate the interference of the noise of image, canny operator was used for binarization to extract the target from the background image.

2) Target extraction: after images were processed, the incomplete part was filled and deleted, the target for breast opening was extracted to improve the efficiency of recognition.

3) Recognition: the target image centroid was marked to obtain the position tracking center.

4) Manipulator grasping: after poultry target centroid coordinates was calculated, information was sent to servo motor drive, the eviscerated grab work was done by the end of the manipulator.

The image processing process of the poultry automatic eviscerated robot system based on machine vision was shown in figure 4, the image acquisition for poultry was got through the camera on the conveyor chain, and through the recognition algorithm for contour recognition, calculating the shape characteristics of the relevant.

2.3 Target extraction

2.3.1 Camera calibration
Camera calibration was the key step in the visual system development, its basic task was processing the image collected through the camera in order to obtain the geometry information in three-dimensional space, and identify the object. According to the result of camera calibration, it could be calculated by the target in the image to the position of the robot coordinate system, the role of camera calibration could be expressed by figure 5. A model of camera calibration algorithm and the direct linear method were used by the system, the calibration results were confirmed with the direct linear method after calibration, The calibration results made this system be more accurate to recognize the target outline for subsequent target tracking and robot grab provided the basis.

![Fig. 3. Poultry eviscerated robot system automatically](image)

![Fig. 4. The flow chart of target recognition](image)
2.3.2. Image preprocessing

Poultry carcass images after abdominal incision were shown in figure 6. Image preprocessing might improve the image in the data signal-to-noise ratio and background noise suppression[20]. The purpose was to reduce the follow-up the pressure of the image processing. The quality of preprocessing directly affected the characteristics to extract, such as the edge of the target image, Angle, area, and the edge of the object centroid etc.

![Fig.6. Opened poultry carcass image](image-url)

![Fig.7. The abdominal cavity contour of poultry](image-url)

The classical edge detection operator, such as Prewitt Sobel operator, Canny operator and the Laplace operator, Sobel operator had better SNR and high performance edge location and good detection effected under the noise environment, suitable for different environment of edge detection. This paper selected Sobel edge detection operator to calculate the edge of workpiece.

Sobel operator was a kind of discrete differential operator. The interpolation points between pixels of the 3x3 window were used for calculation, and different weights were set to suppress noise points. Sobel operator template was small, the relative computation was also small. However, because the size of the template was even, the pixels could not be placed in the center of the template, and there was a half pixel dislocation in the result of processing. The calculation formula of Sobel operator was as follows:

\[ \nabla F = \sqrt{V_x^2 + V_y^2} \]

Where,

\[ V_x = (F(x+1, y) - F(x-1, y)) + 2F((x, y+1) - F(x, y-1)) + F((x+1, y+1) - F(x+1, y-1)) \]
\[ V_y = (F(x+1, y) - F(x-1, y)) + 2F((x, y+1) - F(x, y-1)) + F((x+1, y+1) - F(x+1, y-1)) \]

Sobel operator was used to detect the image edge, the operator used the two-dimensional first derivative of gaussian function to smooth the image, then calculated the gradient of the smooth after image amplitude and direction and the maximum inhibition, finally, edge were detected and connected. The interference factors were removed by morphological operation, and the results were shown in figure 7, the image segmentation result was the contour of the abdominal cavity of poultry.
Under the guidance of the visual system, the manipulator could take the internal organs out from the poultry, so as to realize the evisceration of poultry.

3. Results and Discussion

The main contribution of this study was the development of a region-oriented image segmentation algorithm designed to detect the viscera position of the poultry, and then the robot hand was guided for grabbing the viscera using position recognition. Figure 7 showed an original image of a poultry carcass obtained by the image recognition system, Figure 8 showed the image segmentation result of the Chicken gizzard, Figure 9 showed the image segmentation result of the Chicken heart, therefore, the threshold segmentation method could clearly distinguish the heart and gizzard from the background. To avoid damaging the visceral organs when the poultry viscera were handled, the positioning of the robot hand was very important and should be carefully chosen. When the positioning was incorrect, the robot hand might unevenly grasp the internal organs. Therefore, the robot hand grasped the internal organs according to the internal organs identified by the machine vision system.

Table 1 presented the segmentation performance of the proposed method on images of chickens. The results showed the optimal separation (95.3%) of the poultry carcass areas, which enabled the centroid of each part of the chicken to be estimated accurately. In addition, most errors found in the image segmentation procedure were due to isolate small clusters of pixels, mainly located at the boundaries of adjacent regions. Furthermore, these errors could be detected and corrected when the features of each segmented area were calculated.

| Species               | Chicken (%) |
|-----------------------|-------------|
| The heart area        | 92.0        |
| The gizzard area      | 89.6        |
| Poultry carcass area  | 95.3        |

Fig. 8. The image of chicken gizzard  Fig. 9. The image of the chicken heart

4. Conclusions

In this study, a robot eviscerating system was used for poultry slaughtering, and a method was proposed to determine the position of poultry visceral organs. It was of great significance to research and develop the high degree automatic poultry eviscerated robot system, slaughtering and processing technology equipment could improve work efficiency and avoid human infection in China, large-scale production and the huge demand for technical renovation and upgrade technology were met for the enterprises, and it greatly promoted the fast transformation of poultry processing enterprises, gave rise to mass production to meet the huge demand for the domestic market for high quality meat products.
ACKNOWLEDGMENTS
This work was supported by the 2015 Year Youth Foundation of Wuhan Donghu University and 2016 Year Science and technology research project of Hubei education department.

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