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The Bovine Iris Location Method Based on Dynamic Contour Tracking and Least Square Principle

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Abstract

Bovine iris recognition technology plays a very important role in meat food traceability system about large-scale livestock individual identification. In order to improve the precision and speed of bovine iris location, iris inner and outer edge location method based on dynamic contour tracking and least square principle ellipse fitting were respectively proposed in the paper, according to the characteristics of bovine iris image. For iris inner edge location, firstly, the pupil centroid was determined, and pupil sub-image was separated from eye image, then, using dynamic contour tracking method based on the non-initialized level set model to track the boundary of pupil, and got iris inner boundary. For iris outer edge location, noise reducing template was determined by pupil sub-image, which combined with mathematical morphology operators to further suppress random noise, so, ideal outer edge detection curve was obtained. Finally, it got iris outer edge of ellipse fitting based on least squares principle. Experimental results shown that this method was less running time, high location accuracy, it has a certain practicality in large-scale livestock meat food traceability.

***Keywords**: Bovine iris location, Dynamic contour tracking, Least square principle, Level set*

1. Introduction

At present, governments and consumers pay high attention and widespread concern to "safe meat". European and American countries, and some developed countries and regions asked for beef, pork and lamb meat products that export to these locality, it must be had traceability requirements [1-4]. To achieve meat food full supervision from "farm to table", improving traceability accuracy, accurate individual identification of large-scale livestock is an important part for meat food safety control.

Traditional large-scale livestock individual identification relies mainly on electronic ear tag, or by making brand to identify individual. These methods bring hurt and pain to animals, mark might become difficult to distinguish due to abrasion, and easy to be modified, resulting in loss of credibility [5-6]. Iris has a natural anti-counterfeiting, uniqueness, non-invasive, stability, security, and high recognition accuracy. Using iris biometrics feature as an identification way for large-scale livestock has technological superiority over conventional methods. In beef food safety traceability, using specific tags and some technical means, corresponding to individual identification, it can track individual beef cattle quickly and effectively, help government to improve supervision capability and meat products international competitiveness, and thus protect meat product quality and improve economic benefits of enterprise [6]. It provides certain reference value for large-scale livestock meat food safety management.

Currently, many scholars have done more exploration in iris recognition technology for human identification. Meanwhile, in large-scale livestock individual identification, the

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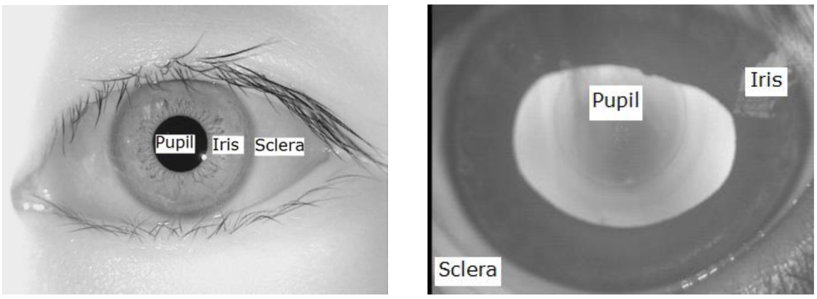
foreign studied more research than China. By constantly invested and studied, some countries had animal iris recognition system, such as American, Japan [6]. In 2001, Massahiko Suzaki has established a racing horse identity authentication system based on iris recognition to manage racing horse [3]. A.Allen and M.Taylor gathered a large number of cattle retinal image, they achieved livestock authentication purpose by using retinal image to study their biometric feature [7]. Combined B-spline interpolation algorithm and Hough transform, Q.Kong and L.D.Zhao took bovine iris as concentric, and located iris boundary [6]. D.W. Sheng detected iris inner and outer edge by using ellipse fitting with least squares principle [8]. There is obviously different in shape between human and bovine iris image, as is shown in Figure1.Human inner and outer iris edges are approximately circular, however, bovine iris region is similar to an irregular ellipse ring, its middle protruding but around concaving, main texture distributes on the outer ring. The contrast of inner and outer iris edge is low. Therefore, inner and outer edges of concentric circle fitting method and pupil approximate ellipse method to separate bovine iris from eye image often can't obtain ideal iris, part iris information will be lost, which will directly affect subsequent recognition accuracy. A fast and accurate bovine iris location algorithm is adopted to detect bovine inner and outer iris edge, dynamic contour tracking combined with least square principle fitting method.



(a)Human iris image (b)Bovine iris image

Figure 1. The Comparison of Human and Bovine Iris

2. Bovine Iris Location Algorithm

Generally, the processing of iris recognition is divided into four stages, image acquisition, iris location, feature encoding and matching. Among them, iris localization is the most important step during the process of iris recognition. It is necessary to determine iris inner and outer edge, then, circular iris region is extracted from iris eye image, the locating result will directly affect subsequent recognition effect.

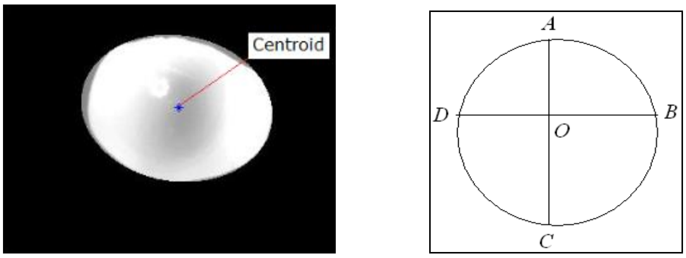
Using circular geometric properties for location, pupil and iris outer edge are seen as circular for many human iris localization algorithm. At first, Daugman detected human iris edges with calculus operator, later, he detected it based on active contour edge [9]. But bovine pupil is similar to oval, a more accurate iris location method must be adopted to get accurate bovine iris inner edge.

In view of the characteristics of bovine iris image, we used different strategies to detect bovine inner and outer edge of iris.

2.1. Pupil Center Detection

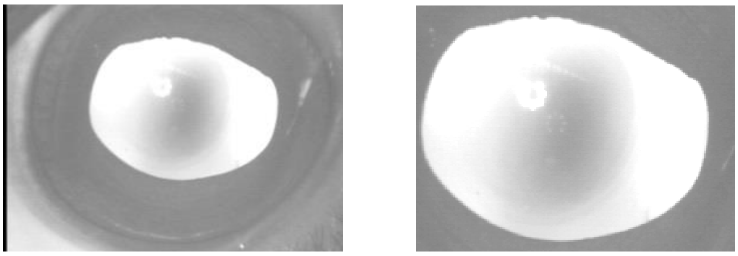
Unlike human iris images, bovine iris image has the highest gray for pupil, followed by sclera, iris gray value is the lowest, the left and right sides of pupil has a higher gray than center. According to bovine eye image gray distribution, binarizing image with certain method, removing part of interference with mathematical morphology, then, obtained a clear pupil curve, calculated the center of pupil with least square principle, then, pupil sub-image is separated from bovine eye image.

Assuming that the pupil centroid O, in horizontal and vertical direction of point O,looking up and down, left and right edges of pupil, respectively, namely A, B, C and D, four points in all, as is shown in Figure 2(b). Fitting a circle to seek and obtain pupil image centroid using the least squares principle, then, obtained pupil sub-image, as can be seen in Figure 3 (b).



(a) Pupil after removing interference (b) Centroid location principle

Figure 2. Pupil Centroid Detection



(a) Original image (b) Pupil sub-Image

Figure 3. Pupil Segmentation of Pupil Sub-image

Assumed center coordinates is (x_c, y_c), r represents radius, fitting circle by using least squares principle [11], there is

$$(x-x_c)^2+(y-y_c)^2=r^2 \tag{1}$$

Let $a=-2x_c, b=-2y_c, c=x_c^2+y_c^2-r^2$, another form of circular curve equation was got

$$x^2+y^2+ax+by+c=0 \tag{2}$$

The center (x_c, y_c) and radius r can be obtained after parameters a, b and c are determined:

$$\begin{cases} x_c=-a/2 \\ y_c=-b/2 \\ r=\sqrt{a^2+b^2-4c}/2 \end{cases} \tag{3}$$

Under the principle of minimizing square error estimation, and least squares estimation for circle parameters is

$$X=(U^TU)^{-1}U^TV=U^{-1}V \tag{4}$$

where

$$X = \begin{bmatrix} a & b & c \end{bmatrix}^T, U = \begin{bmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ x_3 & y_3 & 1 \end{bmatrix}, V = \begin{bmatrix} -x_1^2 - y_1^2 \\ -x_2^2 - y_2^2 \\ -x_3^2 - y_3^2 \end{bmatrix} \tag{5}$$

(x_1, y_1) 、 (x_2, y_2) and (x_3, y_3) were 3 points coordinates among A, B, C and D, calculated 4 cases of center coordinates respectively, finally, the average as pupil center.

2.2. The Location of Iris Inner Edge

Bovine pupil scaling will lead to iris region change, pupil boundary is irregular curve, Taking bovine pupil location result as a circle or an ellipse is not entirely true boundary of pupil. Therefore, how to accurately detect the real pupil boundary, overcome the distortion influence caused that pupil is taken as standard circle or ellipse to normalize iris image, which is a hot study topic for iris recognition. Although pupil edges are not standard circle or ellipse, but it is a continuous closed curve, dynamic contour tracking method may be adopted to detect pupil edge in sub-image, then, it obtained accurate inner iris edge, it was nearly the true pupil boundary.

In 1988, Kass, Witkin and Terzopoulos had a breakthrough in traditional hierarchical visual model, a kind of active contour model based on energy function is proposed [12], was also known as snake algorithm, commonly applied in these field, such as edge detection, image segmentation, moving object tracking and so on. Its location accuracy had nothing to do with target boundary shape, but snake model was easy to fall into local minima, vulnerable to be affected by eyelash noise and texture characteristics of iris itself. Later, Caselles and Kichenassamy were inspired by curve evolution theory, they applied level set method to active contour description and model solution, broaden the scope of snakes model application [13]. According to features of iris image, dynamic contour tracking method based on non-initialized variational level set is adopted in the paper, which detected iris inner edge.

In image segmentation, given a closed initial contour in original image for level set method. Its initial contour will gradually approach goal at a series of external and internal forces. According to constraints, it stopped at the edge to be detected at last.

Although traditional level set method is relatively simple, easy programming. But, in order to ensure stability of evolution, it requires periodic re-initialized to a signed distance function. This will increase complexity of the algorithm and produce too sharp or flat shape, and caused subsequent calculation is no longer accurate. Li *et al* presented a non re-initialization variational level set method [14-15]

,it ensures that level set function remain signed distance function in evolution without re-initialization, by introducing a penalty term in energy function.

Image energy function can be expressed as[14]

$$\begin{aligned} E(\phi) &= \mu P(\phi) + E_g(\phi) \\ &= \mu \int_\Omega \frac{1}{2}(|\nabla\phi| - 1)^2 dxdy + \lambda \int_\Omega g\delta(\phi)|\nabla\phi| dxdy + v\int_\Omega H(-\phi)dxdy \end{aligned} \tag{6}$$

Where Ω presented image domain, $\phi(x, y, t)$ presented signed distance function. $\phi(x, y, t) = \pm d$, where d is the short distance from point (x, y) to curve, $P(\phi)$ is penalty term, it guarantees level set function always as signed distance function, μ as penalty weight coefficient, λ and v as constant coefficient, $\lambda > 0$, $\delta(\cdot)$ is Dirac function, $H(\cdot)$ is Heaviside function, and g is stop function.

$$g = \frac{1}{1+|\nabla G_\sigma * I|^2} \tag{7}$$

When internal energy $\mu P(\phi)$ evolves with the signed distance function, external energy $E_g(\phi)$ pointed to the zero level set. Given variational theory, there are

$$\frac{\partial E}{\partial \phi} = -\mu[\Delta\phi - div(\frac{\nabla\phi}{|\nabla\phi|})] - \lambda\delta(\phi)div(g\frac{\nabla\phi}{|\nabla\phi|}) - vg\delta(\phi) \tag{8}$$

Where Δ is Laplace operator, and energy function E obtains the minimum value, its necessary condition must meet Euler-Lagrange equation $\frac{\partial E}{\partial \phi} = 0$.

Obtaining gradient flow equation by steepest descent method

$$\frac{\partial \phi}{\partial t} = \mu[\Delta\phi - div(\frac{\nabla\phi}{|\nabla\phi|})] + \lambda\delta(\phi)div(g\frac{\nabla\phi}{|\nabla\phi|}) + vg\delta(\phi) \tag{9}$$

We can see that gradient flow is evolution equation of level set function. The right item 2 and 3 reflected zero level curve approximation to target edge. In item 1, where the gradient flow in internal energy $\mu P(\phi)$,

$$\Delta\phi - div(\frac{\nabla\phi}{|\nabla\phi|}) = div[(1-\frac{1}{|\nabla\phi|})\nabla\phi] \tag{10}$$

Where $(1-\frac{1}{|\nabla\phi|})$ is diffusion rate, if $|\nabla\phi|>1$, as usual, it is positive diffusion, reducing gradient, on the contrary, if $|\nabla\phi|<1$, as negative diffusion, increasing gradient.

Using finite difference method to discrete Formula (9), using central difference for $\frac{\partial \phi}{\partial x}$, $\frac{\partial \phi}{\partial y}$, using forward difference for $\frac{\partial \phi}{\partial t}$, so that Formula (9) can be expressed as:

$$\frac{\phi_{i,j}^{k+1} - \phi_{i,j}^{k}}{\tau} = L(\phi_{i,j}^{k}) \tag{11}$$

The realization for the non-re-initialization of level set method, involving the time step τ and selection of space step dx, dy, and selection of energy function parameters, such as $\mu, \lambda, v, \varepsilon, \sigma$ [12]. Time step τ is often much larger than traditional level set method, but it can't too large, generally ranging from 1 to 100. If τ is large, then, iteration speed and convergence speed will be fast, but if it is too large, it will lead to edge detection errors. So, it is necessary to select the appropriate time step to balance the iterative speed and calculation accuracy. Usually, for most images, taken $\tau \leq 10$. To ensure convergence, the relation between time step τ and penalized weighting factor is $\tau \cdot \mu \leq \frac{1}{4}$.

2.3. Bovine Iris Outer Edge Location

According to localization results of pupil centroid, designed a noise suppression template, reduced noise interference points at great extent, so that eye image left iris outer boundary points and less noise. The iris outer boundary near ellipse, ellipse fitting using least squares principle.

For iris outer edge location, as noise influence is relatively large, reducing noise model was designed, the size of pupil sub-image determined the size of noise reducing template. The relatively "clean" outer curve was obtained through noise template and noise suppression method with mathematical morphology, thus, ellipse fitting by least squares principle, fitting result as bovine iris outer edge.

Ellipse equations on plane anywhere can be described as:

$$x^2 + A_1 xy + B_1 y^2 + C_1 x + D_1 y + E_1 = 0 \tag{12}$$

Using least squares principle for ellipse fitting, that is, through calculated Euclidean distance from edge points $U = \{u_1, u_2, \cdots, u_m\}$ to ideal fitting ellipse edge points $V = \{v_1, v_2, \cdots, v_n\}$, the smallest square of Euclidean distance is the best fitting, m , n is the total number respectively for outer edge of iris image point and ellipse fitting [16-17].

By Formula (12), using least squares principle, objective function is defined as:

$$f(A_1, B_1, C_1, D_1, E_1) = \sum_{i=1}^{M} (x_i^2 + A_1 x_i y_i + B_1 y_i^2 + C_1 x_i + D_1 y_i + E_1)^2 \tag{13}$$

Let $\frac{\partial f}{\partial A_1} = \frac{\partial f}{\partial B_1} = \frac{\partial f}{\partial C_1} = \frac{\partial f}{\partial D_1} = \frac{\partial f}{\partial E_1}$ =0, then got the minimum of Formula (12), namely, linear equation of ellipse fitting can be obtained [17].

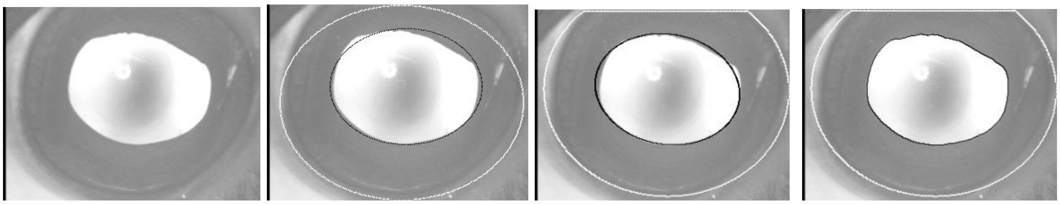
$$\begin{bmatrix} \sum_{i=1}^{M} x_i^2 y_i^2 & \sum_{i=1}^{M} x_i^2 y_i^2 & \sum_{i=1}^{M} x_i^2 y_i^2 & \sum_{i=1}^{M} x_i^2 y_i^2 & \sum_{i=1}^{M} x_i^2 y_i^2 \\ \sum_{i=1}^{M} x_i y_i^3 & \sum_{i=1}^{M} y_i^4 & \sum_{i=1}^{M} x_i y_i^2 & \sum_{i=1}^{M} y_i^3 & \sum_{i=1}^{M} y_i^2 \\ \sum_{i=1}^{M} x_i^2 y_i & \sum_{i=1}^{M} x_i y_i^2 & \sum_{i=1}^{M} x_i^2 & \sum_{i=1}^{M} x_i y_i & \sum_{i=1}^{M} x_i \\ \sum_{i=1}^{M} x_i y_i^2 & \sum_{i=1}^{M} y_i^3 & \sum_{i=1}^{M} x_i y_i & \sum_{i=1}^{M} y_i^2 & \sum_{i=1}^{M} y_i \\ \sum_{i=1}^{M} x_i y_i & \sum_{i=1}^{M} y_i^2 & \sum_{i=1}^{M} x_i & \sum_{i=1}^{M} y_i^2 & M \end{bmatrix} \begin{bmatrix} A_1 \\ B_1 \\ C_1 \\ C_1 \\ E_1 \end{bmatrix} = - \begin{bmatrix} \sum_{i=1}^{M} x_i^3 y_i \\ \sum_{i=1}^{M} x_i^2 y_i^2 \\ \sum_{i=1}^{M} x_i^3 \\ \sum_{i=1}^{M} x_i^2 y_i \\ \sum_{i=1}^{M} x_i^2 \end{bmatrix} \tag{14}$$

Where M was the number of edge points, (x_i, y_i) is edge point coordinates of Cartesian coordinates. Parameters A_1, B_1, C_1, D_1 and E_1 can be obtained through Formula (14), which determined ellipse center (x_o, y_o), long half-shaft , short half-shaft and ellipse tilt angle respectively, resulting in elliptic curve fitting.

$$\begin{cases} (x_o, y_o) = (\dfrac{2BC - AD}{A^2 - 4B}, \dfrac{2D - AD}{A^2 - 4B}) \\ a = \sqrt{\dfrac{2(ACD - BC^2 - D^2 + 4BE - A^2E}{(A^2 - 4B)(B - \sqrt{A^2 + (1-B)^2 + 1}}} \\ b = \sqrt{\dfrac{2(ACD - BC^2 - D^2 + 4BE - A^2E}{(A^2 - 4B)(B + \sqrt{A^2 + (1-B)^2 + 1}}} \\ \theta = \arctan(\sqrt{\dfrac{a^2 - b^2B}{a^2B - b^2}}) \end{cases} \quad (15)$$

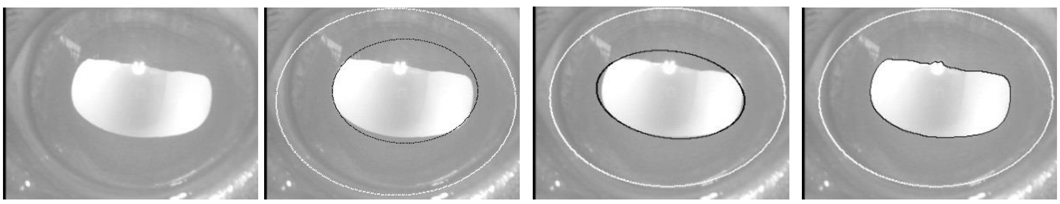
3. Experimental Results and Analysis

Bovine iris image from the first generation of large-scale feeding animals individual iris information base, which attributed the institute of systems engineering, Southeast university, bovine image size is 320 × 240. To verify the validity of algorithm, 20 images were selected. The iris inner and outer edges location method proposed was compared to two methods, one was ellipse fitting method based on Hough transform(HT), another was ellipse fitting method using least squares principle(LS). The proposed iris inner location method, ε =1.5, τ =5, μ =0.2/ τ , λ =5, v =3, the number of iterations is 300. The algorithm was simulated in the Mablab2012a, which running environment was Intel.3.2 GHz, 4GB of RAM for PC. Algorithm performance was measured by location time and accuracy two indicators, test results are shown in Figure 4, Figure 5 and Table 1.



(a) Image o50_0_1_98 (b) HT Method (c) LS Method (d) the proposed method

Figure 4. The Location Result of Image o50_0_1_98



(a) Image s041_0_0_60 (b) HT Method (c) LS Method (d) the proposed method

Figure 5. The Location Result of Image s041_0_0_60

The location method based on Hough transform and least square principle fitting ellipse, which took bovine iris inner and outer edges as two non-concentric ellipse, their ratio of long and short axis was different. As pupil image binarization was relatively clear, noise interference was small, the location accurate of iris inner edge better than outer, and location time was less than outer edge. Compared to ellipses fitting based on Hough transform, pupil image binarization and noise around outer edge affected Hough transform to a certain extent, the fitting time increasing with edge points increasing. Pupil of image o50_0_1_98 is nearly ellipse, but image s041_0_0_60's pupil is not. If the pupil edge is seen as an ellipse, the results will be not ideal.

As can be seen from (b),(c)and(d) of Figure 4 and Figure 5, compared to location results, iris inner edge location based on dynamic contour tracking method is very accurate, it is nearly pupil boundary, some iris information based on HT method will be lost, these can be seen from (b) of Figure 4 and Figure 5. Experimental results shown that the proposed algorithm has better fitting accuracy and faster speed. However, the location accuracy is not very high, for test samples are not many, we will increase experimental samples in the following research work.

Table 1. The Performance Comparison of Three Location Methods

	Iris inner edge		**Iris outer edge**	
	Accurate rate(%)	Average time(s)	Accurate rate(%)	Average time(s)
Method (HT)	85	3.19	80	3.51
Method (LS)	90	0.33	85	0.57
The Proposed	95	0.92	85	0.57

4. Conclusion

Governments and consumers pay high attention to safe meat. Developed countries and regions asked for beef and lamb meat products that export to these locality had traceability requirements. To achieve meat food full supervision and improve traceability accuracy, accurate individual identification is needed.

Due to the accuracy and credibility of traditional large-scale livestock individual identification is not ideal. However, using iris biometrics feature as an identification way for large-scale livestock has technological superiority over conventional methods, which will provides reference value for large-scale livestock meat food safety management, improve government supervision capability and meat products international competitiveness.

Using mathematical morphology and noise reducing model, it can get a clear inner and outer edge curve, which promote location speed. In view of the characteristics of bovine iris image, iris inner edge is located by dynamic contour tracking based on level set, and iris outer edge is obtain by ellipse fitting method using least squares principle. Simulation results show that, compared to other two location methods, especially for iris inner boundary location, it get more accurate fitting results and less running time, which has high practical value. However, due to spot and textures of image, there are still some images failure to accurately locate iris edge, its location accuracy need further improved.

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