Research on Body Mass Estimation Method of Koi Broodstock Base on Feeding State Image Recognition Technology

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Abstract. Koi is graceful and colorful. In the process of breeding, monitoring the growth state and predicting the body mass of the broodstock are both important. The broodstock will surface on the water while being feed. At this time, the digital camera captures the feeding state image rapidly. The head and mouth of the broodstock show the semi-spindle shape and bright color significantly which have very high contrast with the water background in the image. Based on the method of OpenCV image visual, feature triangle was defined based on the extracted colorful semi-spindle shape automatically. The projection area of the triangle in the image was computed through the vector graphics calculation by computer. A great deal of measurement data was taken analysis on the correlation between the shape parameters and the body mass of the broodstock by MATLAB. A correlation analysis model was established between the projection area of the feature triangle and the body mass. Through this method, the body mass of the broodstock in the aquaculture pond was estimated automatically. The estimating error of the body mass was lower than 9 percent. This method will reduce the workload of collecting the growth state data during the breeding process of the broodstock greatly. And the method can also improve the accuracy of the body mass estimating effectively, which has important production and application value.

Keywords. Image recognition; feeding state; extract automatically; semi-spindle; feature triangle; correlation analysis model; body mass estimating.

1. Introduction
Koi is graceful and colorful which has highly ornamental. The koi broodstock has a big body and expensive value. People need to check the growth state of the broodstock including the body mass especially. Based on the result, people can estimate the nutrition and health condition of the broodstock, and make a reasonable breeding scheme in order to ensure the quality of the broodstock as well as the safety of production. At present, the broodstock in the pond are free to move underwater, and the transparency of the water is variable. It is difficult for people to observe the overall growth state of the broodstock on the surface of the water. Usually, while the feeding time in every day, the broodstock concentrates on the feeding site and surface to eat. At this time, people can observe the growth state of the broodstock as a whole, and make a rough body mass estimate of the broodstock. The observation data is dependent on the judgment experience of people which has low accuracy, and needs to be recorded and saved manually. In order to get more accurate growth data of the broodstock, it is necessary to catch and measure manually out of the water sometimes. This method takes time and
effort. At the same time, it is easy to make the high-value broodstock injury which causes economic losses [1].

With the progress of modern information technology and image processing technology, many achievements have been made in the research of nondestructive testing of product quality based on optical image testing technology. And the method has been applied in many areas [2-7]. While cultivated to a certain size, the koi broodstock is spindle-shaped in shape, with a brightly colored and distinct head. When the broodstock rises to the surface of the water for feeding, its head-image can be distinguished from the water background. In this article, through automatic computer image recognition for the feeding status of the broodstock, the feature triangle of the head-and-mouth-part is extracted, and its projection area is computed. The analysis between the feature triangle and weight of the broodstock is taken by MATLAB among lots of sampled measured data. A correlation analysis model is established between the projective area of the feature triangle and the body mass. The body mass of the koi broodstock could be estimated through this method. The problems such as low accuracy of manual observation and measurement, tedious workload and operation risk are solved effectively.

2. Material and Method

2.1. Overview
In this paper, we designed a system solution (figure 1), including the monitoring terminal hardware system (figure 2), the data modeling and the analysis software platform. A high-definition CCD digital sensor was used to obtain real-time and clear images of the water surface at the feeding point of the koi broodstock. The continuous power supply system of solar energy was used to provide continuous power supply for video collection and forwarding. GPRS remote image transmission, storage, view system was designed which realizes the remote view, data storage and backup for people. The projection area of the feature triangle was extracted by computer automatic identification from the feeding koi image. We got the projection area of the feature triangle and the body mass by measuring lots of broodstock samples. Then we analyzed these data through MATLAB and built a correlation analysis model. We could estimate the body mass of the koi broodstock from its feeding image through this model.

![Automatic Estimation Method for Body Mass of the Koi Broodstock](image)

**Figure 1.** Design of overall scheme.
Figure 2. Design and implementation of monitoring terminal hardware system: 1. Equipment Box, 2. Solar Panel, 3. Battery and Converter, 4. Retaining Latch, 5. Lock, 6. Hinge, 7. Studdle, 8. Retaining Latch, 9. Studdle, 10. Studdle, 11. Monitoring Terminal, 12. Feeding Station, 13. Mounting Point, 14. Slope Protection.

2.2. Hardware System of Monitoring Terminal

5 mega pixel CCD Sensor integrated with OV5647 photographic chip was used to obtain 1080p high-definition image. The view angle of the image was 75.7 degree. The image acquisition controller which set time with server by GPRS started at the broodstock feeding time. One piece of image was obtained every 5 seconds. The working time of the image acquisition was set based on the broodstock feeding time through remote software platform. The monitoring terminal slept during the non-working time.

The distance between the monitoring terminal and the water surface could be adjusted by the studdle structure, which ensured the image could cover the whole broodstock feeding area.

High-speed micro-SD card in the monitoring terminal could storage the image on local. The images were transferred to remote server by GPRS. Software processed and analyses the images in batches during one working period. And the average result was feedback to the manager.

The system used 100W single-crystal solar panel, controller and 40Ah Lithium cell. The low-power sleep function ensured the system work continuously for a long time.

2.3. Data Analysis and Modeling

During the feeding time period, the broodstock surface and feed on the water. The most head-and-mouth-part of the broodstock appear over the water surface. The monitoring terminal could acquire the sharp feeding status image rapidly. The colorful semi-spindle shape showed in the image provided the base to realize the computer vision algorithm. The OpenCV open source development library was used as the based library.

First of all, we converted the color-image into grayscale. The grayscale data of the water background was get from the edge of the image and added with 5% random noise. All the head-and-mouth-part of the broodstock was extracted from the water background based on the grayscale thresholding segmentation algorithm. Then we generated a black-and-white binary image. The contour was extracted from the black-and-white binary image using the Canny-algorithm [8-9].

The eyes of the broodstock showed a black elliptical feature in the colorful image. At the same time, we set a double-eyes-distance threshold to extract and couple the double eyes for the broodstock. The threshold was set by the year of the broodstock. For the 3 years broodstock, the threshold was set as 3-4 cm. The eyes position could be extract well based on the grayscale feature while the couple eyes of the broodstock show on the image clearly [10-11]. While the couple eyes were not gathered together because of its gesture, at least one eye could show on the image at this time. The lost eye needed to be filled by special algorithm. The program traced along the contour beginning from the nearest point from the showed eye based on the threshold. While finding the first point on the contour in the threshold, this point position was considered as the lost eye position.
Removing the influence of open mouth to the feature triangle, the program traced along the contour among the couple eyes and computed the tangent slope of the contour for every point. The program set a change threshold of the slope in order to remove the contour points of the open mouth. Then the program closed the breakpoint position of the open mouth with a line.

The head feature of the koi broodstock is left-right symmetric along the mid-perpendicular of the couple eyes. The intersection between the mid-perpendicular and the mouth contour was considered as one vertex of the feature triangle. The couple eyes position were considered as the other two vertices of the feature triangle (figure 3).

\[
p = \frac{a + b + c}{2}
\]

\[ p \text{ (unit: cm)} \] is semi-circumference of the feature triangle. a, b and c \( \text{(unit: cm)} \) is the side length of the feature triangle.

\[
S = \sqrt{p(p-a)(p-b)(p-c)}
\]

\[ S \text{ (unit: cm}^2\) is the area of the feature triangle computed from the image.

\[
\frac{S_{real}}{S} = \frac{L^2}{f^2}
\]

\[ S_{real} \text{ (unit: cm}^2\) is the true area of the feature triangle. L \text{ (unit: cm)} \] is the subject distance. f \text{ (unit: cm)} is the focal length.

The L and f could be set as a constant based on the water surface and imaging condition. And they were set in the remote software platform. The program could compute the \( S_{real} \) automatically.

Body shape of the koi broodstock is spindle shape. The figure proportion of a healthy koi broodstock is very regular. The head size and the body mass have a high correlation [12]. We took 50 tails of broodstock as the samples. And then we weighed the body mass of each broodstock. We gathered the orthorectified image of each broodstock head. We took a 1 cm scale as the reference length, and computer the side length and area of the feature triangle from each image [13]. We analyzed the area data of the true feature triangle and the body mass data through MATLAB software. The body mass estimation model of the koi broodstock was established (figure 4).
Figure 4. Correlation analysis between area of feature triangle and body mass.

\[ W_{\text{test}} = 153.8S_{\text{test}}^{0.9666} - 1316, R^2 = 0.9935 \]  

(4)

\( W_{\text{test}} \) (unit: g) is the true body mass of the broodstock. \( S_{\text{test}} \) (unit: cm²) is the true area of the feature triangle.

The estimation error could be evaluated by the difference between the true data and the estimation data.

\[ f = \frac{|\rho_1 - \rho_2|}{\rho_2} \]  

(5)

\( f \) is the estimation error. \( \rho_1 \) is the estimation data. \( \rho_2 \) is the true data.

3. Result and Analysis

3.1. Experiment Result

In the experiment, we selected 10 tails of koi broodstock which were different varieties. At 10am and 3pm feeding time, the feeding state images were collected. These images were selected and analyzed by the remote software platform. The body mass estimation result of each broodstock was computed. Then we weighed the body mass of each broodstock manually and note the data [14].

The result shows that the body mass estimation error of koi broodstock could be lower than 9% (table 1). The method could meet daily application requirements for the koi broodstock culture.

3.2. Error Analysis

Because the head and mouth of koi broodstock will surface on the water while it feeds. And the water quality is well in the broodstock pond. These factors ensure the quality of the feeding state images. The estimation error mainly includes:

At first, the model error could be reduced while the more sample data was used to build the model [15].

The second, the error comes from the image in which one eye of the broodstock loses. We should collect more images and select good quality image. Then we delete the abnormal data and compute the average data in order to reduce the error.
Table 1. Experiment result.

| Broodstock  | Estimation result/g | Weight body mass/g | error |
|-------------|---------------------|--------------------|-------|
| 1           | 2067.87             | 2210.35            | 6.4%  |
| 2           | 2441.62             | 2287.48            | 6.7%  |
| 3           | 2082.43             | 2163.17            | 3.7%  |
| 4           | 1982.5              | 2053.87            | 3.5%  |
| 5           | 2050.35             | 2127.46            | 3.6%  |
| 6           | 2451.48             | 2257.35            | 8.6%  |
| 7           | 2196.51             | 2364.7             | 7.1%  |
| 8           | 2256.3              | 2351.25            | 4%    |
| 9           | 2387.25             | 2572.6             | 7.2%  |

The third, the head and mouth of the koi broodstock is not on the same image plane with the water surface, which makes some error for the area computing of the feature triangle.

At last, the vector operation of the OpenCV has some error. The optimization of algorithm and data structure could reduce the error.

4. Conclusion

We designed and realized a body mass estimation method for koi broodstock automatically. The method could solve the uncertain of observe and measurement by people. The method also reduced the operation risk of traditional method. The large number of feeding state images also supplies the data base for people to research the behavioral or physiological feature of the koi broodstock. The method has scientific, objectivity and accuracy, which has the guiding significance for the culture and management of the koi broodstock.

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