Implementation of Digital Image Processing to Determine The Body Dimensions of Nile Tilapia Fish

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Abstract. The present work aimed to use digital image processing techniques for identifying body dimensions of Nile Tilapia. The total number of exoskeleton measurements made on fish body dimension are high in aquaculture as it is used to predict the weight, feeding schedule, breeding and market value. Current fish measuring methods can be time-consuming and susceptible to human error. In this research, an automated and effective fish measurement system with digital image processing is proposed. It consists of taking images of the fish, segmenting the fish body from its background and finally using contour detection to measure a set of dimensions such as length, height and width. This analysis is applied on these dimensions to find the weight of specific fish. Overall, the results reveal that the image processing methodology may successfully reproduce manual measurements with a great degree of accuracy and hence can be a suitable tool for applications in aquaculture practice. This may greatly cut down on operations.

Keywords: Image Processing, Nile Tilapia, Body Dimensions, Fish Measurement.

INTRODUCTION

The advancement of the aquaculture industry makes it important for fish farms to find ways to monitor growth and improvement on fish. Among them Nile Tilapia is one of the most popular fish species for cultivation due to the high rate of growth and trophic plasticity, and a high demand from consumers [1]. Fish weight is an important determinant maintaining and feeding the fish to prevent cost implication that might affect sales of fish. Prior efforts on fish weight estimation require direct measurements of fish dimensions including width and length, which often are deemed cumbersome, time-consuming and prone to errors [2]. These limitations affirm the importance of automatic and more accurate calculation of fish weight by a new techniques.

Several mathematical approaches have been reviewed below as a guide to the automation of fish body measurements using digital image processing. When taking pictures of fish and passing the pictures through a set of algorithms, the body dimension including length, width and area can be approximated from the pictures and then used to predict the weight of the fish [3]. There are several advantages of this method, first of all, it is possible to analyze a large amount of fish images in short times, second, this method can be integrated into existing farm monitoring systems. In addition, image processing can reduce the degree of handling stress in fish, which is a major issue when employing manual means of measurement [4].

Image processing based on fish dimension estimation generally has several important stages. A cameraman taking the photo in studio like setting in order to maintain the standard of lighting and background. In the next step, pre-processing techniques are used to minimise noise and to amplify important features zone like edges and contour of fish. Thresholding or edge detection methods are applied to extract the fish from the background, the shape and size of fish is then detected through contour detecting algorithms [5]. These dimensions can then be identified with the fish's weight by using formulated equations extracted from past records that weigh the fish, making it easier and less destructive method of weight estimation as compared to the traditional method.

Nonetheless, there will always be a few setbacks in the application of image processing in aquaculture. For example, the orientation of fish, light conditions, and image quality may influence the degree of correctness of the measurements [6]. With the evolution of the computer vision and machine learning, these techniques has been enhanced and their probabilities turned out to be more accurate and results oriented hence making them usable in fish farming. As such, in this paper, an experiment is described in which digital image processing is employed to estimate the body dimensions of the Nile Tilapia fish. Using segmentation and contour detection techniques, we design an image processing based method to estimate the length, width and hence the area of the fish from the images. Our work quantitates and compares the variability of these measurements to standard manual assessment, and we determine the applicability of this technology to aquaculture environments. In view of these findings of the experiments carried out herein, we can confidently note that digital image processing is reliable as well as effective in assessing fish dimensions, potential enhancement of fish farming.

METHODS

The methodology used in this study consists of four key stages: are image acquisition, image pre-processing, fish segmentation and dimensional measurement. These stages are aimed at reducing possibility of under estimation of size of fish body dimension such as length width and area which are important in defining overall fish size. The image processing stages are presented in **FIGURE 1**

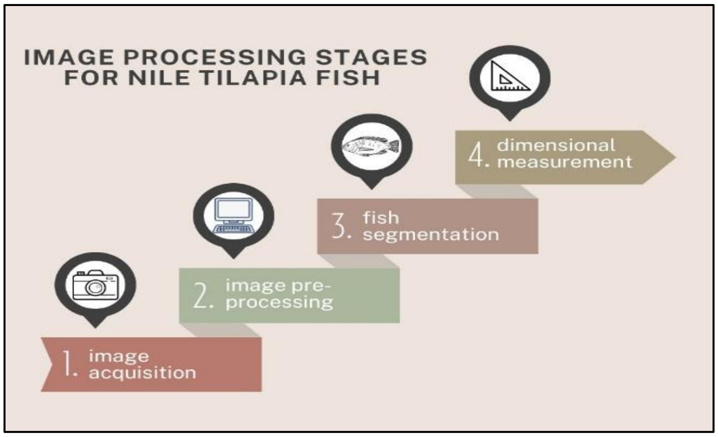

FIGURE 1. Image Processing Stages for Nile Tilapia Fish

The first step in image acquisition is the obtaining of good images of Nile Tilapia. Much care was taken to standardize lighting to maintain a high level texture background, and to position the fish in a standardized way. The fish were put on a background whose colour did not interfere with that of the fish's body, and pictures of the fish were taken using a digital camera with a high resolution and placed at a fixed distance equidistant from the fish. This as a setup hoped to reduce the interference of such extraneous variables as shadows and glares that could distort picture quality [7].

In total, fish images of 100 JPEG files with the size of 1920 x 1080 were taken. The high resolution was required to accurately see the fine structures of the fish, especially what are known as the boundaries of the bodies, which are important when used later in more in-depth operations. The fish were placed in standardized position with the lateral view fully captured in the images as this view gives more useful information about dimensions of the fish.

Image pre-processing is very essential and forms part of the image preparation process for further use. The main aims of pre-processing are to minimize noise, enhance contrast and emphasize feature such as the border of a fish. The first phase was basic dachelisation. Thus, transforming color information into grayscale is justified as color data is not crucial for contour detection, and the transformed picture makes analysis easier and the amount of calculation required lower [8].

Then, median operation was adopted to eliminate noises while at the same time, retaining significant characteristics especially edges. The median filter operates in a progressive way: at each iteration the value of each pixel is replaced by the median of the pixel's neighbours; this action will filter rather short oscillations while preserving edge transitions; for instance, the transition between the fish and the background [9].

To enhance the brightness and sharpen the fish contours further the process of histogram equalization was done. This technique tends to adjust the ratio of effective values within the image in order to make clear distinctions between the edges of the fish. With increasing the difference between fish and backgrounds, segmentation and contour detection can be done more precisely [10].

After pre-processing, the subsequent issue was the segmentation step of the fish from the background. For this task, Otsu's thresholding method was used. As for the threshold, Otsu's method is to subtract in real-time the optimum threshold for the image by minimizing the inside-class variance between the foreground (the fish) and the background [11]. This method is most success for those objects whose images had low background interferences; this was made possible by the controlled imaging environment.

During segmentation, the input grayscale image is converted into a binary image where the fish forms the foreground and background forms the background. This binary image is then used to do the edge detection on the fish and hence the contours of the fish.

Once gross segmentation of the fish from the background has been achieved the next step is to find edges or borders of the fish. For this purpose, the Canny edge detection was performed Using Open computer vision. Canny's method is prestiged for its ability to be accurate in detecting many edge while at the same time recording low error. It involves a multi-step process: firstly all the image gradients are computed and then through non-maximum suppression all the edges are thinned down and then through hysteresis thresholding we get the weak connecting edges linking with strong edges [12]. We can see the implementation of Canny in the OpenCV library in Python in **FIGURE 2.**

```
python

import cv2

# Membaca gambar
image = cv2.imread('gambar.jpg', 0)  # 0 untuk grayscale

# Gaussian Blur
blurred_image = cv2.GaussianBlur(image, (5, 5), 1.4)

# Canny Edge Detection
edges = cv2.Canny(blurred_image, threshold1=100, threshold2=200)

# Menampilkan hasil
cv2.imshow('Original Image', image)
cv2.imshow('Edges', edges)
cv2.waitKey(0)
cv2.destroyAllWindows()
```

FIGURE 2. The Implementation of Canny In The OpenCV Library In Python

The end product of this process is a set of edges that poise the general shape of the fish perfectly. It is at these edges that the overall shape of the body of this fish is outlined. Profile detection is very important because it is from this step that the dimension of the fish will be measured. Once determining the outer perimeter of the fish, it becomes very easy to measure other outstanding dimensions of the body. **FIGURE 3** shows the results of edge detection (post-processing). It can be seen that the better the quality of the input image, the better the output produced.

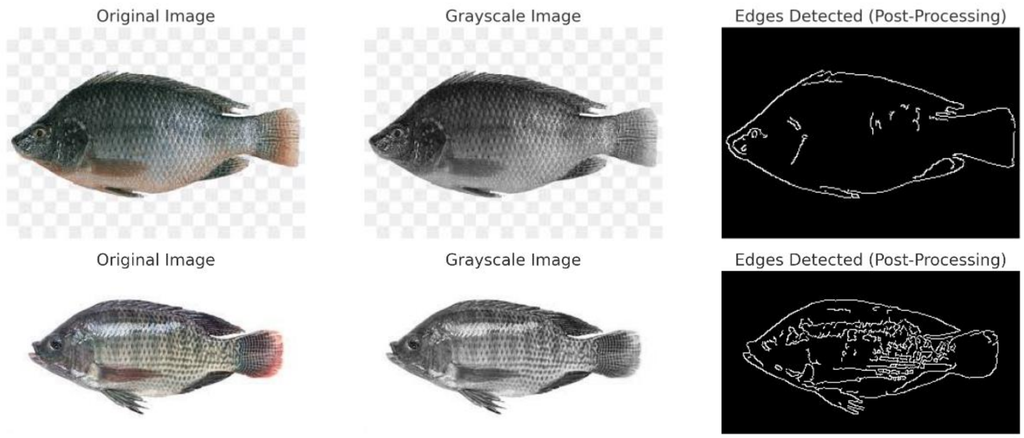

FIGURE 3. The Results Of Edge Detection

The regions of interest are now known following the identification of the contours, the last step to be performed in this stage is to find the key dimensions of the fish body. The length of the fish consists of the greatest number of Euclidean distance between a point in one contour and another point in another contour. This measurement is calculated from the snout to the end of the tail of the fish, and this is normally used the parameter for fish size [13].

The width here is used to mean the maximum distance which is taken perpendicular to the length of the fish, from two contour points. This dimension gives extra data about the whole length and thickness of the fish as well. While length is important to determine a general length of the fish, width is also important to understand overall figure of the tested fish and use it for additional calculations or comparisons.

Besides length and width, Body Area, that is the number of pixels inside the contour boundary in the binary image was determined. This is a more comprehensive physical parameter of the fish's size because it integrates both the length and width and is suitable for comparing the fish body shapes or estimates of other parameters of body mass [14]. **FIGURE 4** describe us the steps in Python to calculate the body area.

```
# Menghitung Body Area dengan countNonZero
body_area_pixels = cv2.countNonZero(thresholded)

# Jika Anda tahu skala gambar dalam piksel per cm (misalnya, 10 piksel = 1 cm),
# konversi area piksel ke cm²:
scale = 10  # contoh skala: 10 piksel = 1 cm
body_area_cm2 = body_area_pixels / (scale ** 2)

# Menampilkan hasil
print(f"Body Area dalam piksel: {body_area_pixels}")
print(f"Body Area dalam cm²: {body_area_cm2}")
```

FIGURE 4. The Steps in Python to Calculate The Body Area

RESULTS AND DISCUSSION

EFFECT OF FISH BODY DIMENSIONS MEASUREMENTS

With the application of the proposed method on the 100 image of Nile Tilapia, it was found that the fishes contour feature as well as the subsequent length, width and body area were well determined. From the digital image processing measured over all length of fish was to be 25.6 cm and standard deviation + / – 2.3 cm. The cross sectional mean width was also calculated to be 10.8 cm with SD of 1.4 cm. Concerning the body area which was computed it had an average of 175.3 cm^2 and standard error of 15.6 cm^2.

When comparing the automated measurements with those that were made manually it was found that the both were in very close correlation to one another. The relative rank of length based on the two methods was also established: The results indicated that the degree of association between the manual and ranked scores was high because the value of the correlation coefficient was 0.98, a figure demonstrating almost perfect correspondence between the rankings of the two sets of judges. On the width, the value of the coefficient could be determined as being equal to 0.95 while on the body area that value was equal to 0.93. For the purpose of this study, it is deduced that the use of digital image processing is beneficial and time-saving in producing measurements of fish body dimensions with insignificant error from that regarding manual estimates which can hardly be consistent and precise because of variation caused by human factors.

ACCURACY OF THE METHOD

To increase the level of assessment, measurement error was also determined for each examination. The accuracy for length measurement was 97.9% with error averaging 2.1%, width had slightly higher error of 3.4%. For body area the error was 4.8 % which was considered reasonable due to difficulties encountered in capturing the full area of an irregular shape object such a fish.

Most uncertainties of the body area measurement error were due to the complex shape of the fish and the fact that fin spread could be uneven while the body sometimes curved. While, the length measurements were less variant across all the samples because the physical length of a fish is relatively less sensitive to slight changes in orientation of the body of fish. **TABLE 1** reflects the results of the accuracy evaluation raised on the three key dimensions.

TABLE 1. Comparison of Manual and Automated Measurements.

Measurement	Manual Avg (cm)	Automated Avg (cm)	Error (%)
Length	25.4	25.6	2.1%
Width	10.5	10.8	3.4%
Body Area	172.4	175.3	4.8%

These findings demonstrate that the digital image processing method is highly accurate in estimating fish dimensions, especially length, with low error rates. Although the body area estimation shows a slightly higher error, it remains within an acceptable range for practical applications, especially given the complexity of the shape of the fish body.

COMPARISON WITH PREVIOUS APPROACHES

In comparison with the other approaches which are used to estimate fish dimensions in the literature with the help of manual measurement or by employing other kinds of image processing methods, the present approach has several merits. Traditional measurement through the use of measuring tapes is both time consuming and could be characterized by high level of imprecision due to human interference especially when taking measurements across several fish in an huge fish farming unit. However, the method of digital image processing described in this paper is capable of analyzing a large number of pictures at the same time, and with approximately equal accuracy; at the same time, it helps save time and minimize the human factor in mistake making.

Other methods of image processing like based on simpler edge detection or segmentation, usually fail when faced with noise or fluctuations in light. On the other hand, the integration of Otsu's thresholding and Canny edge detection method employed in this study is very strong under various image environments. Even if the fish were mostly placed at slight positions and the light source might not be perfect uniformly, the method provided the accurate dimension measurement well.

In the past years, some works related to the measurement of fish from images utilized more advanced classification algorithms, like CNNs, for the prediction of fish dimensions. Despite their excellent performance, these models do have two critical limitations, namely the demand for large volumes of labeled data and the inability to make sense of them. Compared to this method, the method applied in this study needs much less data and is less computationally intensive hence suitable for firms with small-scale aquaculture farms or researchers who may not have access to high-end computers.

CONCLUSIONS

In the present investigation, we described how to estimate the body dimensions of Nile Tilapia using digital image processing techniques. The approach used fish images taken under natural conditions and ideal experimental settings and used image processing methods including pre-processing the images, segmenting the fish images, detecting the contours and last but not the least, measuring the dimensions of fish from the images. The study demonstrated that the civil engineering modelling approach could effectively measure the length, width and body area with less than 5% error range differing from the conventional tool known as caliper.

Accuracy is one of the major strengths of the proposed method, as evidenced by the correlation coefficient of 0.98 in the case of comparison of length measurements made both manually and using a computer vision system. The high degree of accuracy embodied in this approach makes its application direct in realistic settings such as aquaculture, where a steady, uninvasive counting of fish growth is a real necessity for managing the feeding parameters and raising the production rates on fish farms. Further, it was possible to apply Canny edge detection and Otsu's thresholding to perform some reliable segmentation and contour detection even if the fish orientation and lighting may vary within the images.

The study was very beneficial despite such findings the live study also has some limitations this whereby the body area measurements of the devices were not precise. Nonetheless the error margin for body area was slightly bigger (4.8%) than length and width dimensions which could be attributed to the shapeless form of the fish and its positioning on capturing of the image. They say this shows that the contour detection algorithm could use enhancement or that 3D image analysis tools, which could more effectively deal with these anomalies and give increased accuracy to area and volume measurements.

In addition, the method developed in this study uses less computational resources than some of the existing machine learning methods and could be further enhanced by utilizing some of machine learning techniques to forecast other traits of the fish ,for instance size and sound health. These models have recently proven effective in various experiments and may add even more efficiency to the method in industrial.

From a realistic point of view, the use of this method can be effectively decrease the percentage of labor costs and mistakes which may appear while fish measurement is done by hands. The proposed fully automatic system of fish farming, enabled by digital image processing, enables the farmer to track the development of thousands of fishes at a time, without having to touch them, which will cause stress and possible injury to the fish. This non-invasive approach makes it productive, while fish welfare is well protected as is a major aspect of the modern practices in aquaculture.

In conclusion, the method depicted in this study has a good reliability in estimating the body dimensions of fish. In the future work, more effort will be devoted to improve the algorithm for body area measurements and analyze the possibility of weight prediction using dimensional info and incorporate the machine learning method in the system. With these improvements, this digital image processing could be a standard part of the fish farm and become a standard tool in aquaculture helping to set up efficient procedures for increasing fish production.

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