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THE EFFECTIVENESS OF FISH LENGTH MEASUREMENT SYSTEM USING NON-CONTACT MEASURING APPROACH

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Abstract

This paper presents the development of fish length measurement system to obtain the fish length effectively without any contact to the fish. The device which are small and portable, consists of a USB camera that will be connected to a computer for image capturing. A range sensor is combined with the USB camera to detect and fix the image capturing distance. A microcontroller will be the control circuit for the range sensor and LED indication light will be used to allocate the device at the right distance from the fish that it measures. Image processing software, Halcon will be used to analyze and calibrate the fish image for length measurement. Mathematical equations or algorithms are introduced in the image processing software to obtain the actual fish length from the image. The actual fish length from the calculation will be illustrated in the image processing software itself. The experimental results confirms the effectiveness of the proposed system.

Keywords: Measurement system, automatic control, image processing

1.0 INTRODUCTION

Fish size information is a very important factor that affecting the economy of any aquaculture enterprise. The size information can be used to monitor the growth of fish, determine the feeding amount, and medication needed as well as decision making on when to grade, sort or harvest the fish in the fisheries industry [1]. Fish sizing is a very challenging and complex research. There are many attempts in sizing the fish over the years and various type of mechanism and techniques have been developed [2]-[7].

There are two reasons for measuring a fish, to verify the legal length of a fish and to determine the estimated weight of a fish [8]. According to the Marine Living Resources Act (Act No. 18 of 1998), Annexure 6 - Recreational Angling No (2): "The size of the fish shall be measured in a straight line from the tip of the snout to the extreme end of the tail". The different ways of measuring the length of a fish is shown in the Figure 1. [8].

Fish size estimation and inspection by human eye were practiced in the olden days. This traditional method is in accurate, slow, and labor intensive which cannot be used in the industrial environment [9]. The used of roller grader is another method for obtaining the fish thickness [10]. From the thickness, the length of the fish is estimated. However, the result is far from accurate as the proportion of length to the thickness of fish may not applicable in some species. Moreover, there may be a high risk of physical damage to the fish which is intolerable in the industry.

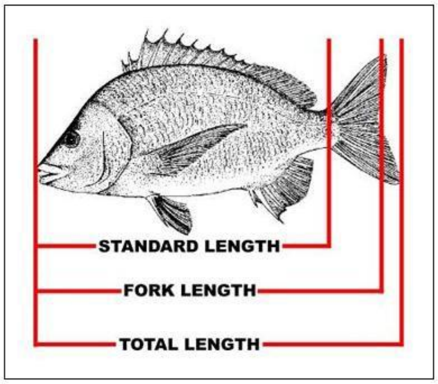


Figure 1 Types of length measurement for fish

The use of computer based vision system has become popular in agricultural industry where a few attempts on machine vision applications for fish industry have been practiced in the early days such as fish bone detection [11]. Many research for the fish industry with the aid of computer vision has been conducted for example in weight estimation [12]. Nowadays, sonar method has been practiced as it provides valuable information about the morphology [13]. However, all those mentioned methods do not satisfy the deep sea exploration. Many visual sub-surface remote sensing techniques are now available for deep sea research such as Remotely Operated Vehicle (ROV) and submersibles, drop and towed camera systems [1]. This method which uses both still and video camera, are not limited by depths for health and safety reason. The development of fish sizing technology is still continued by the demand to obtain a reliable measuring system of fish [7].

Thus, this paper discusses the effectiveness of the developed fish length measurement device based on computer vision-aided system, which contributed to the advancement of low-cost automated fish measuring system. The methodology of the system is described in Section 2. Next, the experimental procedures are defined in Section 3. Furthermore, Section 4 presents the results of the measured fish length based on different camera height. Section 5 conclude the effectiveness of the proposed developed system.

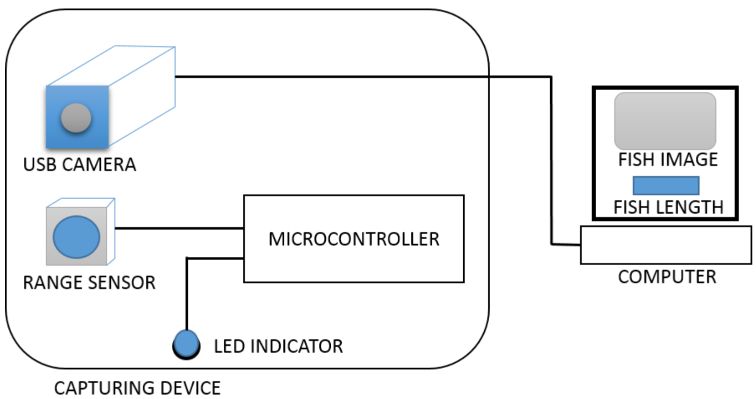


Figure 2 Overall diagram of the capturing system

2.0 FISH CAPTURING SYSTEM

2.1 Overview

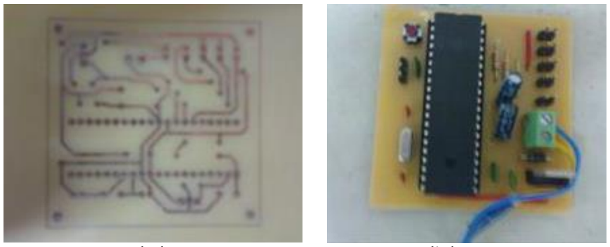
The proposed system of computer based non-contact length measurement device is designed to measure the length of fish. This study is focused on aiding the development of aquaculture industry where the size information of fish is valuable in monitoring the growth of fish, feeding amount and medication needed for certain fish, and the right time when the fish can be harvest.

The overall diagram of the proposed system is shown in Figure 2. This computer based non-contact length measurement device is a portable device which consists of a USB camera that will be connected to the computer. A range sensor is combined with the USB camera in the purpose to detect and fix the image capturing distance from the fish object. A microcontroller will be the control circuit for the range sensor and LED indication light will be used to allocate the device at the right distance from the fish that is measured. The captured fish image will be sent to the computer where the image analysis will be performed by image processing software, Halcon 7.0. Length calculation will be conducted based on the analyzed image where the final result of actual fish length will be displayed in the same software interface.

2.2 Hardware Development

A printed circuit board (PCB) is designed using ARES 7 Professional 8.0 software as shown in the Figure 3(a), which undergone etching process. Furthermore, Figure 3(b) depicts the PCB board with the installed electronics components. The PCB is then connected to the ultrasonic sensor for the range detection purposes.

The circuit is combined and arranged to be together with the USB camera in one 8cm x 8cm x 8cm cubical box. Figure 4 shows the constructed prototype of the measuring device. In that figure, the final product combines the USB camera, microcontroller, and the ultrasonic sensor in a solid casing. The USB camera will be connected to the computer for image capturing process. The ultrasonic sensor that is controlled by the microcontroller will measure the capturing distance where the correct distance information will be indicated via LEDs.



(a) (b)

Figure 3 Printed Circuit Board of the capturing device

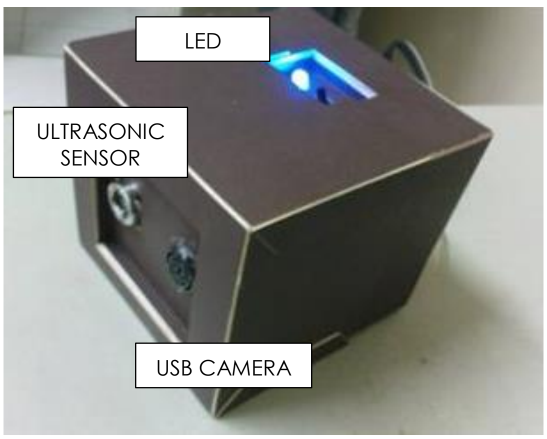
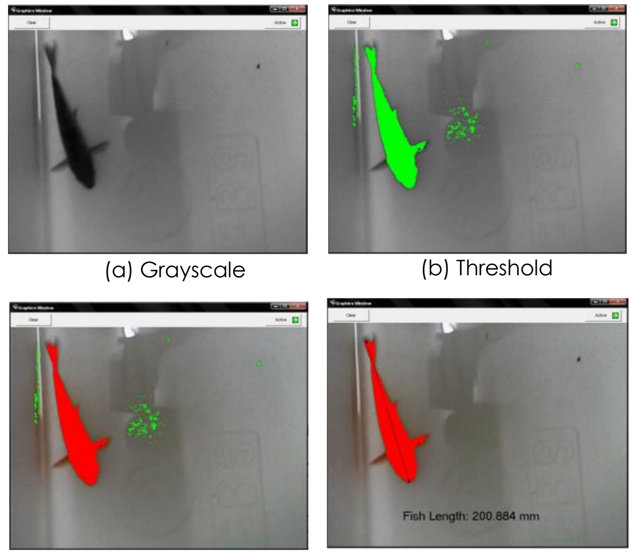


Figure 4 Prototype of the capturing device

2.3 Image Processing Techniques

An image processing techniques are developed using Halcon 7.0 software that can facilitates rapid development of machine vision, medical imaging, and image analysis applications. The captured image will undergo certain image processing and analysis before the actual fish length can be determined. There are few major steps needed to be performed on the fish image before the final result of actual fish length can be obtained. The steps are 1) image grayscale determination, 2) setting the threshold value, 3) select the desired fish region, and 4) calculate the length by the selected pixels of fish image. Figure 5 described the flow of the image processing techniques involved.



(a) Grayscale (b) Threshold

(c) Desired region (d) Length calculation

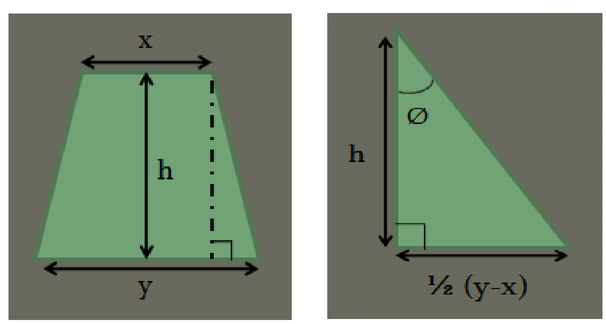
Figure 5 Image processing flow of the developed system

2.4 Fish Length Computational Method

Since the image of an object that is captured at a different distance will resulted in the different size of an image frame, therefore the distance of image capturing needs to be fixed for the computation of fish length accurately. A mathematical equation will be introduced in the fish length calculation.

There are few assumptions need to be made before the calculation of fish length as referred to the isosceles trapezoidal characteristic in Figure 6. The assumptions made are the parameters of *h*, x and y as shown below:

h = capturing distance between the device and the fish,
x = fish image length, and
y = actual fish length.



(a) (b)

Figure 6 Determination of actual length and image length based on camera height distance

In the Figure 6(a), the polygon is identical to the isosceles trapezium shape with the parameters of *h*, *x* and *y*. The side of x is parallel to the side of *y* and the sloping sides are equal. In order to formulate and equation to find the actual fish length, the parameters of *h*, *x* and *y* needs to be equated into an equation to obtain the angle value, Ø. It is proceed by subtracting out the right angle triangle as shown in the Figure 6(b).

Those three parameters are equated using the tangent formula that gives the equation (1) as below:

$$\tan \emptyset = \frac{1}{2}(y - x) \div h. \quad (1)$$

The equation (1) is rearranged to obtain the equation (2) as shown below.

$$y = 2h\,(\tan \emptyset) + x \quad (2)$$

Then, the actual length of the fish can be calculated using equation (2) where x will be the fish length on the image frame and the parameters of Ø and *h* will be set as the constant value.

3.0 EXPERIMENTS

In this section, the fish length measurement will be tested and experimented for the readings accuracy. The length measurement is tested repeatability to compare with its original length at a fix capture distance. Besides, the length measurement will also be tested at different capturing distance and orientation. The experiments not only conducted on a prototype fish but also the real fish to study the device capability in measuring the fish length in the real practice.

3.1 Experimental Setup

In the experiments, the capturing distance will be tested based on differents height of 40cm, 45cm, 50cm, 55cm, and 60cm to observe the measurement accuracy. The capture distance will be determined by the ultrasonic sensor where it shows the distance distance from the fish object. When the device is at the right capturing distance, it will be held steadily on top of the fish object by a stand as shown in the Figure 7.

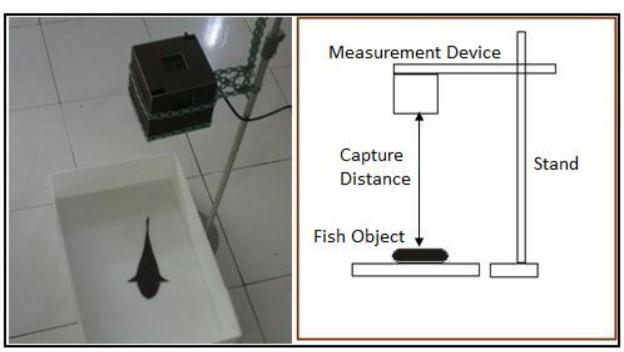


Figure 7 Device at a capture distance from the fish object

For the ultrasonic sensor, three methods can be used to obtain the distance information which are the pulse width output (PW), analog voltage output (AN), and serial digital output (TX and RX). Analog voltage output will be used in the study to access the distance information and the techniques are discussed as follow:

1) Scaling factor for analog voltage is (Vcc/512) per inch where the Vcc will be the voltage supply for the microcontroller. Therefore, the scaling factor for analog voltage is 9.8mV/inch.
2) For the distance of 40cm, it is equivalent to 15.75inch where it will produce 0.154V of voltage distance.
3) By substituting the voltage distance into the equation (3) as shown below, analog value of 31.6 is obtained:

$$Analog\ value = \frac{voltage\ distance}{Vcc} \times 1024 \quad (3)$$

$$Analog\ value = \frac{0.154V}{5V} \times 1024. \quad (4)$$

The capturing distances of 40cm, 45cm, 50cm, 55cm, and 60cm are tested and the results show that the ultrasonic sensor does not stable to provide distance information on a fixed analog value. Hence, tolerance of (+,-) 1cm was introduced into the capture distance where the device can be located in the range of 39cm to 41cm for the experiments conducted on the capturing distance of 40cm. The introduced of tolerance is for the purpose to locate the device in an easier manner.

4.0 RESULTS AND DISCUSSION

4.1 Analysis on Measurement of Prototype Fish

A flat prototype fish is used for the length measurement analysis and the actual length is 168mm as depicted in the Figure 8.

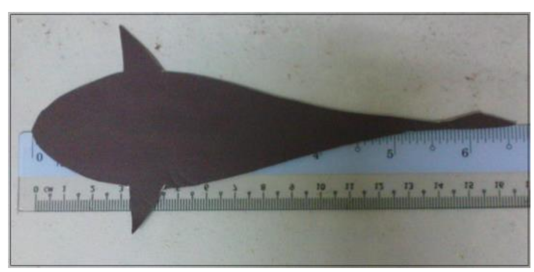


Figure 8 Actual length of the prototype fish

A fish image is needed to be set as a reference before the device is ready to measure the actual fish length. Figure 9 shows the fish image that is captured by the device at the distance of 40cm. The fish image length, fish actual length and the captured distance are determined for the configuration of mathematical equation before the device is ready to capture different sizes of fish, different fish orientations for getting the actual fish length. The configuration of mathematical equation is shown below:

- Capturing distance between the device and the fish, *h* = 400mm
- Actual fish length, *y* = 168mm
- Fish image length, x = 0.24 X image length
  = 0.24 X 187.2
  =44.9mm

When the 3 parameters of *h, x* and *y* are known, the unknown angle, Ø is obtained with the calculation using the equation (1) as Ø = 8.7°. After the value of the angle, Ø is obtained, that value will be substituted into the equation (2) to acquire the mathematical equation that will be programmed in the image processing software, Halcon. Now, the device is ready to measure all the fishes to obtain the actual fish length from the image.

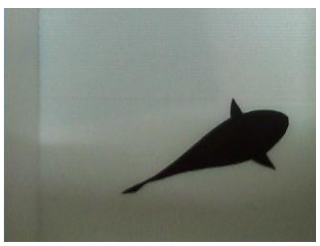


Figure 9 Fish image as the reference at 40cm distance

4.2 Analysis on Fish Orientation

At a fixed capture distance (40cm), prototype fish will be measured at different orientation angle to test for the measurement device accuracy as shown in the Figure 10 and Figure 11. The results of the experiment are shown in the Table 1. The percentage error of the measurement is calculated using the formula as follow:

$$\%\ Error = \frac{|Actual\ length - Average\ measured\ length|}{Actual\ length} \times 100\% \quad (5)$$

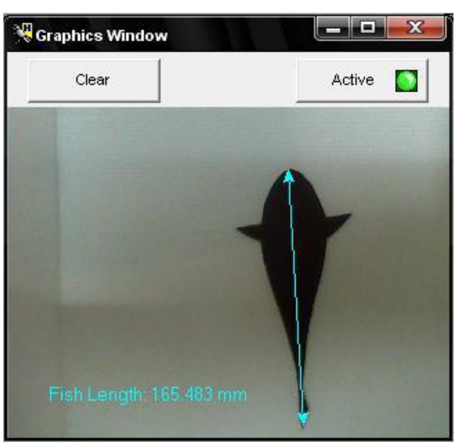


Figure 10 Prototype fish is measured at 0°

Figure 11 Prototype fish is measured at 60°

Table 1 Orientation angle versus measured fish length for prototype fish

Orientation Angle (°)	Measured Fish Length (mm)
0	165.5
60	165.9
120	165.2
180	165.1
240	165.8
300	165.0
Average	165.4

$$\%\ Error = \frac{|168 - 165.4|}{168} \times 100\% = 1.5\% \quad (6)$$

From the Table 1, the fish length measurement obtained is in an average of 165.4mm with the measurement percentage error of 1.5% compared to the actual fish length.

4.3 Analysis of Measurement Accuracy

For a fixed capturing distance at 40cm, the prototype fish was measured repeatedly to observe the accuracy of the measurement device as shown in the Figure 12. The results of the experiment are shown in the Table 2. The average value of the readings is obtained and the percentage error is calculated.

Figure 12 Prototype fish is measured repeatedly at fixed distance

Table 2 Number of trials versus measured fish length for prototype fish

Number of Trials	Measured Fish Length (mm)
1	165.9
2	165.2
3	165.5
4	165.6
5	165.5
6	165.3
Average	165.5

$$\% \, Error = \frac{|168 - 165.5|}{168} \times 100\% = 1.5\% \qquad (7)$$

As referred to the Table 2, the average value of the measured fish length in six trials is 165.5mm and the percentage error of the measurement is 1.5% compared to the actual fish length.

4.4 Analysis of Capture Distance

For the capture distance analysis, the same prototype fish of actual length of 168mm is measured with the device at different distance of 40cm, 45cm, 50cm, 55cm, and 60cm as shown in the Figure 13 and Figure 14.

In the image processing software (Halcon), the *h* parameter needs to be changed for a different image capturing distance before the measurement device is used to measure the actual fish length. The results of the fish length measurement at different capture distance are showed in the Table 3.

Table 3 Image capture distance versus measured fish length for prototype fish

Image Capture Distance (cm)	Measured Fish Length (mm)
40	165.9
45	165.4
50	166.3
55	165.0
60	165.9
Average	165.7

$$\% \, Error = \frac{|168 - 165.7|}{168} \times 100\% = 1.4\% \qquad (8)$$

From the Table 3, the average value of the measured fish length at different capture distance is 165.7mm and the percentage error of the measurement is 1.4%. The result shows that different capturing distance does not affect the measurement accuracy provided the *h* parameter, or the capturing distance is adjusted within the image processing software before the measurement is taken.

4.5 Real Fish Measurement Analysis

Analysis is conducted on the real fish as well for the length measurement comparison with the prototype fish. Besides, experiments are carried out on the real fish to test the capability of the measurement device in measuring the actual length of the real fish. The actual length of the real fish is 155mm as shown in the Figure 13.

Figure 13 Actual length of the real fish

The real fish will be tested on its length measurement using the device inside a certain height of water level as shown in the Figure 14 and Figure 15.

It was measured at different capturing distance of 40cm, 45cm, 50cm, 55cm, and 60cm. The mathematical equation of prototype fish will be used for the length calculation on the real fish. The results of the experiment are shown in the Table 4.

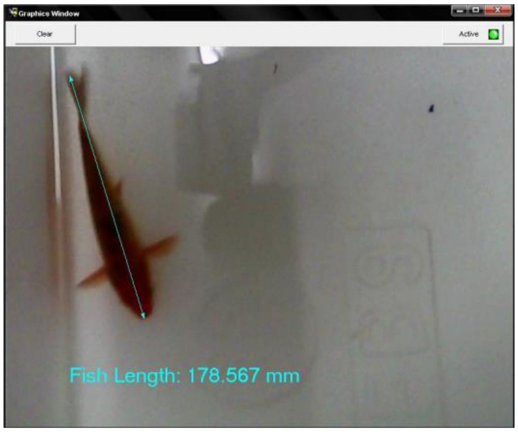


Figure 14 Length measurement on real fish at 40cm capturing distance

Figure 15 Length measurement on real fish at 60cm capturing distance

Table 4 Image capture distance versus measured fish length for real fish inside water

Image Capture Distance (cm)	Measured Fish Length (mm)
40	178.6
45	173.8
50	174.2
55	174.5
60	176.7
Average	175.6

$$\% \, Error = \frac{|175.6 - 155|}{155} \times 100\% = 13.3\% \quad (9)$$

From the Table 4, the average value of the measured real fish length at different distance is 175.6mm and the percentage of error for the measurement is 13.3% as compared to the actual length of the real fish. The experiment results showed that the measured readings are not consistent as compared to the previous analysis

4.6 Discussion

Image capturing distance is a very important factor in the determination of fish length. Precise distance information between the measurement device and the fish object will result in a more accurate fish length measurement. In this proposed device, ultrasonic sensor is used to detect and give the capturing distance information for the fish length calculation. However, the sensor does not provide a stable detection for the distance ranging to allocate the device for the measurement. Hence, tolerance of (+,-) 1cm was introduced to establish a more stable detection for the sensor to allocate the measuring device at the right distance in an easier manner. This result in imprecise distance information obtained where the measurement of the fish length becomes less accurate.

In the length measurement analysis for the prototype fish, the readings obtained from the measurement device show the maximum percentage error of 1.5% as compared to the actual prototype fish length. This is due to the distance tolerance that is introduced in the distance detection for purpose of allocating the measurement device in a stable state. The length measurement is almost identical to the actual length where the device can be used for the fish length determination practically with only a small percentage of error of 1.5%. However, the accuracy of the measurement by the device can be improved by getting rid of the distance tolerance with the use of a better type of range sensor.

For the real fish analysis, the length measurement obtained from the measurement device shows percentage error of 13.3% which is much higher than the length measurement conducted the prototype fish. This is due to the reason that the height of the water level affects the range of detection for the ultrasonic sensor. Besides, the length measurement of the real fish is affected by the refractive index in the water as well as the waving water surface that cause by the moving fish.

Despite of the high percentage error for the length measurement of real fish, this problem can be overcome by using the real fish image as the reference for the parameters in the mathematical equation. The length measurement of real fish will eventually show less percentage of error with the new developed of mathematical equation.

5.0 CONCLUSION

As a conclusion, the proposed system of the non-contact approach of fish length measurement device can be used in the real life practice with the measurement accuracy that is closed to the actual fish length measurement. This measuring device will be able to facilitate the development of the fishery research and the aquaculture industry by providing the useful fish length information obtained from the device. The utilization of the image processing method in the design of this measuring device is able to compute the fish length accurately. The design of the device is in a portable means which is meant for the users that travel. Moreover, the measurement device is fabricated in a user friendly manner that is easy to operate. The actual fish length will be calculated automatically and showed in the image processing software itself. It is no doubt that the fish length information is vital in the development of the fishery industries. Therefore, the fish length measurement device needs to be improved in terms of portability, accuracy, cost and user friendly to cope with the market and technology wise for the development of aquaculture industry.

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