A New Approach in Measuring Fish Length Using FiLeDI Framework

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Abstract: *Fish is an important source of protein in most country in the world. The need to know the reproduction and population of fish is crucial for optimum exploitation of fish resources in maintaining the requirement of mankind in the future. In fisheries research, the length of a fish is the main parameter needed to identify fish reproduction, recruitment, growth and mortality. Current method used to acquire these length samples can be problematic as it is manually done; the fishes need to be purchased in large quantities and then measured one by one. This process is time consuming and may lead to overflowing cost. The FileDI framework attempts to avoid this problem using a combination of optical theory and image processing techniques that automatically measures the length of the fish. It reduces cost, is faster than previous method, and still producing high accuracy results length accuracy. Preliminary test has shown that the confident level of the FiLeDI framework accuracy is as high as 95% for fish length measurement.*

Keywords: *Fish length, image processing, optical theory*

Received July 15, 2009; accepted January 3, 2010

1. Introduction

In fisheries research, the length of a fish is an important parameter in determining fish population, mortality, growth, reproduction, and recruitment which in turn, can help in the assessment of fish stock. During the period of fish reproduction, even if fishing activity is increased, the revenue would be significantly less shown as Figure 1 [17]. Thus knowing the period of fish reproduction is essential to identify the amount of stock available so that fisheries sector can maximize revenue and also maintaining nationwide fish stock.

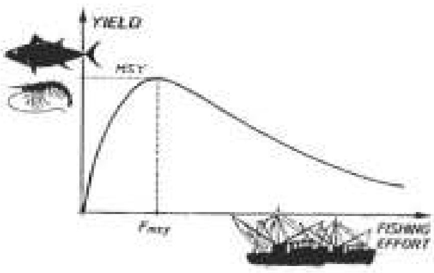

Figure 1. Fish stock assessment.

However, information of fish length is very limited as it is currently obtained manually [9]. This means that the fish is measured one by one using a measuring tool. Needless to say, it is time consuming especially when the number of fish to be measured increases. Moreover, this manual process requires the researchers to purchase the fishes from fishermen, adding to huge amount of cost. Therefore, an easy, fast and cost-effective approach is needed to solve this problem.

The FiLeDI framework, a method of measuring fish length from a digital image is proposed in this paper where several matters are first observed. Firstly is the issue of how to acquire the image itself, secondly is how to process the image to obtain the 'image size' of the fish, and thirdly is how to calculate 'actual size' of the fish from pixel value. These are the issues addressed in this research. This framework uses optical theory and image processing techniques to obtain the actual fish length from the image. In this paper, detailed discussion of the FiLeDI framework, its implementation, testing and evaluation will be presented.

2. Previous Work

Research work has been done previously for various applications and location using stereo vision system [12], stereo video camera system [4], stereo photographic [6], a dual underwater camera [1], and simple video techniques [15]. The main point in these techniques is that the fish are measured underwater. By measuring underwater, fish growth can be monitored, mortality and stress due to fish sampling can be reduced, and divers' intervention can be limited [1]. These techniques are also used to determine the feed and medication and to decide when to gather the yields of fish [12]. Yet, these approaches [4, 6, 12 and 15] can still cause stress to the fish as the underwater equipments used can disturb their ecosystem. Several other methods solve this issue by obtaining fish sampling from fisherman yields. The sampling process can be done right as the fishermen return from fishing activities. In these methods, computer vision approach [16, 19] is applied to obtain the length of the fish. It requires equipments such as conveyor belt, light box, camera, sensor and computer that are expensive and space consuming. Therefore this approach is suitable for industrial sectors with huge capital; and is mainly used to sort the fish based on species, size and weight. However in developing countries, the use of computer vision technology is still unaffordable because of the high investment required to prepare the equipment. Figure 2 shows the current method used instead, which require a measurement tape to manually measure the fish.

Figure 2. Fish Length Measurement Using Measurement tape

In recent years, numerous researches have been done to calculate size of object in a digital image. Some method uses reference object to guide the calculation of the objects' actual size, while some used optical theory. The former method has been implemented in GIS, medical imaging and computer graphics. For example, Pickle *et al.* [14] developed a software name AnalyzingDigitalImages that uses a reference object such as a ruler, to obtain the object of interests' actual size. The advantage of Pickle's method is the image can be measured without parameters such as fix distance and illumination, but even so, when capturing an image, a reference object will always be needed.

Hsiu *et al.* [6] came out with a solution which can directly obtain the actual size of the object from digital image without the need of using any reference object. It opens opportunities for fishery researchers to perform data sampling much faster. Besides, it does not need a lot of equipments which also makes it a lot more cost effective. Although that, Hsiu [6] is still need improvement because Hsiu's approach not automatically when detect of the object in an image. Beside that, Hsiu et al [6] used was a coat which has very simple features. The fish, on the other hand, has more complex and curvy features, especially its head and tail. Therefore, to obtain its accurate size, each edge of the fish must be precisely detected.

From previous work, a lot of techniques to detect object like fish in image automatically such as object recognition [12], contour extraction [1], chain code [18], filtering [8] and corner detection [7]. In Kiranyaz *et al.* [7] method, corner detection were implied by maximizing bending ratio and curvature, which makes it more accurate in detecting corners of an object, and in this case, it can be suitably applied to detecting fish in a digital image. We develop a new method to measure fish length from digital image by combining both Hsiu's and Serkan's method. We call this framework "FiLeDI" where in this paper its framework will be discussed.

3. FiLeDI Framework

FiLeDI stands for Fish Length from Digital Image measurement framework. It is more economical than previous approach and also faster in sampling data. FileDI framework takes advantage of the optical theory introduced in Hsiu's method [6] and combining it with image processing techniques to measure fish length for data sampling process [13]. Firstly, optical theory is used to formulate equation in order to obtain the value of image scaling. Next, image processing techniques are used to obtain fish length in pixel value. Subsequently, the fish length in pixel value will be processed with the scale value obtained from the optical theory to determine the actual size of the fish length. In this proposed FileDI framework, enhancement has been done to improve Hsiu's [6] and Serkan's [7] method in obtaining the scale value and corner detection, respectively. Figure 3 shows the processes involved in FileDI framework.

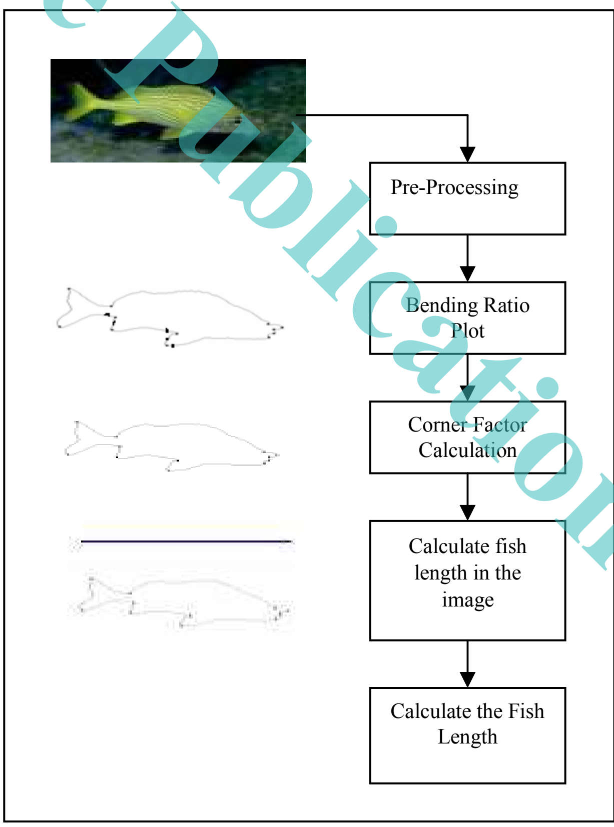

Figure 3. Flow Chart of FiLeDI Framework

3.1. Data

Data used as input in FiLeDI Framework are:

1. Fish Images.
2. Focus Length (*f*).
3. Distance Object (*O*).
4. Pixel Size (mm).

The data required in this framework are already contained in the image properties of the digital images and can be extracted by the FileDI framework system. Fish images must be in digital format; in the testing result presented in this paper, bitmap (*.bmp) file was used. Focus length (*f*) and object distance (*O*) are used to identify scale value, while pixel size is used to calculate fish length in pixel unit.

3.2. Pre-Processing

Pre-processing is done to the image input to detect the head and tail of fish. It is first carried out in order to locate one-pixel thin object boundaries. This process consists of three major parts see [7] for details. Firstly is iterative bilateral filtering and canny edge detection to form the *scale-map*. Secondly, *sub-segment* formation and analysis. Finally the selection of the relevant *sub-segments* using a relevance model. The object(s) can be extracted after the required numbers of relevant sub-segments are selected and the corner detector proceeds over the object boundary (CL segment) or alternatively it can proceed over the NCL sub-segments, one at a time. More detail on this pre-processing phase can be found in [2, 3].

3.3. Bending Ratio Plot

The next process is to calculate bending ratio plot. The formula of the bending ratio can be expressed as follows:

$$BR(p_1) = \frac{L_S}{d_\infty(p_1, p_2)} \quad (1)$$

where, Ls is the number of pixel from $P1$ to $P2$ and $d\infty$ represents the distance in $L\infty$ norm. Figure 4 shows BR calculation.

Serkan *et al.* [11] checked for true corner during the tracing process, if $BR\ (p)\ T\ BR$, where $T\ BR \geq 1$ is an empirical threshold, which can be set higher to detect only sharper (with smaller angle) corners in particular. A discrete curvature approximation is used within the moving window to find exact corner location. The curvature function *κ(u)* is the derivative of the orientation function *Ø(u)* [2], expressed as in equation 2 [7].

$$\phi(u) = \tan^{-1}\left(\frac{\dot{y}(u)}{\dot{x}(u)}\right) \Rightarrow k(u) = \frac{\dot{x}(u)\ddot{y}(u) - \ddot{x}(u)\dot{y}(u)}{(\dot{x}^2(u) + \dot{y}^2(u))^{3/2}} \quad (2)$$

The curvature at a given contour pixel from the positions of neighbouring pixels (*p*-1), *p*, and (*p*+1) can be approximated as in equation 3 [7]:

$$\kappa(p) = \frac{(x_{p+1} - x_{p-1})(y_{p-1} - 2y_p + y_{p+1}) - (y_{p+1} - y_{p-1})(x_{p-1} - 2x_p + x_{p+1})}{((x_{p+1} - x_{p-1})^2 + (y_{p+1} - y_{p-1})^2)^{3/2}} \quad (3)$$

basically in equation 1, all the (potential) corners yielding a peak in BRP are detected.

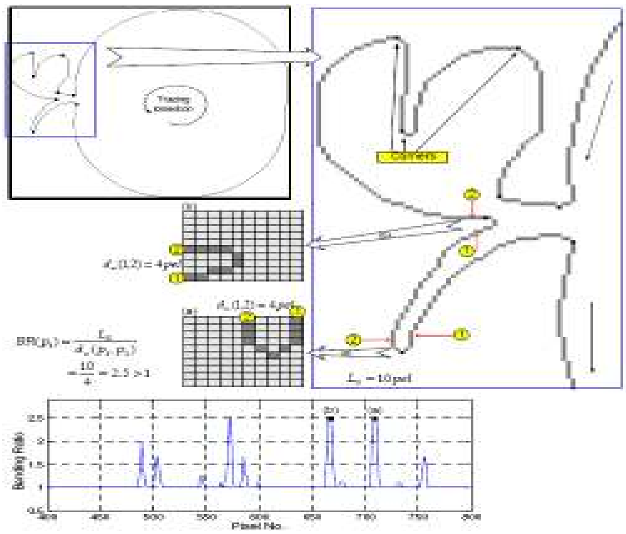

Figure 4. BR calculation on a sample shape for two corner (a and b) detected [7].

3.4. Corner Factor Calculation

In this step corner factor is used to obtain the actual value of the corners of a fish. Let $CF(p_C^i)$ be the *corner factor* of the i^{th} potential corner, p_C^i and can be expressed as follows:

$$CF(p_C^i) = BR(p_C^i) \times \kappa(p_C^i) \quad (4)$$

this will give a result of two points, representing the head and the tail of the fish.

3.5. Calculate Fish Length in the Image

The head and tail pixel points obtained from the previous step is next used to calculate the image size of the fish by multiplying the number of pixels with pixel size shown equation 5.

$$\textit{Fish length in image (fl)} = \textit{(Number of pixels) x (Pixel Size)} \quad (5)$$

3.6. Calculate the Fish Length

The final step in this framework is to obtain the actual length of fish. For that, we must multiply the value of fish length in image (*fl*) with ratio value.

$$\textit{Actual Fish Length} = fl\ x\ (O/f) \quad (6)$$

Equation 6 is obtained from optic theory shown as Figure 7. There are four important variables:

1. The size of the object (Y1).
2. The distance of the object from the lens (X1).
3. The size of the image on the sensor or the film (Y2).
4. The distance between the sensor and the lens (X2).

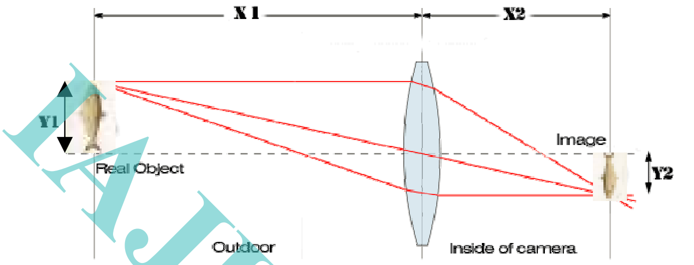

Figure 5. A simple imaging system.

Referring to Figure 5, two right triangles can be found. Several rules concerning triangles are used in this framework shown as Figure 6.

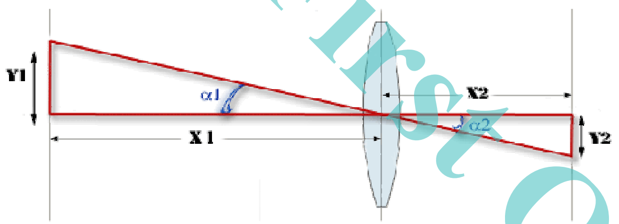

Figure 6. Geometry concept.

a1=a2 ==> tag a1=tag a2, tangent is an opposite side or adjacent:

$$Tag\ a1 = Y1/X1 \qquad (7)$$

$$Tag\ a2 = Y2/X2 \qquad (8)$$

Tag a1=tag a2 ==> Y1/X1=Y2/X2 ==> we can inverse both sides of the equation:

$$\boldsymbol{X1/Y1 = X2/Y2} \qquad (9)$$

The variable name of Y1 is a size of object, which in FileDI framework represents the fish length. However, this framework requires three variables, *Y2*, *X2* and *X1* to obtain the fish length. The variable *Y2* is the size of the image on the sensor or the film, which in this framework represents the length of fish image (*fl*). Variable *X2* refers to focal length (*f*), while *X1* refers to mean object distance (*O*).

4. Testing and Evaluation

To evaluate the implementation result of the FileDI framework, two types of species were chosen with different sizes. There are twenty fishes each from the species Selar Crumenophthalmus (SC) and Rastrelliger Kanagurta (RK). Images were taken with different types of camera and illumination. The comparisons with position of camera were tested only with SC species. Figure 7 shows the process to measure fish length using FiLeDI framework for testing the SC species.

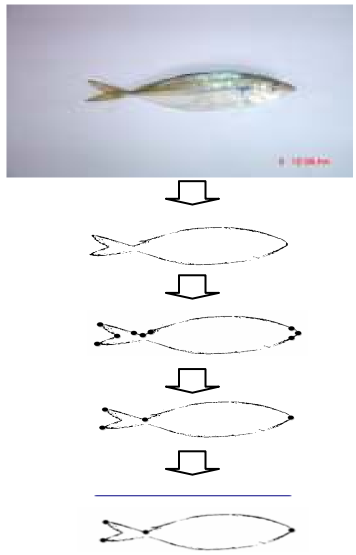

Figure 7. The process to measure fish length using FiLeDI framework.

5. Result

The results were divided in three conditions; camera types, illumination and camera position, to determine which of these conditions influence the accuracy of the fish measurement.

5.1. Camera

Table 1 and Figure 8 show the measurement result of the SC species. Pentax camera (8.0 megapixel) has shown a better result with 0.74% error, compared to Sony (5.0 megapixel) with 2.19% error. In this case, the manual method (manually measuring the fish using measuring tape) acts as a true value. Meanwhile table 2 and Figure 9 show the testing result of RK species. Sony camera recorded a result closest to the true value with 1.81% error while Pentax recorded a 2.85% error.

Table 1. Result of comparison with different types of camera for selar crumenophthalmus species.

Number	Manual (cm)	Pentax 8M (cm)	Sony 5M (cm)
1	14.5	14.27	14.57
2	14.0	14.04	14.14
3	15.8	15.73	15.83
4	12.7	12.85	12.95
5	14.7	14.63	14.55
6	15.6	15.51	15.56
7	14.4	14.35	14.54
8	13.0	13.33	13.15
9	13.7	13.72	13.67
10	13.4	13.38	13.50
11	14.0	14.10	14.42
12	15.2	15.15	15.22
13	14.5	14.43	14.54
14	15.6	15.59	15.91
15	16.2	16.50	16.40
16	14.2	13.95	13.86
17	15.8	16.00	16.01
18	13.5	13.60	13.28
19	15.0	14.97	15.35
20	15.2	15.46	15.43

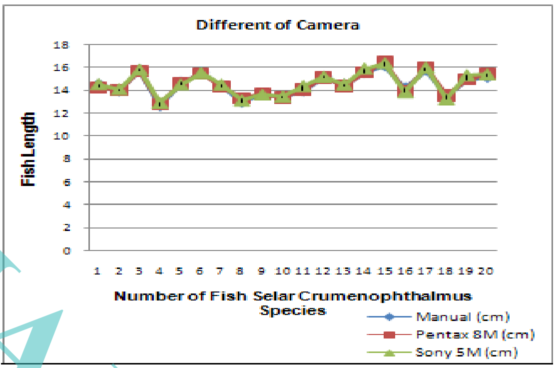

Figure 8. The comparison with different types of camera for selar crumenophthalmus species.

Table 2. Result of comparison with different types of camera for rastrelliger kanagurta species.

Number	**Manual (cm)**	**Pentax 8M (cm)**	**Sony 5M (cm)**
1	19.2	19.20	19.20
2	19.2	18.85	18.87
3	19.0	18.77	18.68
4	19.5	19.30	19.41
5	18.7	18.17	18.24
6	17.8	17.38	17.43
7	20.0	19.59	19.28
8	18.3	17.77	18.07
9	22.2	21.65	21.75
10	20.9	20.06	20.58
11	21.8	20.57	20.95
12	20.4	19.58	19.94
13	21.1	20.34	20.03
14	22.1	21.11	21.28
15	21.9	21.45	21.32
16	21.0	20.33	20.77
17	21.0	20.57	21.22
18	18.0	17.66	17.93
19	19.3	18.77	18.64
20	20.7	19.48	21.24

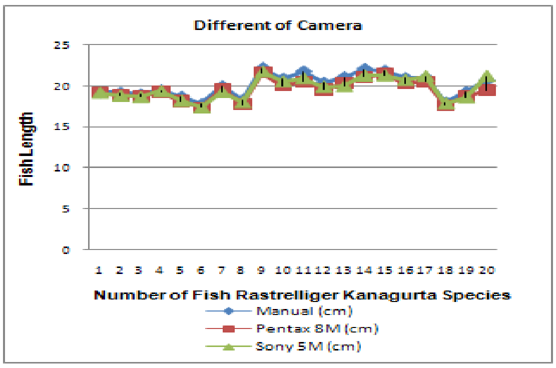

Figure 9. The comparison with different types of camera for rastrelliger kanagurta species.

5.2. Illumination

Table 3, 4 and Figures 10, 11 shows the comparison result of using Pentax camera with and without flash. For SC species shown as Figure 10, the result with flash recorded a 0.74% error compared to 6.03% error without flash. Meanwhile, the result for RK species shown as Figure 11 recorded a 2.85% error with flash compared to 3.68% error without flash.

Table 3. Result of Comparison with Different of Illumination for Selar Crumenophthalmus species

Number	**Manual (cm)**	**Without Flash (cm)**	**Flash (cm)**
1	14.5	13.50	14.27
2	14.0	13.14	14.04
3	15.8	14.78	15.73
4	12.7	11.97	12.85
5	14.7	13.90	14.63
6	15.6	14.52	15.51
7	14.4	13.45	14.35
8	13.0	12.58	13.33
9	13.7	12.79	13.72
10	13.4	12.66	13.38
11	14.0	13.28	14.10
12	15.2	14.21	15.15
13	14.5	13.61	14.43
14	15.6	14.49	15.59
15	16.2	15.56	16.50
16	14.2	13.07	13.95
17	15.8	14.93	16.00
18	13.5	12.68	13.6
19	15.0	14.03	14.97
20	15.2	14.31	15.46

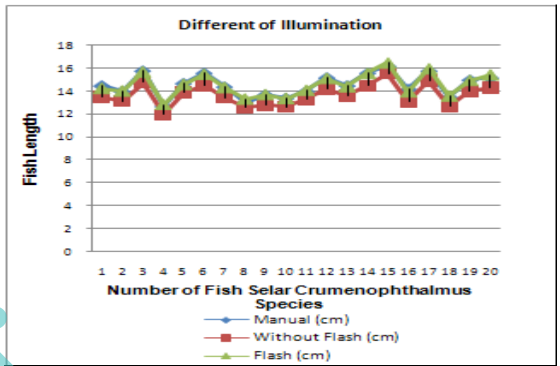

Figure 10. The Comparison with Different of Illumination for Selar Crumenophthalmus Species.

Table 4. Result of Comparison with Different of Illumination for Rastrelliger Kanagurta Species

Number	**Manual (cm)**	**Without Flash (cm)**	**Flash (cm)**
1	19.2	18.98	19.20
2	19.2	18.47	18.87
3	19.0	18.11	18.68
4	19.5	18.52	19.41
5	18.7	17.82	18.24
6	17.8	16.89	17.43
7	20.0	18.96	19.28
8	18.3	17.28	18.07
9	22.2	21.17	21.75
10	20.9	20.17	20.58
11	21.8	21.13	20.95
12	20.4	19.73	19.94
13	21.1	21.05	20.03
14	22.1	20.79	21.28
15	21.9	21.29	21.32
16	21.0	20.41	20.77
17	21.0	20.37	21.22
18	18.0	17.69	17.93
19	19.3	18.28	18.64
20	20.7	20.18	21.24

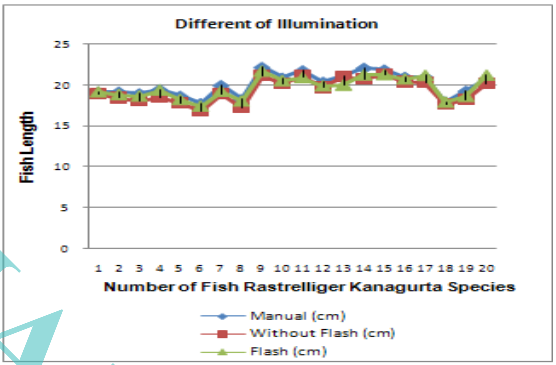

Figure 11. The Comparison with Different of Illumination for Rastrelliger Kanagurta Species.

5.3. Position of Camera

Table 5 and Figure 12 show the comparison result of using different camera positions. In this testing, three position angles, 90°, 45° and 135° were used. From the testing outcome, the position of 90° produced the closest result to the true value.

Table 5. Result of Comparison with Position of Camera for Selar Crumenophthalmus species

Number	Manual	90˚	45˚	135˚
1	14.5	14.27	9.74	9.81
2	14.0	14.04	10.18	8.68
3	15.8	15.73	11.04	10.35
4	12.7	12.85	8.97	8.30
5	14.7	14.63	9.42	9.78
6	15.6	15.51	10.52	10.19
7	14.4	14.35	10.37	8.58
8	13.0	13.33	9.37	8.35
9	13.7	13.72	8.91	9.58
10	13.4	13.38	9.41	9.21
11	14.0	14.10	9.91	9.24
12	15.2	15.15	10.74	9.80
13	14.5	14.43	9.96	9.84
14	15.6	15.59	10.89	10.20
15	16.2	16.50	11.46	11.56
16	14.2	13.95	9.53	9.56
17	15.8	16.00	11.45	11.04
18	13.5	13.60	10.23	9.11
19	15.0	14.97	10.99	10.06
20	15.2	15.47	12.08	9.81

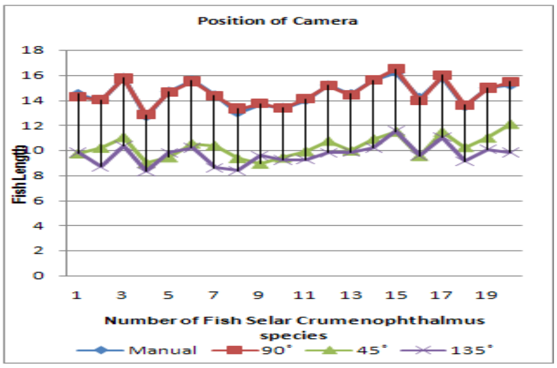

Figure 12. The comparison with position of camera for selar crumenophthalmus species.

6. Discussion

Based on the preliminary testing done and the results shown, the FiLeDI framework gave a good accuracy result when Selar Crumenophthalmus (SC) species was tested using Pentax Optio E40 (8 megapixel) with flash. For Rastrelliger Kanagurta (RK) species, the result shows that Sony is better than Pentax when in fact, the result produced by Pentax is supposed to be more accurate since its resolution is higher than Sony. This inaccuracy result occurred due to blurred pictures taken when testing RK species using Pentax camera. Therefore, it can be concluded that the acquisition of a good quality image is important before the image is processed. From the results it can also be concluded that the images should be taken with flash, and that illumination is another important element in image acquisition step.

The testing also includes comparison of different camera positions where it is shown that the best position is 90˚ [11]. In Table 1 and 2, the results show that when the size of fish increases, the error also increases.

This study demonstrates that FiLeDI framework can be used in measuring the length of a fish; and also that there are still rooms for improvement. Hence, the next step to enhance this framework will focus on how to detect edge accurately to further obtain better accuracy in measuring fish length.

7. Conclusions

This research is expected to contribute an automated method of measuring the length of a fish using optical theory and image processing techniques. This method has high potential to be commercialized given its high reliability, durability and accuracy factors; as well as minimizing cost and time needed for such task. This means that, it is able to measure the length of a fish without having a person holding the fish. The idea is to capture the image of the fish using a digital camera, and then processed into the FiLeDI framework software to automatically determine the actual length of the fish [13]. In fisheries sector, the impact of the contribution from this research ensures the stability and security of the country's main source of protein.

Acknowledgements

This work has been done under research grant project E-Science Fund RMK9, Vot Number 79356 sponsored by the Ministry of Science Technology and Innovation (MOSTI), Malaysia. The authors would like to thank the Faculty of Computer Science and Information System (FSKSM) and the Rearch Management Center (RMC), Universiti Teknologi Malaysia for the support and facilities provided.

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