Fish Freshness Determination through Support Vector Machine

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***Abstract*—In this study, the fish freshness determination system used digital image processing to determine the freshness quality and shelf life span of the three most consumed fish in the Philippines namely: (1) milkfish (Chanos chanos), (2) round scad (Decapterus maruadsi) and (3) short mackerel scad (Rastrelliger brachysoma). Moreover, it used a method based on support vector machine (SVM) algorithm that would classify the redness of the fish's eyes and gills as a measure of the fish freshness quality level. It will be able to determine the shelf life of a raw fish after it has been stored in a slurry ice. Standard images were set with technical assistance from the Philippines' Bureau of Fisheries and Aquatic Resources (BFAR) that will be used as database of the program. The database for the network, which was successfully verified and approved by the aquaculturists from BFAR, includes 720 images for milkfish, 480 images for round scad, and 480 images for short mackerel scad. The captured image of the fish to be tested will be processed by the MATLAB program. It will be compared to the images in the database. The results of the testing is compared with the manual sensory assessment done by the aquaculturists from BFAR achieving 98% accuracy in determining the freshness of the fish samples.**

***Index Terms*—Fish Freshness; Support Vector Machine; Digital Image Processing.**

I. INTRODUCTION

Fishing is a common livelihood to about one million residents in the Philippines where the country has a coastline of 17, 460 km and 26.6 million ha of oceanic water [1]. In 2013, the Philippines was the 7th country in the world in terms of fish production (4.87 million metric tons). It covers 2.46% of the 191 million metric ton world's fish production [2]. According to BFAR, three of the most consumed fish here in the Philippines are milkfish (Chanos chanos), round scad (Decapterus maruadsi) and short mackerel scad (Rastrelliger brachysoma).

Fish is a highly perishable commodity. To maintain the fish's meat quality, its freshness must be maintained. It is very critical for the consumer to properly assess whether a fish that they were about to buy were fresh. Fish that was not fresh may be toxic and would surely harm the consumer.

The end of shelf life or how long the fish will last before spoilage is usually determined when sensory attributes related to spoilage such as foul odor or the color of the fish's eyes and gills. The Philippines' Bureau of Fisheries and Aquatic Resources refers to a quality table for fresh fish using sensory evaluation as shown in Table 1 based on the work of Johnson and Clucas [3]. As seen from the table, for every description and condition of the fish's gills and eyes, there is a corresponding class attributed to them.

Table 1
Sensory evaluation table for fish freshness [3,4]

Class	Gills	Eyes
5	Dark red color; some thin clear slime; marine smell	Bright, metallic; clear pupils; convex
4	Red color; some slime, but still thin and clear; no smell	Dark; white spot pupils ; a little concave; bloody
3	Red-brown color; some thick slime; beerly/mousely/warm smell	Dark; white spot pupils; a little concave; bloody
2	Brownish; several slime; stinky smell	Dark; white spot pupils; a little concave; bloody
1	Brownish; several slime; very foul smell/ammonia smell	Dark; pupils cloudy; concave or swelling out; bloody

There are different methods for identifying the level of fish freshness cited in the literature. First is by applying electrode on its muscle and skin [5]. The disadvantage of this is it can only be used with fish samples having 0°C to 10°C temperature with the absence of ice crystals. Second is fish freshness detection by using electronic nose [6,7,8]. Another method is using measuring of RGB color indices9 where the average values of RGB reflectance color space was correlated with qualities of fish.

Previous studies [7,10,14] had implemented different algorithms such as artificial neural network (ANN), k-nearest neighbor (KNN), and support vector machine (SVM) for recognition and classification that helped in their testing. Different studies, as seen in Table 2, shows that the support vector machine (SVM) is better in comparison with other algorithms in terms of classification performance, recognition rate, and classification of results.

Table 2
Comparison of different neural networks

Categories	Artificial Neural Network (ANN)	K- Nearest Neighbor (KNN)	Support Vector Machine (SVM)
Classification performance [11]	56.68%	50.44%	88.6%
Recognition rate [12]	82.5%	77.5%	91%
Classification results [13]	-	78.03%	91.9% to 92%

This study will focus on the determination of the freshness of fish meat, whether it is fresh or not, (milkfish, round scad, short mackerel scad) and will determine the shelf life of the fish examined. Digital image processing will be utilized.

This study will examine a digital image captured by the user that will be processed using the preferred algorithm based on SVM. The algorithm is created in MATLAB and will generate a report based on the results and findings.

This paper is ordered as follows. The methodology of the study is given in Section 2 while the experimental results are presented in Section 3. Finally, this paper is summarized in the last section.

II. METHODOLOGY

Figure 1 shows the conceptual framework of the study. The study focuses on determining the freshness quality of the three prevalent types of fish in the market. It also determines its shelf life, if the fish is still fresh. The figure shows the composition of the study: (a) Input; (b) Process; and (c) Output.

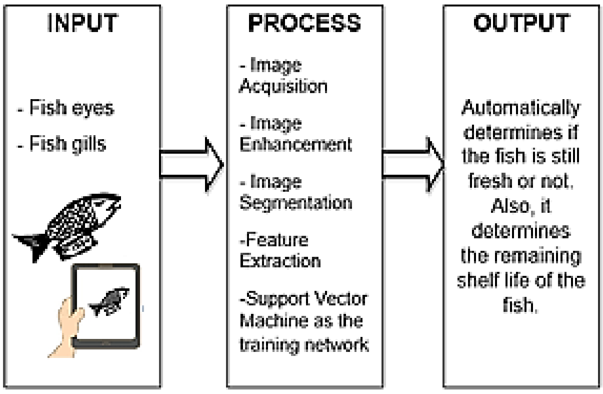

Figure 1: Process flowchart

The input parameter in the system includes the image of fish eyes and gills. For the process, it includes image processing that is composed of five sections namely: Image Acquisition, Image Enhancement, Image Segmentation, Feature Extraction, and machine algorithm (Support Vector Machine).

The images of the fish's eyes and gills will serve as the input of the system. These images will be previewed automatically accessed by a webcam. The program will use the MATLAB functions to process the images. The images will undergo several image enhancements to achieve the desired result.

The Support Vector Machine (SVM) algorithm serves as the training and classifying model. This lessens the classification time and increases the accuracy of the system because it is a machine learning algorithm which can be used for converting the data and then it looks for the best boundary between the probable outputs. In short, it performs complex data conversions and determines how to isolate the data based on the defined outputs. Thus, making the whole system work accurately.

The researchers will use MATLAB as the Graphical User Interface (GUI). It will allow the user to preview and capture the image. The MATLAB codes will be called to execute the image analysis. After finishing the process, a PDF report will be generated with recommendation and results verified by BFAR.

A. *Redness Determination*

As seen in Figure 2, the image was captured using a 16MP webcam built in the module box.

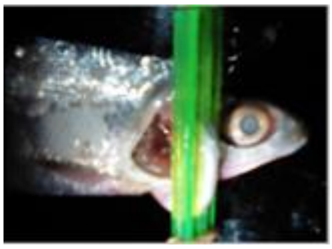

Figure 2: Original acquired image

By cropping, it divides the image into two regions of interest as shown in Figure 3. This will improve the image's framing and accentuate the subject matter or the ROI.

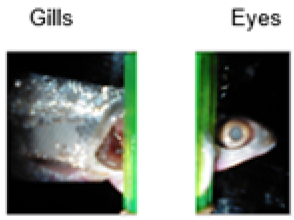

Figure 3: Cropped eyes and gills

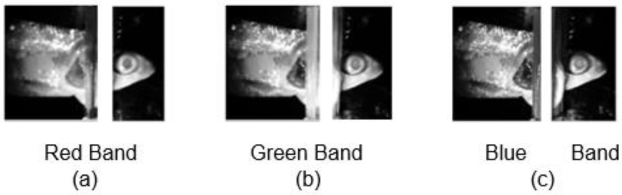

Figure 4: RGB Bands

In RGB color model, as shown in Figure 4, each color appears in its primary spectral components of red, green, and blue.

The color of a pixel consists of red, green, and blue (RGB), defined by their equivalent intensities. Color components are also called color channels or color planes. In the RGB color model, a color image can be represented by the intensity function.

$$I_{RGB} = (F_R, F_G, F_B)$$

After getting the RGB band, the next process is computing the histogram and getting the threshold of the image. Histogram equalization (Figure 5) is used for modifying image intensities to improve contrast. To illustrate histogram equalization, variable f is an image represented as a 'mr by mc' matrix of integer pixel intensities ranging from 0 to L − 1. L is the number of possible intensity values and its usual values is 256. Variable p is the normalized histogram of f with a bin for each intensity. Hence,

$$p_n = \frac{\text{number of pixels with intensity } n}{\text{total number of pixels}} \qquad n = 0, 1, ..., L-1.$$

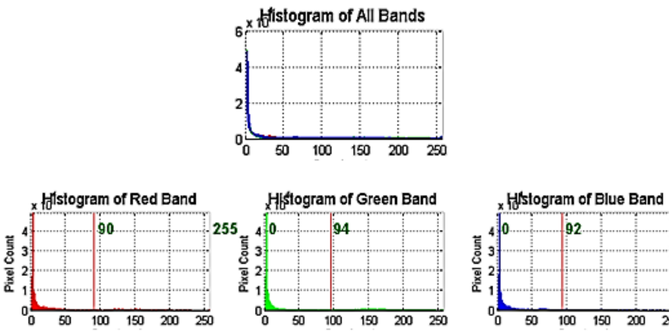

Figure 5: Histogram equalization and determination of the threshold ranges of each color band

Hence, the histogram equalized image g will be defined by

$$g_{i,j} = \text{floor}((L-1)\sum_{n=0}^{f_{i,j}} p_n),$$

where floor() rounds down to the nearest integer. Referring to the figure 6, a masked image of the object will be created due to equalization.

Figure 6: Masked image of the red object

After the histogram equalization of the captured image, red objects are detected using the threshold values detected from the previous process.

Then the image is converted to binary-level image using the process of thresholding and applying its value results a masked image. After the conversion, there is a presence of white pixels or noises as shown in the figure. Blob extraction, border smoothing and filling holes were applied as seen in Figure 7.

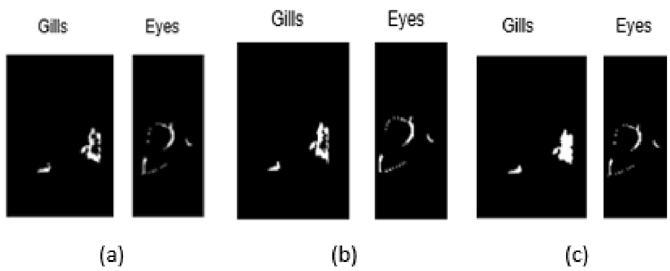

Figure 7: (a) Blob Extraction, (b) Border smoothing, (c) Filling holes

Finally, the masks will be applied to the original image. RGB values from the final results will be extracted and will be back propagated to the support vector machine.

B. Support Vector Machine

The algorithm classifies a given test set using an SVM classifier according to a one vs all relation, the data contains *N* number of different classes. One vs all, a multiclass SVM implemented in this study, will train one classifier per class in total *N* classifiers for every class and labels it as positive, otherwise, negative.

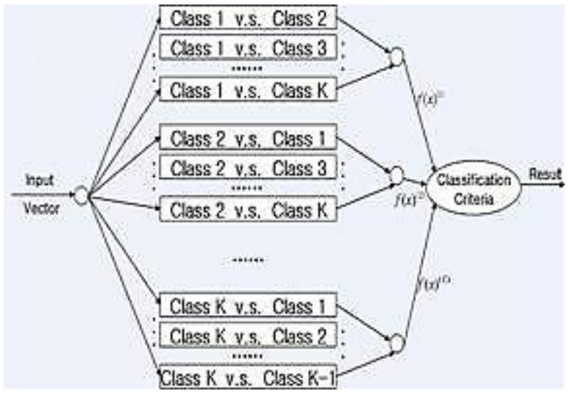

Figure 8: One vs All Multiclass SVM

In Figure 8, for a given input vector or test data classes, class 1 will be compared to class 2 unto class K and class 2 wild be compared to class 1 unto class K and so on until the test data is fully classified. In the case of fish freshness determination, the shelf life of the fishes has multiple classes.

The number of classes corresponds to the time it takes for the fish to spoil. Class 1 corresponds to the freshest state of the fish. With interval of six hours per class until the "not fresh" state of the fish is reached.

Table 3 shows the fish database. The database for the network includes 720 images for milkfish, 480 images for round scad, and 480 images for short mackerel scad. These are images of fresh and not fresh fish which were successfully verified and approved by the aquaculturists from BFAR.

Table 3
Fish Database

Types of fish	Number of classes	Number of fish database	Number of actual fish (Number of Fish database/5 [picture per fish])	Number of models
Milkfish	24	720	144	24
Round scad	15	420	84	14
Short mackerel scad	20	600	120	20

III. EXPERIMENTAL RESULTS

Figures 9, 10, 11 shows that there are no remarkable changes in RGB value of milkfish, short mackerel scad, and round scad, respectively in every 3 hours of sample. Thus, the proponents implemented sampling for every 6 hours to acquire significant changes in the RGB value of the fish's eyes and gills.

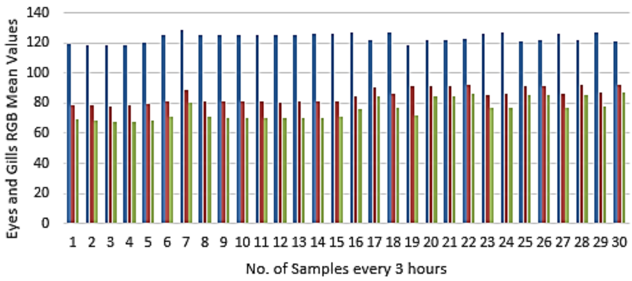

Figure 9: Tabulated results for milkfish mock database

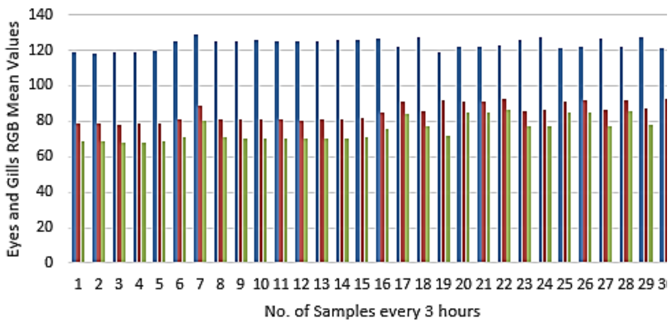

Figure 10: Tabulated results for short scad mock database

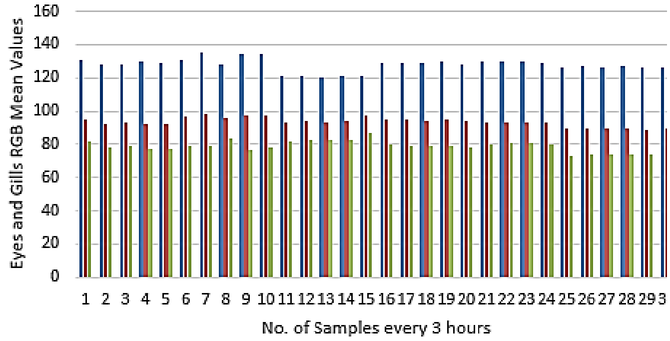

Figure 11: Tabulated results for round scad mock database

Based on the conducted database, the maximum shelf life of milkfish, round scad, and short mackerel scad are 5 days, 4 days and 4 days respectively. Beyond these days, the fish exhibit qualities that are considered not fresh based on the standard evaluation sheet from BFAR. The fish samples are rated from 1 to 5 based on their features as seen in Table 1. The fish samples that are rated by 5 are considered not fresh (class 1).

Figures 12. 13, 14 and 3 compares the actual shelf life of milkfish, round scad, and short mackerel scad, respectively, to the shelf life results that were obtained using the algorithm implemented in the system. They show the consistency of the program under several trials from the first to last day. The figures were graphed with the result of the algorithm of the system as the y-components in the y-axis and the actual shelf life of fish when it is first caught as the x-components in the x-axis. It is evident in the figure the accuracy of the program in determining the actual shelf life. It is also observable on the 5th, 4th, and 4th actual day for the milkfish, round scad, and short mackerel scad, respectively, that the program was biased to not fresh to maximize the accuracy of the result that the study concluded. Hence, milkfish, round scad, and short mackerel scad are often considered as fresh for 4, 3, and 3 days, respectively.

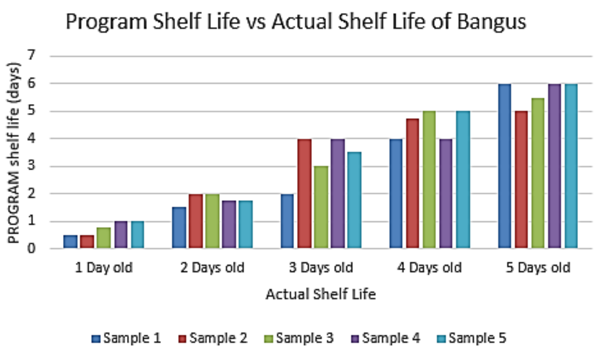

Figure 12: Milkfish shelf life

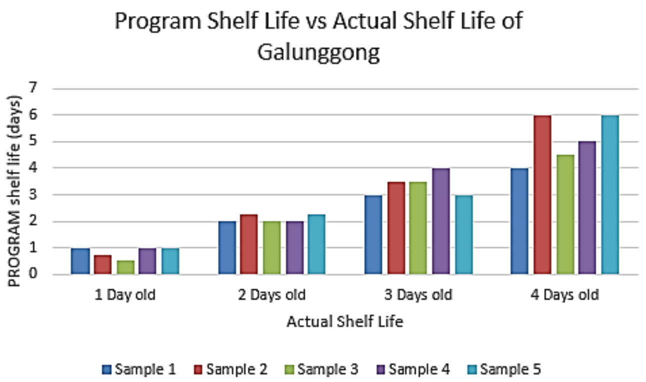

Figure 13: Round scad shelf life

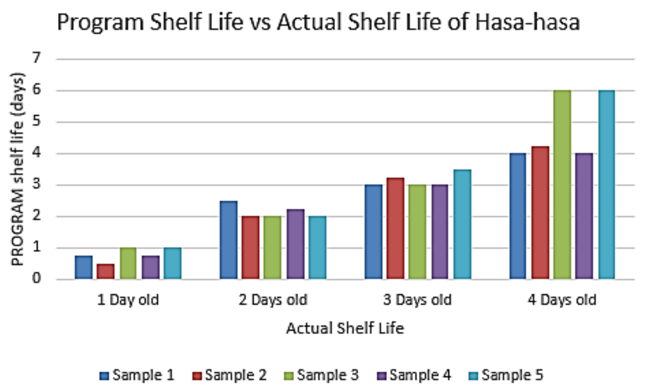

Figure 14: Short mackerel scad shelf life

Tables 4, 5, 6 shows the assessment on milkfish, round scad, and short mackerel scad, respectively. The second column of the said tables shows the manual sensory verification by the aquaculturist from BFAR using the quality table from Table 1 while the third column shows the result of the system verification.

Table 4
Assessment on Milkfish

Sample No.	Sensory Verification by aquaculturist	System result	Result (1 if same, 0 if not)
B1	FRESH	FRESH	1
B2	FRESH	FRESH	1
B3	FRESH	FRESH	1
B4	NOT FRESH	NOT FRESH	1
B5	FRESH	FRESH	1
B6	FRESH	FRESH	1
B7	FRESH	FRESH	1
B8	NOT FRESH	NOT FRESH	1
B9	FRESH	FRESH	1
B10	FRESH	FRESH	1
B11	FRESH	FRESH	1
B12	NOT FRESH	NOT FRESH	1
B13	FRESH	FRESH	1
B14	FRESH	FRESH	1
B15	FRESH	FRESH	1
B16	NOT FRESH	NOT FRESH	1
B17	FRESH	FRESH	1

Table 5
Assessment on Round scad

Sample No.	Sensory Verification by aquaculturist	System result	Result (1 if same, 0 if not)
G1	FRESH	FRESH	1
G2	FRESH	FRESH	1
G3	FRESH	FRESH	1
G4	NOT FRESH	NOT FRESH	1
G5	FRESH	FRESH	1
G6	FRESH	FRESH	1
G7	FRESH	FRESH	1
G8	NOT FRESH	NOT FRESH	1
G9	FRESH	FRESH	1
G10	FRESH	FRESH	1
G11	FRESH	FRESH	1
G12	NOT FRESH	NOT FRESH	1
G13	FRESH	FRESH	1
G14	FRESH	NOT FRESH	0
G15	FRESH	FRESH	1
G16	NOT FRESH	NOT FRESH	1
G17	FRESH	FRESH	1

Table 6
Assessment on Short mackerel scad

Sample No.	Sensory Verification by aquaculturist	System result	Result (1 if same, 0 if not)
H1	FRESH	FRESH	1
H2	FRESH	FRESH	1
H3	FRESH	FRESH	1
H4	FRESH	FRESH	1
H5	NOT FRESH	NOT FRESH	1
H6	FRESH	FRESH	1
H7	FRESH	FRESH	1
H8	FRESH	FRESH	1
H9	FRESH	FRESH	1
H10	NOT FRESH	NOT FRESH	1
H11	FRESH	FRESH	1
H12	FRESH	FRESH	1
H13	FRESH	FRESH	1
H14	FRESH	FRESH	1
H15	NOT FRESH	NOT FRESH	1
H16	FRESH	FRESH	1

The evaluators from BFAR certified that the project met the standards of the institution in determining the freshness and shelf life of fishes: milkfish, round scad and short mackerel scad.

The project achieved 98% accuracy in determining the freshness of the fish samples, which is 49 out of the 50 fish samples (17 milkfish, 17 round scads and 16 short mackerel scads) matched the results of system verification compared to the manual sensory assessment done by BFAR.

IV. Conclusion

The development of a program that determines the fish freshness and shelf life through image processing was successfully executed using MATLAB image processing techniques which helps to enhance the image to yield desired result. In addition to that, the improvement and accuracy of the program was well implemented through Support Vector Machine classifier.

The program in determining the shelf life was biased to "not fresh" to increase the device accuracy. For the shelf life, milkfish is considered as fresh for 4 days, 3 days for round scad and 3 days for short mackerel scad. Therefore, beyond these days the fish is considered as not fresh and may not be safe to consume.

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