Design and implementation of fish freshness detection algorithm using deep learning

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Abstract. Organoleptic assessment of fresh fish includes specifications for the quality of the eyes, gills, mucus, odor, texture and flesh (color and appearance). However, not everyone has knowledge about it. This research uses the tiny yolov2 to facilitate the determination of fish freshness levels (good quality, medium quality, poor quality) correctly and fast. There are a few stages in this research, included organoleptic test accompanied by taking fish eye image dataset every hour, processing organoleptic test data labeling, training, and validation. There are three types of fish used, consists of Rastrelliger, Euthynnus affinis, and Chanos chanos. Detection of fish freshness level for three species was successfully carried out with the result of average precision is 72.9%, average recall is 57.5%, and accuracy is 57.5%. The factors that affect the prediction results in this study is the collection of dataset before the training process is carried out consisting of fish samples obtained from traditional markets, which are considered inadequate so that it affects the organoleptic test process itself, the organoleptic test that was carried out as a reference for image sorting was considered inaccurate because it used less than 30 untrained panelists and dataset imbalance.

Keywords: fish freshness, deep learning, tiny yolov2

1. Introduction

The handling and distribution of marine products must comply with the quality assurance and security requirements of fishery products contained in the Decree of the Minister of Marine Affairs and Fisheries (KEPMEN-KP) No. 52A of 2013. Good distribution can prevent fish from spoiling due to external influences. Fish that do not meet the requirements for quality assurance and safety of fishery products can decrease the quality of fish freshness due to biological, enzymatic, physical, and chemical damage [1]. The low quality of fish freshness causes public unrest to consume fish. To determine the level of freshness of fish can be used a simple method in the form of organoleptic assessment of fresh fish includes specifications for the quality of the eyes, gills, mucus, odor, texture, and flesh (color and appearance). Fish is said to have maximum freshness if its characteristics are still the same as live fish, both in appearance, taste, and texture [2]. However, not all people know the characteristics of fresh fish, and this is the background of research on the design and implementation of fish freshness detection algorithms with deep learning methods to assist in determining fish freshness levels appropriately.

The method used in measuring the freshness of fish was previously made by Jaya and Ramadhan with the title "Application of the acoustic method to test the freshness of fish" [3]. This method utilizes sound wave pulses emitted and received by the transducer to determine the condition or characteristics of the sound reflection against the observed target in the form of an instrument. Then the method from
Munandar with the title "Design of a fish freshness measuring device using an infrared sensor" utilizes an infrared sensor as a detector [4]. The next method was developed by Bee et al. with the title "Application for determining the freshness level of tart fish based on digital images with the least squares method" [5]. This method utilizes RGB digital images that are converted to grayscale. In addition, there is another method for measuring fish freshness made by Indrabayu et al. with the title "The system for detecting the freshness of milkfish using images" [6]. The method used is a digital image in the form of a simple instrument.

This research uses a deep learning method, namely tiny YOLOv2 to facilitate the determination of fish freshness levels (good quality, medium quality, poor quality) correctly and fast. The concept of deep learning with artificial neural networks has been developing in recent decades. Deep is defined as an artificial neural network with many layers to imitate the workings of the human brain [7]. Deep learning is a branch of machine learning inspired by the human cortex by applying an artificial neural network with many hidden layers and uses non-linear transformations [8-9]. Deep learning significantly improves the “state of the art” in speech recognition, visual object recognition, object detection, and many other domains [10]. Deep convolutional networks are a breakthrough in processing images, video, audio, and recurrent networks for sequential data such as text [10]. The use of deep learning is also possible because of the availability of computer facilities with good performance, cloud storage, and high computing so that they are able to collect, manage, and analyze large amounts of data. This study utilizes deep learning methods to process fish eye image data to see the level of freshness so that it is expected to be the proper method in detecting the freshness level of fish.

2. Methodology

Organoleptic test data was collected in April and May 2018 at the Marine Instrumentation and Robotics Laboratory. Data processing and analysis were carried out in June and July 2018 and February-April 2020 at the Marine Instrumentation and Robotics Laboratory, Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, IPB University. The tools used in this study can be seen in Table 1.

![Table 1. Research tools.](image)

The materials used in this study can be seen in Table 2.
Table 2. Research materials.

| Materials         | Total | Description |
|-------------------|-------|-------------|
| Rastrelliger      | 2     | -           |
| Euthynnus affinis | 2     | -           |
| Chanos chanos     | 3     | -           |
| Dataset           | 3378  | -           |

The fish used are sourced from TPI Kronjo, Tangerang, Banten and Pasar Mawar, Bogor.

2.1. Organoleptic test

The condition of the fish shortly after catching will experience a post-mortem phase. The deterioration of fish quality is divided into three phases: pre rigor, rigor mortis, and post rigor. The pre rigor stage is characterized by the release of mucus from the glands under the fish's skin, allowing bacteria to grow. The rigor mortis stage is characterized by the spasm of the fish body after death due to the glycogen content and ambient temperature. The postrigor stage is characterized by the softening of the fish meat texture and is the beginning of the decay process [11]. One way to determine the level of freshness of fish that is subjectively naturally is the organoleptic test.

The organoleptic test is one of the parameters to determine the freshness level of fish based on panelist sensing. Parameters observed were eyes, gills, mucus, texture, smell, and flesh. According to SNI 01-2729-2013, the level of freshness of fish can be divided into three, namely good quality, medium quality, and poor quality. The fresh level has an interval of 7-9, the medium quality level is 4-6 and the poor quality is 1-3. Organoleptic tests were carried out every hour so that a decrease in fish quality could be seen. The data obtained will be calculated by a formula, graphed, and the final result will be a reference for categorizing the image dataset into three categories: good quality, medium quality, and poor quality. Based on SNI 01-2346-2006, the following is the formula for calculating the organoleptic test of fresh fish,

\[
\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (1)
\]

\[
S^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n} \quad (2)
\]

\[
s = \left( \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n} \right)^{1/2} \quad (3)
\]

\[
P(\bar{x} - (1.96 \cdot \frac{s}{\sqrt{n}})) \leq \mu \leq (\bar{x} + (1.96 \cdot \frac{s}{\sqrt{n}})) \quad (4)
\]

where,
\[
\bar{x} = \text{average quality score}
\]
\[
n = \text{number of panelists}
\]
\[
S^2 = \text{diversity of quality values}
\]
\[
1.96 = \text{coefficient standard deviation}
\]
\[
x_i = \text{quality value from panelist to } i, \text{ where } i = 1,2,3,...n
\]
\[
s = \text{standard deviation of quality value}
\]

2.2. Dataset collection

The dataset collection in the form of images is carried out using a cell phone camera with 16 MP specifications. The collection of images is carried out simultaneously with organoleptic tests that are
carried out every hour. The eye is the part where the picture will be taken. The image dataset of each species will be divided into three types, namely good quality, medium quality and poor quality (SNI 01-2729-2013) based on the final results of the organoleptic test calculations. The number of pictures that have been taken is 3378.

2.3. Dataset pre-processing
The collected dataset is re-checked to remove blurry images so that they do not interfere with detection by the model, affecting its performance. The dataset is divided into two parts, namely training and validation, with a ratio of 70:30.

2.4. Dataset annotation
Annotation is the process of creating a label by providing a ground truth box along with the class name for the object in each image. Image annotation is done using the LabelImg Tools software. The result of the annotation is data containing information on the position of the boundary box and its label in .xml file format. Dataset labeling illustration is shown in Figure 1.

![Figure 1. Labeling with labeling tools.](image)

2.5. Training
The training stage aims to train the algorithm in recognizing the dataset and forming a model based on the training. The training stages consist of feed-forward propagation and backpropagation processes. Feed-forward propagation is an algorithm that only calculates the output of the input so that there is no feedback to the input, while backpropagation is an algorithm for training (adjusting weights) consisting of feed-forward and backpropagation to calculate the error/loss [12]. The backpropagation process is carried out repeatedly to get the smallest error/loss value so that it is expected that the detection accuracy will be better [13].

The things that must be prepared in the training process of this research are the darkflow repository, tiny YOLOv2 model consisting of network code (.cfg), .txt file containing class names and pre-training weights (weights), tensorflow framework, and anaconda navigator. The training process produces output in the form of a file containing the weight value and saved in the protobuf file format (.pb). Illustration of detection with YOLO is shown in Figure 2. The training stage aims to train the algorithm in recognizing the dataset and forming a model based on the training. The training stages consist of feed-forward propagation and backpropagation processes. Feed-forward propagation is an algorithm that only calculates the output of the input (feed-forward) so that there is no feedback to the input, while backpropagation is an algorithm for training (adjusting weights) that consists of feed-forward (feed-forward propagation) and feedback (feed-forward propagation).
calculate the error/loss [12]. The backpropagation process is carried out repeatedly to get the smallest error/loss value so that it is expected that the detection accuracy will be better [13].

![YOLO detection model system](image1)

**Figure 2.** YOLO detection model system.

YOLO applies a single neural network to the entire image by dividing each image into S x S grids, and then each grid predicts B bounding boxes, confidence values in each box and C class probabilities [14]. YOLO is able to perform real-time detection with a simple architecture in the form of a convolutional neural network. Tiny YOLOv2 is shown in Figure 3.

![Tiny YOLOv2 network architecture](image2)

**Figure 3.** Tiny YOLOv2 network architecture

The tiny YOLOv2 architecture consists of nine convolutional layers with each layer using a rectified linear unit (ReLU) activation function and a batch normalization layer with each operation interspersed with six max pooling layers and a region layer and using an input image size of 416 x 416 pixels [15].

2.6. Validation

The validation process aims to identify the dataset based on the weight value of the training results. The validation stage only consists of a feed-forward process. Validation was carried out using 200 images for each level of freshness that was not included in the dataset for training. This is done to find out whether the trained model is able to detect the level of freshness of the fish, if it is validated using new data. The validation results are followed by evaluating the classifier's performance by measuring the value of precision and recall. Measurement can be done with a predictive confusion matrix. The confusion matrix can be interpreted as a tool that has a function to analyze whether the classifier is good at recognizing tuples from different classes [16]. The values of true positive and true negative provide information when the classifier in classifying data is true, while false positives and false
negatives provide information when the classifier is wrong in classifying data. This can be seen clearly in Figure 5.

| Predicted class | Actual class |  |
|-----------------|--------------|---|
| yes  | no | Total |
| yes  | TP | FN | P |
| no  | FP | TN | N |
| Total | P' | N' | P + N |

**Figure 4.** The confusion matrix displays the total positive and negative tuples.

where,

- **True Positive (TP)** = the actual value was positive and the model predicted a positive value
- **False Positive (FP)** = the actual value was negative but the model predicted a positive value
- **False Negative (FN)** = the actual value was positive but the model predicted a negative value
- **True Negative (TN)** = the actual value was negative and the model predicted a negative value

Precision is the ratio of correct positive predictions compared to the overall positive predicted results or data taken based on information that is lacking or incorrect or incorrect. Here is the formula for precision,

\[ \text{Precision} = \frac{TP}{TP + FP} \]  

Recall/sensitivity is the ratio of true positive predictions compared to the overall data that is true positive or data that cannot be predicted correctly. Here's the formula for recall,

\[ \text{Recall} = \frac{TP}{TP + FN} \]  

Accuracy explains how regularly the model predicts the correct outputs and can be measured as the ratio of the number of correct predictions made by the classifier over the total number of predictions made by the classifiers. Here's the formula for accuracy,

\[ \text{Accuracy} = \frac{TP + TN}{TP + FP + TN + FN} \]

3. Results and discussion

3.1. Organoleptic test result

According to SNI 01-2729-2013 the level of freshness of fish can be divided into three, namely good quality, medium quality and poor quality. The good quality level has an interval of 7-9, the medium quality level is 4-6 and the poor quality level is 1-3. The following are the results of calculations from organoleptic tests that have been carried out twice at different times,

**Table 3.** Organoleptic test results 1.

| Time  | Euthynnus affinis (Bogor) | Rastrelliger (Banten) | Chanos chanos (Bogor) | Chanos chanos (Banten) |
|-------|---------------------------|-----------------------|-----------------------|-----------------------|
| Score | Label | Score | Label | Score | Label | Score | Label |
| 9:00  | 8 | pre rigor | 7 | pre rigor | 7 | pre rigor | 6 | rigor mortis |
Euthynnus affinis (Bogor) has a good quality at 09.00-11.00, medium quality at 11.00-14.00, and poor quality after 14.00. Rastrelliger has a good quality at 09.00-10.00, medium quality at 10.00-13.00, and poor quality after 13.00. Chanos chanos (Bogor) has a good quality at 09.00-10.00, medium quality at 10.00-16.00, and poor quality after 16.00. Chanos chanos (Banten) has a medium quality level at 09.00-14.00 and poor quality at over 14.00. The first organoleptic test used 20 panelists and the results obtained were 426 images. The fish samples obtained were from TPI Kronjo, Tangerang, Banten and Pasar Mawar, Bogor.

Based on Table 3, changes in the level of freshness of fish are followed by changes in time. Euthynnus affinis has a good quality at 09.00-11.00, medium quality at 11.00-14.00, and poor quality after 14.00. Rastrelliger has a good quality at 09.00-10.00, medium quality at 10.00-13.00, and poor quality after 13.00. Chanos chanos (Bogor) has a good quality at 09.00-10.00, medium quality at 10.00-16.00, and poor quality after 16.00. Chanos chanos (Banten) has a medium quality level at 09.00-14.00 and poor quality at over 14.00. The first organoleptic test used 20 panelists and the results obtained were 426 images. The fish samples obtained were from TPI Kronjo, Tangerang, Banten and Pasar Mawar, Bogor.

Table 4. Organoleptic test results 2.

| Time   | Euthynnus affinis (Bogor) | Rastrelliger (Banten) | Chanos chanos (Bogor) | Chanos chanos (Banten) |
|--------|---------------------------|-----------------------|-----------------------|-----------------------|
| Score  | Label                     | Score                 | Label                 | Score                 | Label                 |
| 10:00  | 7 pre rigor               | 6 rigor mortis        | 6 rigor mortis        | 5.5 rigor mortis      |
| 11:00  | 6 rigor mortis            | 5 rigor mortis        | 6 rigor mortis        | 5 rigor mortis        |
| 12:00  | 5 rigor mortis            | 4 rigor mortis        | 5 rigor mortis        | 4 rigor mortis        |
| 13:00  | 4 rigor mortis            | 3 post rigor          | 5 rigor mortis        | 4 rigor mortis        |
| 14:00  | 3 post rigor              | 3 post rigor          | 4 rigor mortis        | 3.5 post rigor        |
| 15:00  | 3 post rigor              | 3 post rigor          | 4 rigor mortis        | 3 post rigor          |
| 16:00  | 2 post rigor              | 2 post rigor          | 3 post rigor          | 2.5 post rigor        |
| 17:00  | 1 post rigor              | 2 post rigor          | 2 post rigor          | 2 post rigor          |

Based on Table 4, changes in the level of freshness of fish are followed by changes in time. Euthynnus affinis has a good quality level at 13.30-15.30, medium quality at 15.30-21.30, and poor quality after 21.30. Rastrelliger has a medium quality level at 13.30-17.30 and poor quality after 17.30. Chanos chanos has a good quality at 13.30-14.30 and medium quality at 15.30-21.30. The second organoleptic test used 8 panelists and produced 2952 images. The fish samples obtained were from Mawar Market, Bogor. Due to bacterial attack starting from the rigor mortis phase, fish mucus
becomes thick, gummy, fishy, eyes set, gills, and stomach contents change color with a messy arrangement of stomach contents and a pungent odor [17] The decline in fish quality was also followed by changes in the texture of the meat which became softer and less elastic [18].

3.2. Training

The collection of fish image datasets was carried out simultaneously with organoleptic tests. The images obtained were 3378 images. The results of the organoleptic test table obtained in the previous stage are used as a reference for sorting images based on their level of freshness. Detection is divided into three classes, namely good quality, medium quality, and poor quality. The number of image datasets used from 3378 in the training stage is 1688 images, and the validation stage is 600 images (Table 5). The training process is carried out for one sample. The number of image datasets used has been reduced by blurring images.

| Freshness Level     | Number of Datasets |
|---------------------|--------------------|
|                     | Training | Validation |
| Good Quality        | 229      | 200        |
| Medium Quality      | 800      | 200        |
| Poor Quality        | 659      | 200        |
| Total               | 1688     | 600        |

Table 5. Number of datasets used for training and validation.

Figure 5. Graph of changes in training loss to steps performed on the tiny YOLOv2 model

The training stages for the tiny YOLOv2 model are 7125 steps, as can be seen in Figure 5. The loss value starts from the value range of 100 and decreases drastically at step 4500 with a loss value below the value 20. Starting from that step the loss value fluctuates up to step 7125. The loss training graph
measures how well the neural network performs in predicting the target, the lower the error, the better the model is expected to detect.

3.3. Validation
The following are the results of the validation test of the model that has been generated in the training process using 200 images at each level of freshness.

| Predicted | Good Quality | Medium Quality | Poor Quality | Not Detected |
|-----------|--------------|----------------|--------------|--------------|
| Actual    |              |                |              |              |
| Good Quality | 99          | 38             | 5            | 58           |
| Medium Quality | 37         | 59             | 19           | 85           |
| Poor Quality | 3           | 3              | 187          | 7            |

Based on Table 6, for the good quality category, as many as 99 images were detected correctly, 43 images were detected incorrectly (38 images were detected as medium quality and 5 images were detected as poor quality), and 58 images were not detected. In the medium quality category of 200 validation images, 59 images were detected correctly, 56 images were detected incorrectly (37 images were detected as good quality and 19 images were detected as poor quality), and 85 images were not detected. Then, for fish in the poor quality category of 200 validation images, 187 images were detected correctly, 6 images were detected incorrectly (3 images were detected as good quality and 3 images were detected as medium quality), and 7 images were not detected.

| Class        | Precision (%) | Recall (%) | Accuracy (%) |
|--------------|---------------|------------|--------------|
| Good Quality | 71.2          | 49.5       |              |
| Medium Quality | 59.0       | 29.5       |              |
| Poor Quality | 88.6          | 93.5       |              |
| Average      | 72.9          | 57.5       |              |

Based on Table 7, the result from average precision value is 72.9% (71.2% good quality, 59% medium quality, and 88.6% poor quality), and the recall value is 57.5% (49.5% good quality, 29.5% medium quality, and 93.5% poor quality). One of the factors that influence the prediction results in this study is the collection of datasets before the training process is carried out. Fish samples obtained from traditional markets were deemed inadequate, thus affecting the organoleptic test process itself. The organoleptic test that was carried out as a reference for image sorting was deemed inappropriate because it used less than 30 untrained panelists. Then, another factor is the imbalance of the dataset. The balanced dataset is a condition where the distribution of data classes is not balanced, the number of data classes (instances) is one less or more than the number of other data classes [19]. The dataset used in the training process is dominated by medium quality classes. That is as many as 800 images, while the good quality data as many as 229 images, and poor quality as many as 659 images. The training process is carried out only for one sample, so it is feared that it is not optimal in representing each class.
Figure 6. Example of *Euthynnus affinis* validation results for freshness level of (a) good quality, (b) medium quality, and (c) poor quality.

Figure 7. Example of *Chanos chanos* validation results for freshness level of (a) good quality, (b) medium quality, and (c) poor quality.

Figure 8. Example of *Rastrelliger* validation results for freshness level of (a) good quality, (b) medium quality, and (c) poor quality.

Based on the examples of the validation results of the three types of fish, it can be seen in Figure 6, 7, and 8 that the organoleptic test observations that focused on the eyes showed a very clear difference between the eyes of good quality, medium quality, and poor quality. Changes in fish freshness will significantly affect eye brightness so that the eyes can be used as the easiest indicator to detect fish freshness [20]. One of the consequences of the growth of bacteria is that the eyes become immersed and their light fades [17].

4. Conclusion
The detection of fish freshness levels for three different species of marine fish using the deep learning method, namely tiny YOLOv2 was successfully carried out. The result of average precision value is 72.9%, the average recall value is 57.5%, and the accuracy value is 57.5%. The factors that affect the prediction results in this study is the collection of datasets before the training process is carried out consisting of fish samples obtained from traditional markets which are considered inadequate so that it affects the organoleptic test process itself, the organoleptic test that was carried out as a reference for image sorting was considered inaccurate because it used less than 30 untrained panelists, and another
factor is dataset imbalance. This research can be developed with other deep learning methods to increase accuracy, and can be implemented into various platforms such as android applications so that they can be used by the community.

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