Clustering of fish freshness using discrete wavelet transform and Kohonen self organizing map

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Abstract. Fish freshness is one of the criteria of fish, whether it is good or not for consumption. A fish can be categorized as a fresh condition if it looks like alive fish. The observation about level of fish freshness generally can be checked directly through the human senses, but along with the development of technology, fish freshness observation can detected using a technology. One of them is by utilizing digital image processing. The purpose of this research is to cluster fish into three clusters namely fresh, not fresh, and rotten using the discrete wavelet transformation and Kohonen Self Organizing Map (SOM). Stages of clustering of the fish freshness are pre-processing, feature extraction, and clustering. At the pre-processing stage, RGB to grayscale images are converted. After pre-processing, the next stage is image decomposition in pre-processing result which is applied using Discrete Wavelet Transform (DWT) Haar level 3 and takes the statistical parameters of the mean and standard deviation from the horizontal detail coefficient. Mean and standard deviation obtained are used as the input in clustering process using Kohonen SOM. Based on the test result, it showed that the percentage of fish was clustered correctly is 92.857%.

1. Introduction

Fish freshness is one of the criteria of fish, whether it is good or not for consumption. Consumers are very concerned about the fish freshness because it can affect taste and even affect the health. A fish can be categorized as fresh condition if it looks like alive fish. Testing freshness of the fish is usually evaluated by the human senses sensory based on the color of the pupil, the elasticity of flesh, muscle contraction, the color of gills and skin odor. In general, there are two methods of testing fish freshness, namely the sensory method (depends on the human senses) and non-sensory (through laboratory testing). Both methods have advantages and disadvantages of each. Sensorial freshness testing of fish cannot be guaranteed if experts do not do it, whereas testing through laboratory using chemicals can damage fish samples. To obtain accurate test results of both methods can be done at once, but it takes time and costs.

Some research has been done to produce alternative fish freshness testing that is easier and more accurate by utilizing image processing. Image processing is a technique for processing images with a computer to improve the quality or extract important information in an image so that it can be analyzed as needed. Assessment fish freshness using image processing will not damage fish samples, as research conducted by Kishore Dutta et al. In his research, fish gills were used as freshness parameters and
wavelet transformation methods to determine the freshness level [3]. Wavelet transformation provides convenience in compression, transmission, and image analysis [5].

The clustering process needed to group fish freshness. Clustering is the process of grouping data or objects into a group based on similarity of input data. One of the clustering algorithms is the Kohonen Self Organizing Map (SOM). Kohonen SOM can group input data into a group with unsupervised learning.

This study proposes a method of discrete wavelet transformation and Kohonen Self Organizing Map (SOM) to clustering the freshness of fish. Fisheye image is used as a freshness parameter, which will be extracted by DWT Haar and takes the value of statistical parameters (mean and standard deviation). Furthermore, the mean and standard deviation obtained are used as input parameters for clustering with Kohonen SOM to cluster fish into 3 class based on their freshness level, namely fresh, not fresh, and rotten.

2. Methodology

The steps taken in this study include preprocessing, feature extraction using Wavelet transform, and clustering using Kohonen Self Organizing Map (SOM). The system diagram of the process flow is shown in Figure 1.

![System Diagram](image)

**Figure 1.** Diagram of the system.

2.1 Pre-processing

Preprocessing is a process to eliminate noise and improve image quality making it easier to recognize image characters at initial stage. In this research, before the image is transformed in a wavelet domain, the RGB to grayscale image is converted.

The color image is composed of 3 matrix layers, namely R (red), G (green), and B (blue) layers are changed to 1 grayscale matrix layer with gray degree values between 0-255 [9]. The formulation of RGB to grayscale conversion based on commonly used linear transformation standards shown in the equation (1) [7].

\[
X_{rgb} = 0.2990 \times R + 0.5870 \times G + 0.1140 \times B
\]  

(1)

where  

- \(X_{rgb}\): Grayscale value  
- \(R\) : Red layer value  
- \(G\) : Green layer value  
- \(B\) : Blue layer value
2.2 Feature extraction

The feature extraction process is obtained from the wavelet transformation process. Transformation is the process of converting data into another form to be easily analysed. Wavelet transform is an improvement from Fourier transformation. Fourier transform can only determine the frequency of a signal without providing information about the time domain. In wavelet transforms, the signal converted into various wavelet waves (mother wavelet) with shifting and scaling functions [5]. The simplest and oldest wavelet function is wavelet Haar transform. There are two types of wavelet transforms, namely continuous wavelet transforms and discrete wavelet transforms. In this study, using discrete wavelet transforms.

2.2.1 2-D wavelet transform

Decomposition is the process of breaking a signal into several components with low resolution. The basic operation in the decomposition process is filtering and down sampling. In 2-D images, the decomposition process is carried out on rows and columns that correspond to the horizontal and vertical directions of the image. Generally, the process of wavelet decomposition is carried out through screening of two-channeled sub-fields with two filters, namely a leveling or scaling filter called a low-pass filter (Lo_D) and a detailed filter or high-pass filter (Hi_D) [5]. 2D discrete wavelet transform will produce the coefficient of approximation (CAi + 1), horizontal detail (CHi + 1), vertical detail (CVi + 1), and diagonal detail (CDi + 1) of the input image as shown in Figure 1. [5]. In this study, grayscale images will be transformed using Haar wavelets at level 3 decomposition.

After the discrete wavelet transformation process, the horizontal detail coefficient value will be taken from the decomposition of the fish eye image I (i, j) in MxN size. This value will be used to calculate the mean and standard deviation using equations (2) and (3) following [3]:

\[
\text{Mean } (\mu) = \frac{\sum_{i} \sum_{j} I(i,j)}{M \times N} \tag{2}
\]

\[
\text{Standard deviation } (\sigma) = \sqrt{\frac{\sum_{i} \sum_{j} (I(i,j) - \mu)^2}{M \times N}} \tag{3}
\]

The mean represents the average of pixel intensity value in the image, while the standard deviation represents the size of the spread of the pixel intensity value. The mean and standard deviation will be the input parameter variable in the clustering process with Kohonen SOM.

2.3 Data normalization

The mean and standard deviation are normalized before being used as input variables in the clustering process. The purpose of data normalization is so that each attribute is on the same interval so that the
The grouping process of these attributes can run proportionally. The formulation used for data normalization is shown in the equation (4) [6].

\[
\text{X}_{\text{normalized}} = \frac{X_i - \text{min}(X)}{\text{max}(X) - \text{min}(X)}
\]  

(4)

where

- \( X_{\text{normalized}} \) : data values after normalization
- \( X_i \) : data values before normalization
- \( \text{min}(X) \) : minimal data values
- \( \text{max}(X) \) : maximum data value

2.4 Kohonen Self Organizing Map (SOM)

Kohonen Self Organizing Map (SOM) is one of the topology forms of the Unsupervised Artificial Neural Network (ANN) that was first introduced by Teuvo Kohonen in 1982. It was said unsupervised because in the training process it did not require supervision (target output) and only the neurons were the winners that will be updated in weight [8]. The SOM network architecture shown in Figure 3.

![Figure 3. Kohonen Self Organizing Map](image)

In Figure 3, can be seen Kohonen SOM structure consisting of two layers, namely the input layer (Xn) and the output layer (Yn), each neuron in the input layer is connected to each neuron in the output layer through a weight vector (wnxm). Cluster neurons that have the minimum Euclidean distance with the input weight vector will be the winning neurons and the weight vector will be updated [4].

The SOM Kohonen process includes:

a. Initialization of random weights \( w_{ij} (i=1,2,\ldots,n; j=1,2,\ldots,m) \), learning rate \( \alpha \), number of groups (m), and maximum iteration.

b. While stopping condition is false, do steps c-h.

c. For each input vector \( x \), do step d-f.

d. For each \( j (j=1,2,\ldots,m) \), calculate:

\[
D(j) = \sum \left( w_{ij} - x_i \right)^2
\]  

(5)

e. Find index \( j \) such that \( D(j) \) has the smallest value, as the winning neuron.

f. Update the weight \( w_{ij} \) of the winning neuron uses equation (6).

\[
w_{ij}^{\text{new}} = w_{ij}^{\text{old}} + \alpha \left[ x_i - w_{ij}^{\text{old}} \right]
\]  

(6)

g. Update learning rate at the time of iteration to \( t (t=1,2,3,\ldots) \) using equation (7).

\[
\alpha(t+1) = 0.5^* \alpha(t)
\]  

(7)

h. Test the stopping condition (maximum iteration).
The results of clustering using the Kohonen SOM network are influenced by the parameters used, namely the number of groups to be formed, learning rate, and maximum iteration.

3. Results and Discussion

The data used in this study are 70 milkfish eye images consisting of 33 fresh fish images, 18 not fresh fish, and 19 rotten fish images. The format of this image is .jpg with a size of 216 x 216 pixels. The eye of the fish is used as a freshness parameter because the difference between fresh and rotten fish is very clearly seen from the eye of the Milkfish. Fresh fish eye characteristic is bright, black pupil, cornea clear, bulging eyeballs. While the fish’s eyes are not fresh, they are sunken, cloudy, yellow even red. Examples of fish eye images used in this study shown in Figure 4.

![Fish eye images](image)

Figure 4. Image of a fish’s eye. (a) Fresh fish, (b) rotten fish

There are three stages in this research, including pre-processing, feature extraction, and clustering. Preprocessing stage is the first step that is done so that the image can be more easily extracted. All fish-eye images converted into a grayscale image. The result of this stage is shown in Figure 5 (b).

![Fish eye images](image)

Figure 5. Fisheye image. (a) RGB, (b) grayscale, (c) third level coefficient horizontal of 2D wavelet Haar transform.

The second step is to transform the image into a wavelet domain using 2D Discrete Wavelet Transform (DWT). This process is using the wavelet toolbox on Matlab R2017a. Examples of the results of image transformation shown in Figure 3 (c). Wavelet type used is Haar wavelet with third level decomposition. Third level of decomposition is used because at this level can be found the discriminatory features that can be used as a parameter to cluster fish freshness. In this study, the mean and standard deviation of the horizontal detail coefficient on third level decomposition chosen as a discriminatory feature. The mean and standard deviation obtained are shown in Table 1.

| Image to- | Mean | Standard Deviation | Image to- | Mean | Standard Deviation | Image to- | Mean | Standard Deviation |
|-----------|------|-------------------|-----------|------|-------------------|-----------|------|-------------------|
| 1         | -9,606 | 75,08             | 24        | -10,98 | 38,38             |
| 2         | -8,595 | 82,77             | 25        | -7,352 | 68,54             | 48        | -5,934 | 42,81             |
| 3         | -9,774 | 80,26             | 26        | -7,684 | 68,33             | 49        | -4,306 | 45,65             |
| 4         | -4,711 | 82,2              | 27        | -7,969 | 96,86             | 50        | -8,278 | 92,15             |
| 5         | -10,67 | 98,75             | 28        | -5,539 | 55,35             | 51        | -4,116 | 83,79             |
Table 2. The result of the clustering using various learning rate and maximum iteration.

| No | Learning Rate | Iteration | Incorrect | Percentage (%) | No | Learning Rate | Iteration | Incorrect | Percentage (%) |
|----|---------------|-----------|-----------|----------------|----|---------------|-----------|-----------|----------------|
| 1  | 0.2           | 100       | 11        | 84.286         | 10 | 0.5          | 200       | 11        | 88.571         |
| 2  | 0.2           | 200       | 11        | 84.286         | 10 | 0.5          | 300       | 12        | 85.714         |
| 3  | 0.3           | 100       | 11        | 84.286         | 13 | 0.6          | 200       | 14        | 88.571         |
| 4  | 0.3           | 200       | 11        | 84.286         | 17 | 0.6          | 300       | 11        | 88.571         |
| 5  | 0.4           | 100       | 11        | 84.286         | 15 | 0.6          | 300       | 12        | 85.714         |
| 6  | 0.4           | 200       | 8         | 88.571         | 14 | 0.6          | 300       | 8         | 88.571         |
| 7  | 0.4           | 100       | 5         | 92.857         | 19 | 0.6          | 300       | 8         | 88.571         |
| 8  | 0.4           | 200       | 8         | 88.571         | 20 | 0.6          | 300       | 8         | 88.571         |
| 9  | 0.4           | 300       | 8         | 88.571         | 21 | 0.6          | 300       | 8         | 88.571         |

The next step is to normalize the data in Table 1 so that the values are in the interval [0,1]. This step is very necessary so that each data attribute is at the same interval, so the grouping process of these attributes can run proportionally. Normalized data will be used as input data in the clustering process so that there are two units in the input layer. In this study, the clustering process uses Kohonen SOM and three groups will be formed based on the freshness level of the fish namely fresh, not fresh, and rotten. Kohonen SOM does not need training data for the learning process, but uses input data as learning. So the normalized data is used for the training and testing process.

In the training process, obtained an ideal weight that connects every input neuron to the output neuron. Furthermore, the weight will be used in the testing process of each input data by calculating the Euclidean distance. Neurons with the smallest distance will be the result of the clustering using various learning rate and maximum iteration can be seen in Table 2.
Table 2 shows that learning rate and iteration can affect cluster results. The best clustering results is obtained when the learning rate is 0.4 and 100 iteration, with 92.857% of fish clustered correctly. Table 3 shows the results of clustering in experiment 4 that compared to the actual freshness of fish. Obtained 65 fish that successfully clustered correctly out of 70 fish.

Table 3. Comparison of freshness of fish with the results of clustering

| No | Freshness | Clustering Result | Result | No | Freshness | Clustering Result | Result |
|----|-----------|------------------|--------|----|-----------|------------------|--------|
| 1  | Fresh     | Fresh            | True   | 36 | Fresh     | Fresh            | True   |
| 2  | Fresh     | Fresh            | True   | 37 | Not Fresh | Not fresh        | True   |
| 3  | Fresh     | Fresh            | True   | 38 | Not Fresh | Not fresh        | True   |
| 4  | Not Fresh | Not fresh        | True   | 39 | Fresh     | Fresh            | True   |
| 5  | Fresh     | Fresh            | True   | 40 | Rotten    | Rotten           | True   |
| 6  | Not Fresh | Not fresh        | True   | 41 | Rotten    | Rotten           | True   |
| 7  | Fresh     | Fresh            | True   | 42 | Fresh     | Fresh            | True   |
| 8  | Fresh     | Fresh            | True   | 43 | Rotten    | Rotten           | True   |
| 9  | Not Fresh | Not fresh        | True   | 44 | Rotten    | Rotten           | True   |
| 10 | Not Fresh | Not fresh        | True   | 45 | Rotten    | Rotten           | True   |
| 11 | Fresh     | Fresh            | True   | 46 | Rotten    | Rotten           | True   |
| 12 | Fresh     | Not fresh        | False  | 47 | Rotten    | Rotten           | True   |
| 13 | Fresh     | Fresh            | True   | 48 | Rotten    | Rotten           | True   |
| 14 | Not Fresh | Not fresh        | True   | 49 | Rotten    | Rotten           | True   |
| 15 | Not Fresh | Not fresh        | True   | 50 | Fresh     | Fresh            | True   |
| 16 | Not Fresh | Not fresh        | True   | 51 | Fresh     | Not fresh        | False  |
| 17 | Rotten    | Rotten           | True   | 52 | Rotten    | Rotten           | True   |
| 18 | Not Fresh | Not fresh        | True   | 53 | Rotten    | Rotten           | True   |
| 19 | Fresh     | Fresh            | True   | 54 | Not Fresh | Not fresh        | True   |
| 20 | Not Fresh | Not fresh        | True   | 55 | Rotten    | Rotten           | True   |
| 21 | Fresh     | Fresh            | True   | 56 | Rotten    | Rotten           | True   |
| 22 | Fresh     | Fresh            | True   | 57 | Rotten    | Rotten           | True   |
| 23 | Rotten    | Rotten           | True   | 58 | Rotten    | Rotten           | True   |
| 24 | Fresh     | Fresh            | True   | 59 | Rotten    | Rotten           | True   |
| 25 | Fresh     | Fresh            | True   | 60 | Not fresh | Not fresh        | True   |
| 26 | Fresh     | Fresh            | True   | 61 | Not fresh | Not fresh        | True   |
| 27 | Fresh     | Fresh            | True   | 62 | Not fresh | Not fresh        | True   |
| 28 | Rotten    | Rotten           | True   | 63 | Fresh     | Not fresh        | False  |
| 29 | Fresh     | Fresh            | True   | 64 | Fresh     | Fresh            | True   |
| 30 | Fresh     | Fresh            | True   | 65 | Fresh     | Fresh            | True   |
| 31 | Fresh     | Fresh            | True   | 66 | Fresh     | Fresh            | True   |
| 32 | Fresh     | Not fresh        | False  | 67 | Not fresh | Not fresh        | True   |
| 33 | Fresh     | Fresh            | True   | 68 | Not fresh | Not fresh        | True   |
| 34 | Fresh     | Fresh            | True   | 69 | Not Fresh | Fresh            | False  |
| 35 | Fresh     | Fresh            | True   | 70 | Fresh     | Fresh            | True   |

Figure 6 shows the clustering results of experiment 4 in the form of a 2-D plot. The red cluster is fresh fish with low mean high standard deviation, the green cluster is not fresh with high mean and standard deviation, and the blue is rotten with low mean and low standard deviation.
4. Conclusion

Based on the results and discussion, can be concluded that DWT Haar and Kohonen Self Organizing Map (SOM) can clusters fish into three clusters namely fresh, not fresh, and rotten through the fish eye images goodly. In the clustering process using Kohonen SOM, maximum iteration and learning rate parameters used can affect cluster results. Based on the test result with 70 images used learning rate of 0.4 and maximum iteration of 100, show that 92.857% of fish was clustered correctly.

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