IMAGE THRESHOLDING BASED ON HIERARCHICAL CLUSTERING ANALYSIS AND PERCENTILE METHOD FOR TUNA IMAGE SEGMENTATION

Alifia Puspaningrum[1), Nahya Nur[2), Ozzy Secio Riza[3), Agus Zainal Arifin[4)
[1,2,3,4)]Department of Informatics, Sepuluh Nopember Institute of Technology (ITS)
Jl. Teknik Kimia, ITS Sukolilo, Surabaya, 60111
e-mail: alifia.puspaningrum@gmail.com[1)], nnahya16@gmail.com[2)], ozzysecio@gmail.com[3)], agus-za@cs.its.ac.id[4)]

ABSTRAK

Klasifikasi citra ikan tuna otomatis membutuhkan segmentasi yang baik sebagai proses utama. Citra tuna diambil dengan karakteristik background yang bertekstur dan bayangan ikan di belakang objek. Paper ini mengusulkan thresholding berbobot terbaru untuk segmentasi citra yang mengadaptasi metode hierarchical clustering analysis (HCA) dan metode persentil. Metode yang diusulkan mempertimbangkan tidak hanya seluruh bagian citra tuna tetapi juga beberapa bagian citra tuna. Pertimbangan ini akan digunakan untuk mengestimasi objek yang telah diketahui proporsi ukuran dari objek tersebut. Untuk mendeteksi tepi dari citra tuna, 2D Gabor filter diimplementasikan terhadap citra. Hasil citra tersebut selanjutnya akan dilakukan threshold berdasarkan nilai yang telah dihitung menggunakan HCA dan metode persentil. Morfologi selanjutnya diimplementasikan pada gambar hasil thresholding.Padahasilpercobaan, metode yang diusulkandapatmeningkatkanakurasisebesar20.04%, sensitivity sebesar29.94%, danspecificitysebesar17,23% dibandingkandengan HCA.Hasil menunjukan bahwa metode yang diusulkan dapat mensegmentasi citra dengan baik dan lebih akurat dibandingkan dengan HCA.

Kata Kunci:*Hierarchical Clustering Analysis,Image Thresholding, Percentile Method,Segmentasi Tuna.*

ABSTRACT

Automatic classification of tuna image needs a good segmentation as a main process. Tuna image is taken with textural background and the tuna's shadow behind the object. This paper proposed a new weighted thresholding method for tuna image segmentation which adapts hierarchical clustering analysisand percentile method. The proposed method considering all part of the image and the several part of the image. It will be used to estimate the object which the proportion has been known. To detect the edge of tuna images, 2D Gabor filter has been implemented to the image. The result image then threshold which the value has been calculated by using HCA and percentile method. The mathematical morphologies are applied into threshold image. In the experimental result, the proposed method can improve the accuracy value up to 20.04%, sensitivity value up to 29.94%, and specificity value up to 17,23% compared to HCA. The result shows that the proposed method cansegment tuna images well and more accurate than hierarchical cluster analysis method.

Keywords:*Hierarchical Clustering Analysis,Image Thresholding, Percentile Method, Tuna Segmentation.*

I. INTRODUCTION

One of Indonesia's prior exports commodity in fisheries sector is tuna. Indonesia is an exporter of tuna to many other countries, such as Japan, Hongkong, Taiwan, USA, etc. [1]. Production of tuna is getting decreased because the tuna's standard of processing and production quality need more attention. One of process of tuna production is sorting which still done manually. Therefore,the misclassification is often occured. In the other hand, technology is currently widely used for many sectors, one of them is fisheries sector. To overcome that problem, the classification of tuna can be done automatically by processing image of tuna using the aid of computer. In addition, automatic classification needs a good segmentation of tuna as a main component. Segmentation will be a border that separates object and background. So that, it is important to get the accurate segmentation.

One of the methods on preprocessing to find features of an image is image segmentation. Segmentation becomes an important step for the determination and intrepetation of an image input [2]. There are various methods of segmentation have been proposed. All existing segmentation methods are classified under three categories such as, threshold-based, clustered-based, and statistics-based. Compared to all the existing techiques used for image segmentation, thresholding is the most preferential technique cause of its simple and efficient charachteristic [3]. Threshold-based method has been used by various algorithms to find the optimal threshold from the image. One widely known threshold method is Otsu's thresholding method. Otsu thresholding method use discriminant analysis to get the best class spread [4]. Otsu's

thresholding can provide good segmentation results when object and background of the image have almost similar variant value. However, this criterion-based thresholding has weakness when size of an object just a small fracture of the input image, and the illumination of the image is not separated well.

Several studies have been done to solve imbalances class problem. One of them is the percentile method that consider the proportion of object of the whole image. Nevertheless, this method only consider the value of the inter-class variant within the proportion of the object.Some researchers have been proposed methods to solve those problems. One of that methods is Hierarchical clustering analysis (HCA). This method attempts to build a dendrogram of the gray level histogram of an image based on the similarity of the inter-class variance of the clusters that will be merged and the intra-class variance of the new merged clusters.

This paper proposes a new weighted thresholding method adapts HCA and percentile method to overcome the problem of tuna image segmentation. This proposed method considers all part of the image and the several part of the image. In addition, the method can provide a good segmentation of tuna images so that could reduce the misclassification in production process. The performance of the result will be measured in terms of Accuracy, Sensitivity and Spesificity. While strikingly simple, the proposed method is shown to yield segmentation accuracy in dataset compared to HCA that is very similar to or better than previous methods.

The paper's structure is organized as follows: Section I describes introduction, methodology described in Section II. Section III defines result and discussion. Section IV presents the conclusions and future works of this research

II. METHODOLOGY

In this paper, we use weighted thresholding that consist of HCA and percentile method. HCA thresholding process using gabor image, while percentile method process using intensity image. Then both of threshold result will combine and produce the final threshold value. Mathematical morphology is used to improve the result images. The proposed method's performance will be calculated by using accuracy, sensitivity and spesificity. The proposed method consists of some process as shown in Fig.1:
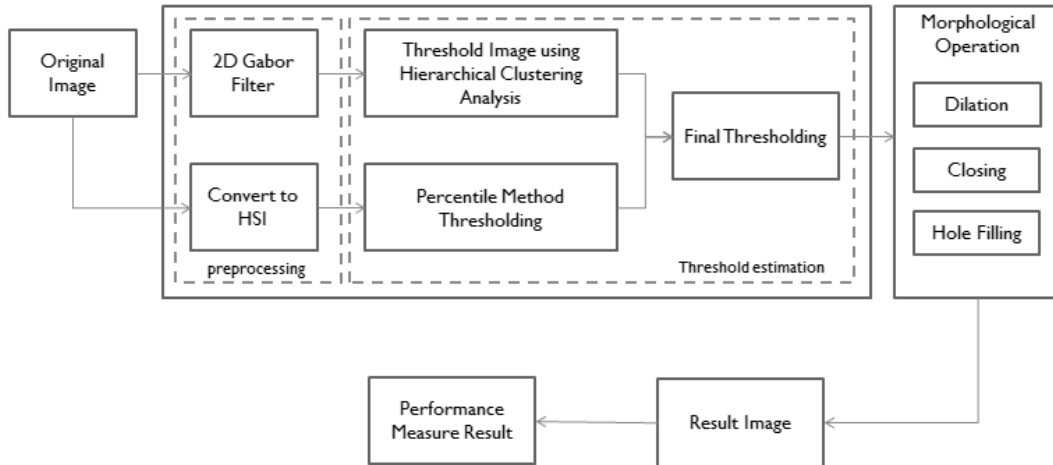

Fig.1. Flowchartofthe proposed method.

A. Pre-Processing

Preprocessing is the first step of image processing. The preprocessing consists of two stages which each of the process results will be the input for the thresholding process. The first preprocessing converts original image into Gabor feature image then will be calculated by using HCA thresholding method. Another step converts original image into HSI color space and take the intensity image only. The result image will be used for the percentile method thresholding.

1). 2-D Gabor Filter

Various applications of pattern recognition and computer vision are held by gabor filter favorable due to the properties of the scale, translation invariant, rotation, and illumination [7][8][9]. 2D Gabor is used to edge detection of input images of the experiment. In addition, it can withstand interference photometric contained in images such as noise and uneven illumination. Original image takes the Gabor features as

$$G(x, y) = f(x, y) \otimes g_f(x, y). \qquad (1)$$

$f(x, y)$ is the original gray image, $g_f(x, y)$ is the impulse response of the 2-D Gabor filter, and the sign $\otimes$ represents the convolution sum. Gabor feature matrix can be generated by convolving the image with 8 Gabor filters.

$$G = \begin{bmatrix} r(x_0,y_0) & r(x_1,y_0) & . & . & r(x_W,y_0) \\ r(x_0,y_1) & r(x_1,y_1) & . & . & r(x_W,y_1) \\ . & & . & . & . \\ . & & . & . & . \\ r(x_0,y_H) & r(x_1,y_H) & . & . & r(x_W,y_H) \end{bmatrix}$$

The Gabor feature matrix gives intensity variations near the object boundaries. After convolution the resultant Gabor feature matrix is normalized using *L2* norm. The *L2* norm can be denoted as

$$g'(x, y) = \|G(x,y)\|. \qquad (2)$$

L2 norm used to normalize the resultant Gabor feature matrix after convolution that denoted as

$$g(x, y) = g'(x, y) / \max \{ g'(x, y) \}, \qquad (3)$$

whereGabor feature image is denoted by *g*.

2). Intensity Image

Intensity image is used as input image for thresholding process using percentile method that measured according to pixel value on the intensity. In this experiment, RGB image is converted into HSI. Furthermore, intensity image obtained by taking only the *I* component of *HSI* color space will be inputted to the threshold based on percentile method.

B. Weighted Thresholding

1). Threshold Estimation

Threshold estimation consists of three kind of thresholding method. The proposed threshold *t'* is a weighted thresholding combined by value of $t_h$that are computed by HCA and t_s which a thresholding based on intensity value of the image.

Feasible approach to find thresholding percentage adaptively is an agglomerative approach which proposed segmentation method by collecting hierarchical cluster organization of gray level dendrogram from histogram image. Firstly, each gray level is defined as a cluster. Secondly, the similarity on each cluster will be calculated based on interclass variance analysis (average similarity and pixel probability between neighbor cluster), then the most similar pair of the cluster will be merged to be a new cluster [5].

For each cluster (C_k) of *k*th cluster of gray level.$P(z) = h(z)/N$, where $p(z)$ is a pixel probability for each gray level *z* (*z=0.1, .., L-1*) according to *h* frequency for value of each gray level *z* divided by *N* (sum of pixel for the image). $T_k$is the highest value of gray level in the cluster C_k. Function $P(C_k)$ for cluster C_k is defined by this equation:

$$P(C_k) = \sum_{z=T_k+1}^{T_k} p(z), \quad \sum_{k=1}^{K} P(C_k) = 1. \qquad (4)$$

This function shows the pixel probability of C_k cluster. The distance between cluster C_{k1} and C_{k2} is defined by this equation:

$$Dist(C_{k1}, C_{k2}) = \sigma_1^2 (C_{k1} \cup C_{k2}) \sigma_A^2 (C_{k1} \cup C_{k2}). \qquad (5)$$

The estimation of inter-class varianceand intra-class variance will be used to calculate similarity measure of each cluster. For inter-class variance, the calculation is defined by:

$$\sigma_1^2 (C_{k1} \cup C_{k2}) = \frac{P(Ck1)P(Ck2)}{(P(Ck1)+P(Ck2))^2} [m(C_{k1}) - m(C_{k2})]^2. \qquad (6)$$

$m(C_k)$ is the cluster C_k's mean variable that defined in Equation 7:

$$m(C_k) = \frac{1}{p(Ck)} \sum_{z=T_{k-1}+1}^{T_k} z \, p(z). \qquad (7)$$

$m(C_{k1} \cup C_{k2})$ is the average variable of global cluster C_{k1} and C_{k2} that defined as follows:

$$m(C_{k1} \cup C_{k2}) = \frac{P(Ck1)m(Ck1) + P(Ck2)m(Ck2)}{P(Ck1)+P(Ck2)}. \qquad (8)$$

In contrary, the intra-class variance is all pixel'svariance value from the merged cluster. Intra-class variance calculation is defined as follows :

$$\sigma_A^2 \quad (C_{k1} \cup C_{k2}) = \frac{1}{P(Ck1)+P(Ck2)} \quad x \quad \sum_{z=T_{k-1}+1}^{T_{k2}} [(z - MCk1 \cup Ck22p(z)] . \qquad (9)$$

Some of thresholding problem can be solved by having repeated merging of this method and stop the cluster calculation when the value needed has been obtained. The result of this process will be use as $t_h$value.

Threshold $t_s$is measured according to pixel value on the intensity. In this threshold, $\Gamma_v$for$v = \{0.3, 0.5\}$ is 30th and 50th percentiles of the intensity image in *I*. The consideration of percentile value is that the object pixel values below the median $\Gamma_{0.50}$are unlikely. The value of 0,5 represents the intensity value of background pixels typically are lower in *I* than those in the object area. These conservative percentiles are used to model the dispersion of the intensity values. In addition, parameter *β* is expected could balance the result of percentile thresholding as defined in Equation 10:

$$t_s = \Gamma_{0.5} + \beta. (\Gamma_{0.5} - \Gamma_{0.3}). \qquad (10)$$

Therefore, final thresholding *t'* is a weighted thresholding which combines threshold t_h from HCA method and t_s from thresholding based on percentile method. In addition, parameter *α* is expected could balance the result of thresholding using HCA thresholding and percentile thresholding.The calculation of *t'* is defined as follows:

$$t' = \alpha . t_h + (1 - \alpha) . t_s. \qquad (11)$$

Parameter *α* and *β* provide flexibility in the thresholding process. To avoid the exhausted iteration process of training set in finding parameter *α* and *β*, cuckoosearch algorithm will be used as the optimization algorithm.

2). Optimization paramater using Cuckoo Search Algorithm (CSA)

In 2009, Yang and Deb formulated CSA, an optimization algorithm inspired by population of cuckoo bird[10]. In this experiment, CSA will be implemented to optimalize the balancing parameter *α* and *β*value of percentile thresholding and final thresholding. Furthermore, this algorithm use Levy flight distribution to generate new solution which influenced by parameter*α* as defined in Equation 12:

$$x^{(t+1)} = x_i^{(t)} + \alpha \oplus Levy (\lambda) . \qquad (12)$$

The procedure for implementing the method is described in the following steps:

Step1: Choose the number of solutions stated as nests, appropriate value for the parameter of mutation probality, and simple bounds of domain solution, namely: lower and upper bound

Step2: Initiate random solutions and then evaluate the

solutions using objective function (Equation 11 for optimizing parameter alpha and Eq. 10 for optimizing parameter beta)

Step3: Use Levy flights to get a cuckoo randomly if the stopping criteria has not been accomplished. Then, measure the fitness and save it as the current value. Take one of nests randomly to be compared with the current value. If it meets the criteria, then replace it with the new value

Step4: Abandon a fraction (pa) of worst nests and

create new nest by generate a new locations using Levy flights

Step5: Keep the value of the best solutions then rank all of the solutions to find the current best

Step6: Show the value of optimal threshold according to the best nests

TABLEI.
PARAMETER OF CSA FOR t_s

Parameter	Value
Number ofcuckoo	5
Number of eggs	Minimal=2 Maximal=4
Iteration	50
Dimension	2
Position	Minimal=0,25 Maximal= 4
Minimumfunction	0
Radius	10
Maximumnumber of cuckoo	10
Limitposition differenceeggs	0.000000000001

TABLEII.
PARAMETER OF CSA FOR t'

Parameter	Value
Number ofcuckoo	5
Number of eggs	Minimal=2 Maximal=4
Iteration	50
Dimension	2
Position	Minimal=0 Maximal=0.9
Minimumfunction	0
Radius	10
Maximumnumber of cuckoo	10
Limitposition differenceeggs	0.000000000001

C. Post Processing

The main objective of the post-processing stage is to eliminate small/thin objects, that might be remaining of the object, and select the single connected region that is more likely to be the object. The type of structuring element we used in this experiment is disk. We start by applying a morphological opening to the input image. After that, the opening image will be processed using morphological dilation. The resulting image is then closed. Finally, eventual holes in the binary image are filled.

III. RESULT AND DISCUSSION

The experiment is developed by using MATLAB (ver. 8, R2016A). The proposed method has been tested by using 18 images from PT. Aneka Tuna Indonesia in order to evaluate the performance. It is RGB imageand has size 448×229 pixels, which has a single object image, different intensity, and textured background as seen in Fig. 2
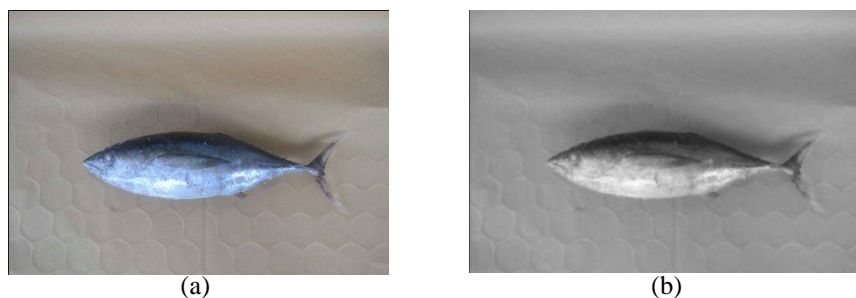

(a)   (b)
Fig. 2 .Tuna image (a) Original Image, (b) Intensity Image.

a. Determination of Parameters for Gabor Filter

Parameter k_{max} of gabor filter influences the performance of the result image, especially in measuring Accuracy, sensitivity, and spesificity. After having some experiment that is not briefly said in this paper. k_{max} value is obtained by doing some experiment with some value of k_{max}, namely, π, $\frac{\pi}{2}$, dan $\frac{\pi}{3}$. The optimal performance is obtained in value of $k_{max} = \frac{\pi}{2}$ based on the result of performance measure.
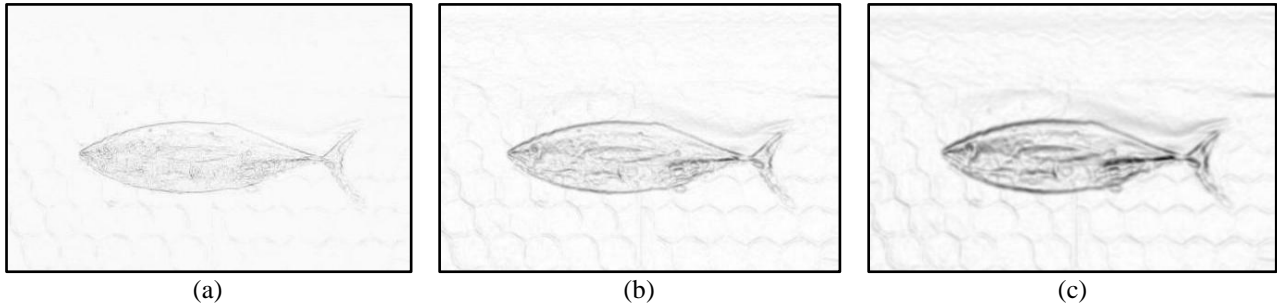

(a)   (b)   (c)

Fig. 3 .Gabor filter result using different value of k_{max}, (a).$k_{max}= \pi$, (b). $k_{max}= \pi/2$, (c). $k_{max}= \pi/3$.

b.   Tunning Parameters of Weighted Thresholding

To improve the performance of weighted thresholding, it is needed to select the appropriate value of two parameters (α, β). The parameter α (alpha) is the balancing parameter for final thresholding (t'). In addition, parameter β (beta) is the balancing parameter for percentile thresholding (t_s). Incorrect determination of the parameters may lead to an over-fitting problem for the experimental data, so the values must be chosen well. The optimal value of α and β were gained by using CSA. After having some experiment that is not briefly said in this paper, the optimal values for the experiment are $\alpha = 0,8$ and $\beta = 2,53$. After implementing the value of α and β, we can see the spread of the histogram in the Fig 4 and the result of thresholded image in Fig.5.
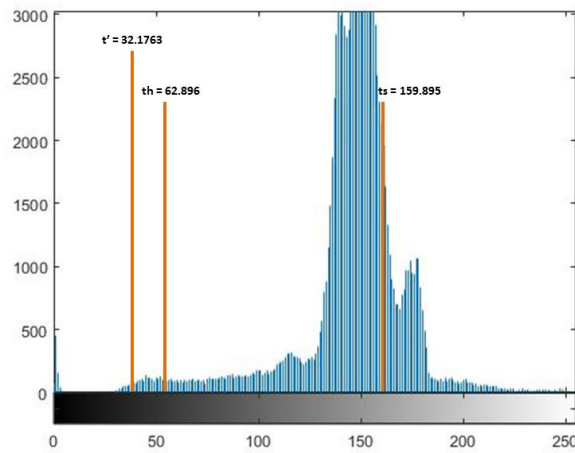

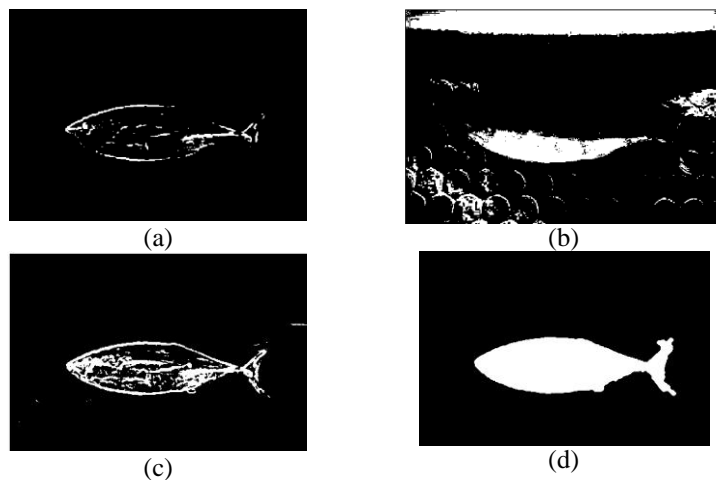Fig.4. Histogram of the image and its threshold estimation.

(a)

(b)

(c)

(d)

Fig. 5.The proposed method image. (a) Image using the threshold t_h, (b) Image using the threshold t_s, (c) Image using the threshold t', (d) final image after having several morphological operations.

c.   Performances on the datasets

For evaluation of the results, the segmentation performance was measured by using the accuracy, sensitivity, and spesificity. True positive (TP) denotes the number of object pixels being correctly identified as object and true negative (TN) signifies the number of non-object pixels being correctly detected as non-object whereas false positive (FP) represents the number of non-object being wrongly classified as object and the false negative (FN) corresponds to the number of object pixels wrongly recognized as non-object. Using the values of TP, TN, FP and FN, the accuracy, sensitivity and specificity value is computed as follows.
Accuracy refers to the closeness of a proposed method value to the ground truth value.

$$\text{Accuracy} = \frac{TP + TN}{TP + FN + FP + TN} . \tag{13}$$

Sensitivity, defined as the ratio of correctly identified object to the total number of object, is computed as given in Eq. (14).

$$\text{Sensitivity} = \frac{TP}{TP + FN} . \tag{14}$$

Specificity, defined as the ratio of correctly detected non-object to the total number of non-object, is measured as depicted in Eq. (15).

$$\text{Spesificity} = \frac{TN}{TN + FP}. \tag{15}$$

Accuracy, sensitivity, and specificity values listed in Table III. The best value of accuracy, sensitivity, and specificity are the highest values.
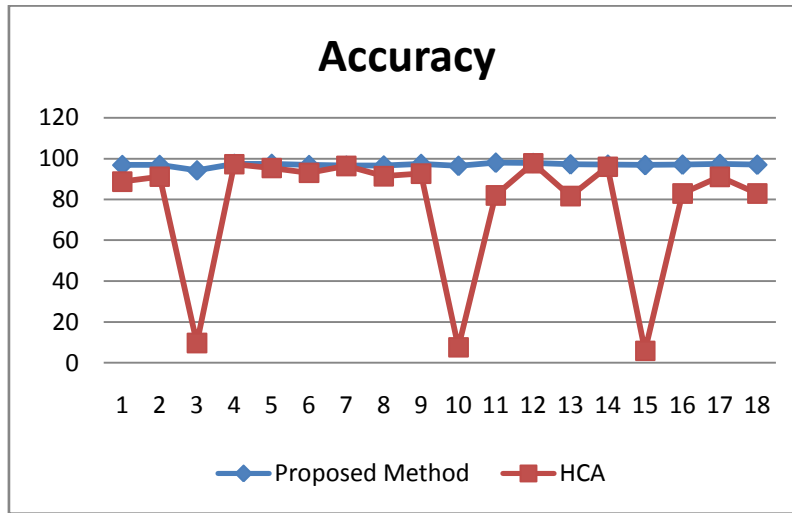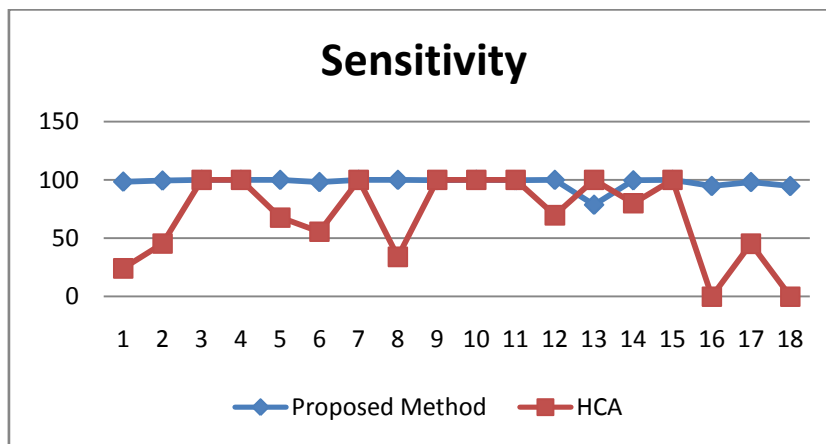

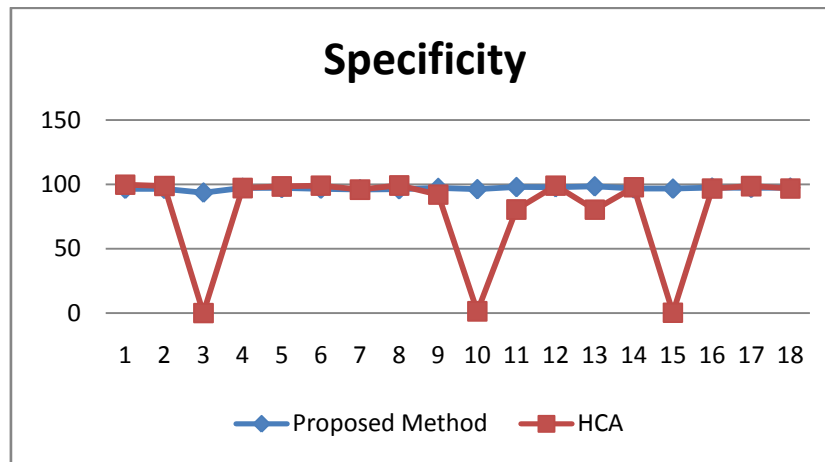Fig. 6.Comparison of accuracy.

Fig. 7. Comparison of sensitivity

Fig. 8. Comparison of specificity

TABLE III.
RESULT OF EXPERIMENT

Image	Accuracy(%)		Sensitivity (%)		Specificity (%)	
	Proposed Method	HCA	Proposed Method	HCA	Proposed Method	HCA
1	96.77	88.7	98.48	24.27	96.48	99.69
2	96.79	91.08	99.38	45.43	96.36	98.68
3	94.16	9.7	100	100	93.53	0
4	97.32	97.26	100	100	97.17	97.11
5	97.34	95.38	99.98	67.76	97.05	98.36
6	96.75	93	98.14	55.63	96.52	98.98
7	96.44	96.35	100	100	96.01	95.91
8	96.54	91.33	100	34.06	96.07	99.08
9	97.3	92.57	99.68	100	97.12	92.01
10	96.39	7.57	100	100	96.15	1.35
11	97.92	81.94	99.65	100	97.78	80.47
12	97.75	97.66	100	69.75	97.65	98.98
13	97.09	81.6	78.66	100	98.33	80.35
14	96.93	95.93	99.59	79.97	96.63	97.77
15	96.75	5.88	99.97	100	96.56	0.21
16	96.97	82.88	94.75	0	97.35	96.76
17	97.28	91.05	98.13	45.36	97.14	98.6
18	96.94	82.89	94.7	0	97.31	96.76
Mean	96.86	76.82	97.84	67.90	96.73	79.50

Based on the performance measurements shown in Table III, the average resultaccuracy of the proposed methodreached 96.86% and 76.82% for HCA. The accuracy value indicated how appropriate the proposed method used in the segmentation process, which the object is correctly detected as an object, and vice versa. Accuracy value is directly proportional to the resulting segmentation. The plot of comparison of accuracy using proposed method and HCA method are shown in Fig.6.

Besides, the average of the sensitivityresult by using proposed method and HCA are respectively97.84 % and 67,90%. From that result, we can state that the proposed method is better than the result of HCA. This result indicates that the proposed method is better to identify the object of tuna image than HCA. The comparison is shown in the Fig. 7.In addition, the average result specificityof the proposed method reached 96.73% and 79.50% for HCA. It means that the proposed method is better to identify the background of the image than HCA.

For images that have small object and bright lighting, the segmentation result of the proposed methodis reached higher performance than images with large objects. This is proven by all images except image 3. Image 3 has smaller level of accuracy than the other images because the object of image has low quality that is shown with blur captured image and bad lighting. It is not only affects the accuracy value but also the values of specificity. In the other hand, image 3 has a good sensitivity value because the object can be identified well. Sensitifity value for image 3 is 100% and specificity value is 93.53%.

The proposed method segments the image that has different characteristics such as the size of the object and the level of illumination. These characteristics affect the outcome of the segmentation. In addition, the segmentation result is determined by the threshold values that obtained from the combination of percentile and weighted thresholding values.Furthermore, by using HCA to the weighted thresholding, the superiority of HCA can define the

threshold value well according to cluster similarity of the image. Nevertheless, Since the percentile value has been specified, the size of the object affects the result of the segmentation. If the size of image exceeds the specified percentile value, then the segmentation result will be less good.

The experimental result shows that t_h is a global threshold which found by estimating the spread of the image histogram. t_s try to obtain threshold according to the intensity of the image. So that, t' which combine the value of t_s and t_h. In addition, the value of t_s and t' are balanced by using balancing parameter, alpha and beta which obtained by running CSA. After doing the experiment that not described in this paper, the value of parameter alpha and beta respectively 0.8 and 2.53 which optimal for the images that consist small size of objectso when the value of that parameter applied to images that have large objects, the results obtained are not optimal. As a result, if the proposed method and the value of balancing parameters are implemented to an image with large size of object and low illumination, the result will show a mediocre performance result. On the other hand, if it is implemented to an image with small size of object and higher illumination, the result will show a better result.

IV. CONCLUSION

A new weighted thresholding method isproposed for segmenting tuna image. The proposed method adapts hierarchical clustering analysisand percentile method. Experimental results stated that the proposed method can segment tuna images well, especially for images containing smaller size of the object. Furthermore, the proposed method can improve the segmentation performances which has been proved by accuracy value up to 20.04%, sensitivity value up to 29.94%, and specificity value up to 17,23% compared to HCA. For the future work, this method can be improved to extend to various type of images.

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