Egyptian Nile Tilapia Fish Freshness Assessment Based on an Efficient Image Processing Method

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***Abstract*—The Egyptian Nile Tilapia fish are mainly freshwater fish inhabiting shallow streams, ponds, rivers and lakes and less commonly found living in brackish water. The tilapia fish freshness quality is mainly affected by the handling and storage conditions during the period of post harvesting. The two main factors that affect the fish quality are the retention time and medium used in the storage process. As the days pass, the quality of the fish sample may be decreased till it finally reaches the consumers. This paper proposed an automatic method for classifying tilapia fish freshness based on having fish image only. The proposed method is applied to real data-set images captured during several different days. The experimental results show the effectiveness of our method in determining fish freshness in terms of both accuracy and processing time.**

I. INTRODUCTION

Fish Production considers one of the most important food production industry. Fish freshness is one of the main indicators in determining the quality of fish for the commercial access. Fish harvest process usually takes place in local ponds, then fish consuming is done in other different places where fishes are popular for profitability and marketability. Ice preservation is the main storage medium that used to maintain fish freshness during the transportation process [3]. There are other factors that affect the efficiency of preservation process including fish origin, type of fish, climatic conditions and quality of ice used for preservation, storage temperature and post-harvesting time between death and consumption. Fresh fish are identified by the pleasant and neutral smell, bulging and shiny eyes, bright red color gills, naturally metallic glow skin and so on. There is a need for a fast, simple and effective tool to validate fish quality issues. Image processing methods can be used as a non-destructive, non-hazardous tool for evaluating fish quality based on fish samples captured by imaging software.

There is some work that already done as an application of using image processing tools in the fish food sector. Early work was done by Zion et al. (2007) [5] in providing a system for fish species detection using traditional image processing methods. Later machine learning methods had been utilized in providing a classification system for fish freshness. Hosseini et al. (2008) [6] proposed an enhanced work of fish spices classification using support vector machine. In 2009 Muhamad et al. [7] use fuzzy logic in providing freshness classification system. Wang et al. (2013) [8] proposed a regression model to detect freshness from fish-eye. A more general model of fish freshness detection is proposed by Dowlati et al. (2013) [9] by using eyes and gills color feature to feed into a neural network. A related work of Nile Tilapia fish classification is proposed in [15] by utilizing the use of Scale Invariant Feature Transform (SIFT) with support vector machines (SVMs) algorithm in order to provide an automatic classification tool between Nile Tilapia fish and other types of fish.

Recent work was proposed by Dutta et al. (2016) [10] aiming to analyze the changes in fish sample upon cypermethrine exposure using wavelet transform. Another recent work was proposed by Issac (2017) [14] with the purpose of introducing a complete automated segmentation tool of fish gills segmentation using active contour-based methods. Set of statistical features was extracted to be used later in the design of the framework for fish quality and freshness identification.

Despite the fact that a great deal of work had been done in this field yet there is still a need of real-time detection framework which utilizes the most recent image processing methods in providing a complete automated fish freshness framework. Many challenges face the progress of providing such an automatic computer-based fish freshness classification framework. One of the main challenges is the accurate segmentation result for the region of interest. Such a region will be used later for feature extraction. Another challenge is the accurate removal of noise such as fins and scales. One more important challenge is the choice of appropriate features which can provide a discriminatory variation between different samples.

This work aims of providing a completely automatic method of Egyptian Nile Tilapia fish freshness classification quality by using a set of features from fish gills region as a quality indicator. The tilapia fish gills are segmented using various strategic image processing techniques like color space transformation, adaptive intensity threshold, and area thresholding based methods. The model for fish freshness classification is based on utilizing sum and difference histogram texture features derived from the gills region. Such a set of features are used with the k-nearest neighbor classifier(k-NN) as freshness identification of tilapia fish. This method is considering being non-destructive providing an efficient Tilapia fish quality assessment scheme in real time. The remaining paper is divided into 3 sections. Section 2 discusses the proposed method which have been used for assessment of fish freshness. Section 3 shows the result analysis of the proposed method, and finally, Section 4 is related to the conclusions from the results and some discussion.

II. The Proposed Method for Fish Freshness Assessment

In this work, we give interest to Nile Tilapia fish due to its popularity in our country and its economic importance. The fish samples consist of various body parts. Out of the many body parts, fish gills are the region of interest for the proposed freshness assessment method. We can define fish gills as a red colored respiratory tissue of fish. It considers one of the suited organs for determining the freshness and quality of a fish [1]. In this work, the images of gills from post-harvested Nile Tilapia fish samples were captured at a regular time interval and being analyzed to provide an assessment for fish freshness. The proposed method for fish freshness assessment is performed according to a set of steps as shown in Fig 1. The proposed image processing based method of freshness assessment in fish samples involves feature extraction from the segmented image of gills followed by feature classification using Knn classifier. These set of steps can be illustrated in details in the following subsections

The flowchart with more details of the proposed method is shown below in Fig 2. The fish gills segmentation from a fish sample image can be divided into 3 basic blocks. The first block is the conversion of the input sample image into a suitable color space which is best for the segmentation. The automatic threshold is applied to the color space transformed an image in order to segment the gills accurately and efficiently. A post-processing method based on area thresholding is performed to come out with segmented gills as ROI of the sample image. Feature extraction method is used to obtain sum and difference histogram texture based features, such features can be used in the knn classifier to determine The Nile Tilapia fish freshness quality.

A. Sample Collection

The proposed method is applied to the Egyptian Nile Tilapia fish. Tilapia are mainly freshwater fish inhabiting shallow streams, ponds, rivers and lakes and less commonly found living in brackish water. Historically, they have been of major importance in artisanal fishing in Africa, and they are of increasing importance in aquaculture and aquaponics. The popularity of tilapia came about due to its low price, easy preparation, and its mild taste [2]. Some Nile tilapia can grow as long as two feet, and it can live for up to nine years [4]. Fig 3 shows a sample of one Tilapia fish image over two different days. These images are used to provide a guide to freshness assessment of the fish samples using image processing techniques. The proposed method is applied to the Egyptian Nile Tilapia fish.

B. ROI segmentation

Fish gills discriminatory changes seem to be a good choice for freshness assessment, they are chosen as the Region of Interest (ROI) in this work. The captured fish sample image is an RGB image. On analyzing all the 3 RGB channels, i.e. red, green and blue, of the captured image, it was observed that the gills segmentation is not accurate as it contained a lot of noise in the form of eye and scales. Instead of this, the image represented in RGB color space was converted into different color space. Fig.4 shows the fish sample in HSV color space compared with RGB color space. In HSV color space the image can be shown in three channels Hue 'H', Saturation 'S', and Value 'V' as shown in Fig.5.

It was observed that the HSV color space and 'S' component was best suited for gills segmentation as shown in Fig 6. The 'S' channel is thresholded on the basis of the intensity using the Otsu Threshold method to convert the image to a binary image based on the adaptive threshold value. The thresholded binary image consists of fish gills and other parts of the fish body as shown in Fig.6c. All other objects other than gills is considering as noise and removed from the binary image using some morphological operation followed by area thresholding. It is clear from the Fig.6c, the gills have the largest area among the eyes and fins, so the pixels in the binary image are grouped on basis of area and then the labeled region of maximum area is segmented as gills and marked as ROI as shown in Fig.6d. The gills in the input image are manually marked by experts and the marked gills are known as ground truth. A correlation is established between the gills which are segmented using the proposed segmentation method and the ground truth image to measure the accuracy of the extracted ROI image. Algorithm 1 shows in steps the process of ROI segmentation

C. Feature Extraction

In this work, we utilize the use of sum and difference histogram as image features. Sum and difference histogram was defined by Unser (1986) in [11] as values that are calculated from the sum and difference of two intensity values with ($d1$, $d2$) as displacement values. Sum and difference histograms are introduced as an alternative to the usual co-occurrence matrices used for texture feature extraction. Sum- and difference-histograms provide an efficient approximation for the joint probability by counting the frequencies of sums respectively differences of pixel pairs [12]. In its original version proposed by Unser, he considered the displacement in x- and y-directions simultaneously, but it lacks some information which is present in the x- and y-directions separately. The

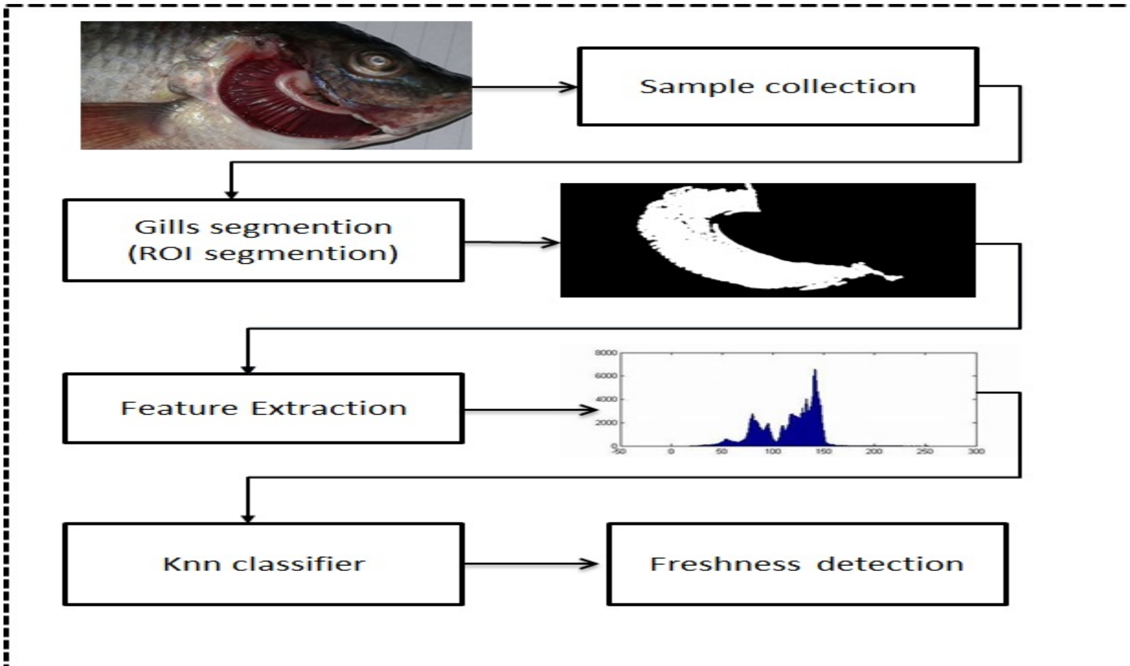


Fig. 1: Main steps of the proposed method for fish freshness assessment

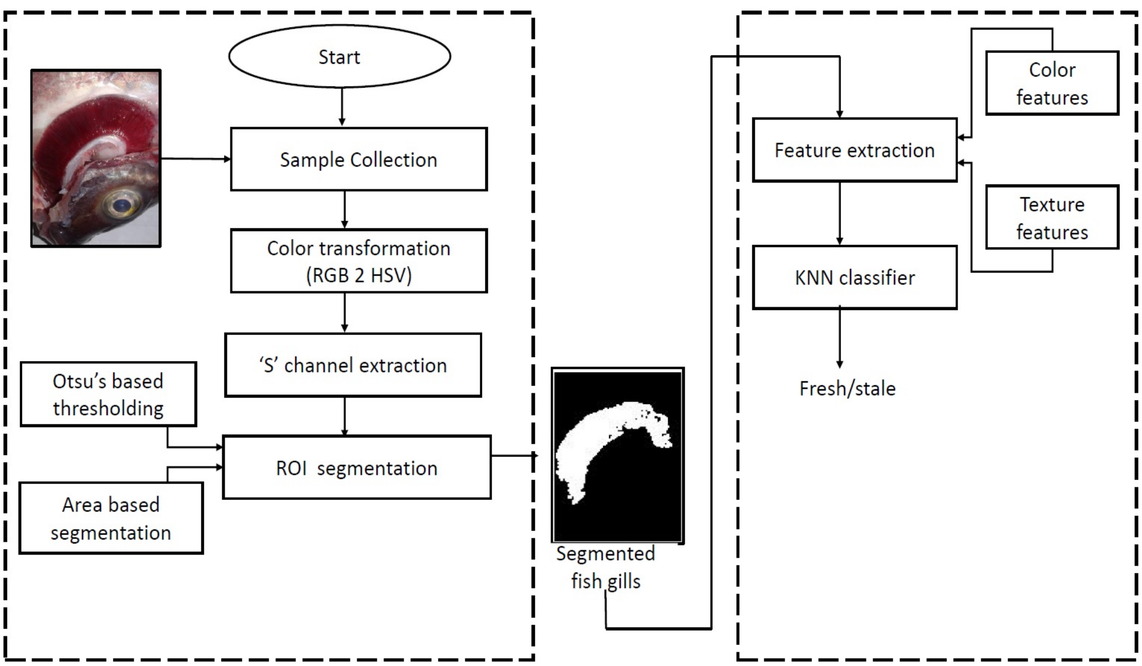


Fig. 2: Flow Chart of the proposed method for fish freshness assessment

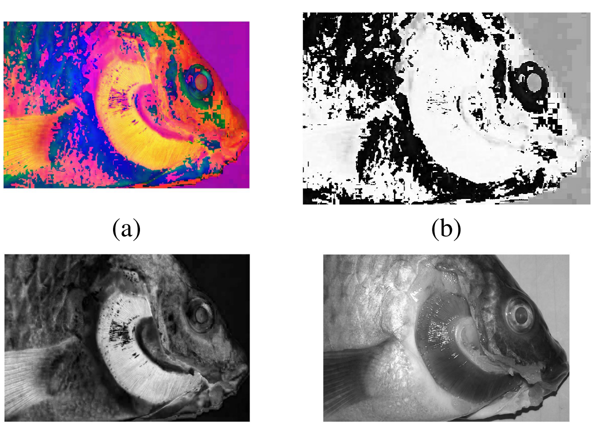
Day 1 Day 2

Fig. 3: A sample of tilapia fish images

RGB image HSV iamge

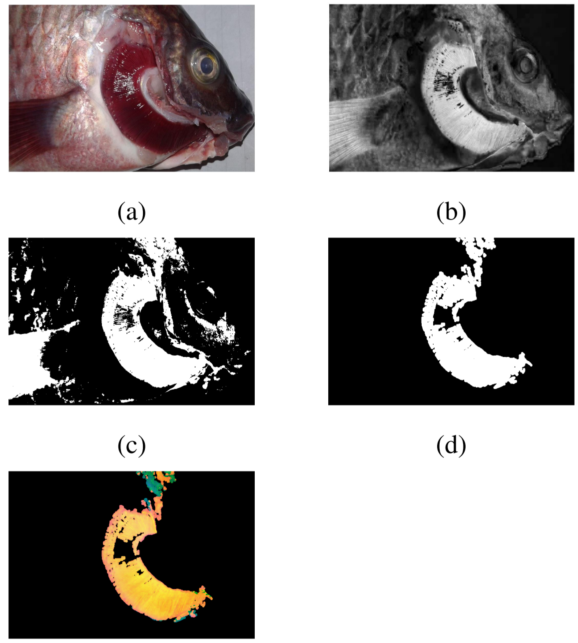
Fig. 4: RGB color space Vrs. HSV color space

improvement of the Unser's descriptor known as an Improved sum and difference histogram (ISADH) by considering the information present in x- and y-direction separately is proposed by Dubey et el [13]. In order to calculate ISADH feature, we first calculate the sum and difference in the x-direction and then simulate this result in the y-direction. Simulation is carried out by taking the sum and difference in the y-direction on the outcome of x-direction. ISADH texture element depends upon the force benefits of neighboring pixels [13]. The histogram of two pictures of a similar class may differ altogether. Then again, the ISADH highlight has less distinction for these pictures. On the off chance that the distinction in a highlight of two pictures is less, at that point pictures are more probably has a place with a similar class. In any case, if the distinction is noteworthy, at that point pictures



(a) (b) (c) (d)

Fig. 5: HSV color image (a) HSV (b) H channel (c) S channel (d) V channel



(a) (b) (c) (d) (e)

Fig. 6: Gills segmentation (a) Input RGB image (b) 'S' channel (c) Otsu's based threshold (d) area based threshold (e) ROI segmentation in S channel

Algorithm 1 Gills Segmention using Thresholding Method

Input: RGB color image
Result: Binary gills image
Procedure
RGB to HSV color transformation using the following equation:

$$H = \theta (if B \leq G), 360 - \theta (if B > G) \quad (1)$$

$$Where, \theta = \cos^{-1}\left\{\frac{0.5[(R-G)+(R-B)]}{[(R-G)^2+(R-B)(G-B)^{0.5}]}\right\} \quad (2)$$

$$S = 1 - \frac{3}{R+G+B}[min(R,G,B)] \quad (3)$$

$$V = \frac{1}{3}(R+G+B) \quad (4)$$

Select S channel only
Apply Otsu's threshold method to get appropriate threshold value between two classes corresponds to the maximum $\sigma_b^2(t)$

$$\sigma_w^2(t) = \omega_0(t)\sigma_0^2(t) + \omega_1(t)\sigma_1^2(t) \quad (5)$$

with $Weights \omega_0$ and ω_1 are the probabilities of the two classes separated by a threshold t ,and σ_0^2 and σ_1^2 are variances of these two classes.
Apply open morphological operation with disk structure element
Select maximum connected component object as gills object

are more probably has a place with the diverse class.

D. Freshness Assessment using KNN classifier

Classification of input images is done on the basis of the extracted features. We use K-nearest neighbor's algorithm to classify the fish into either fresh or stale fish. We utilize the use of k-Nearest Neighbors algorithm (or Knn algorithm) as a non-parametric method used in pattern recognition for classification and regression. A set of k nearest neighbors are labeled as neighbor-hood of sample i to be classified [16]. In order to get the proper class of i, we consider the majority voting over the all samples in the neighborhood with or without taking into account the distance-based weighting. In this work, we apply the knn classifier with k=2.

III. Result Analysis

A. Experimental design and photography

The Nile tilapia (Oreochromis niloticus) were sampled from National Institute of Oceanography and Fisheries NIOF, Brullus, Kafrelsheikh, Egypt. The average weight and the average length of fishes were 123.71 Âś 1.20 g and 23.60 Âś 0.56 cm respectively. The pond was free from pathogenic infection and toxic pollutant as were recorded through periodical toxicity and microbial detection protocol. Fishes from the aquariums were placed into chilled water to avoid rigor mortis. The fishes were preserved for imagining the study in boxes with a fish/ ice ratio of 1: 2. Images of gill were taken using a Fujifilm X-T10 digital camera daily till the end state of death. The experiments were performed using 138 fish samples with 70 samples as fresh fish and 68 sample as non-fresh fish.

B. ROI segmentation results

Fig.7 shows the output of the proposed segmentation method. It shows the original fish image in the first column, followed by ROI segmentation compared with ground truth image. The first four images are representing the fresh samples while the last four images are representing non-fresh samples. Table I indicates the assessment measures of segmentation results for a set of fish samples. The first column refers to the image number, followed by the correlation coefficient ($CorrCoef$) between the segmented image and ground truth image. The third column shows the Jaccard similarity index (sometimes called the Jaccard similarity coefficient) ($JaccardCoef$). It can be used in comparison between two sets members to check which members are common and which are different [18]. It's a similarity measure for the two sets of data, with a range from 0 to 1 representing both values Jaccard index and Jaccard distance. The Jaccard distance is complementary to the Jaccard index, which measures dissimilarity between sample sets. The higher the Jaccard index and the lower the Jaccard distance means more similar to the two sets. Finally, we use the Dice Similarity Coefficient (DSC) as another measure of similarity between the segmented image and ground truth image. It is a statistic used broadly in the field of segmentation as a measure of spatial overlap [17]. The function ranges are $[0-1]$, with no overlap indicating by zero value, while exact overlap indicating by 1.

TABLE I: Assessment of segmentation results

Image no.	$CorrCoef.$	$JaccardCoef.$	DSC
1	0.912	0.872,0.127	0.931
2	0.806	0.713,0.286	0.832
3	0.765	0.653,0.346	0.7903
4	0.903	0.852,0148	0.920
5	0.748	0.621,0.378	0.766
6	0.899	0.861,0.139	0.925
7	0.907	0.862,0.137	0.926
8	0.879	0.808,0.191	0.894
9	0.869	0.791,0.208	0.883
10	0.831	0.740,0.259	0.850
11	0.850	0.790,0.209	0.882
12	0.777	0.671,0.328	0.803
13	0.812	0.702,0.298	0.824
14	0.781	0.683,0.316	0.811
15	0.841	0.756,0.243	0.861

C. Classification results

The proposed method use Knn classifier to classify the given samples as fresh or stale sample. The training of classifier is performed using k-fold cross validation with $k = 5$. Fig.8 shows some sample results of the classifier output with the first column indicating fish samples classified as a fresh and second column as stale samples.

Fig. 7: A sample of tilapia fish images with first 4 images as fresh samples, and last 4 images as non-fresh samples

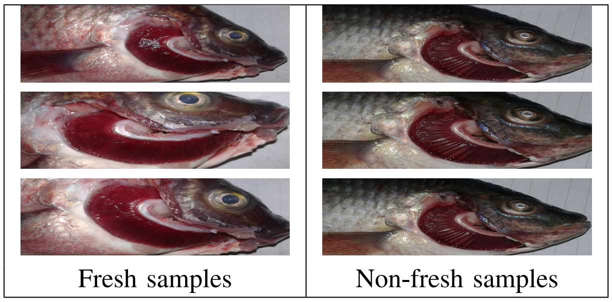


Fig. 8: A sample of knn classifier response

TABLE II: Confusion matrix of classification

	Fresh	Non-fresh	Row total
Fresh	68	6	74
Non-fresh	2	62	64
Column total	70	68	138

Table II shows the confusion matrix of classification results. The columns represent the actual classification while the rows represent the predicted results from the knn classifier. The total number of samples are 138 samples with True Positive ($TP = 68$), True Negative ($TN = 62$), False Positive ($FP = 6$), and False Negative ($FN = 2$). Table III summarize the assessment measures of classification result with overall accuracy Miss classification Rate , True Positive Rate, False Positive Rate , Specificity , and finally precision .

IV. Conclusion

In this work, we proposed a complete automatic framework for determining Nile tilapia fish freshness using image processing methods. We use fish gills as one of the main indicators of fish freshness in the fish body. In this paper, we proposed an image processing based method for gills segmentation using a combination of color thresholding and area thresholding. Set of a sum and difference texture histogram features were extracted from segmented region to be used later within knn classifier in order to provide a classification result of fish freshness. This work can be extended by providing a complete system of freshness grading over different days. Such work required more samples, more features, and different classifier models.

TABLE III: Assessment of classification results

Total samples	138
Fresh samples	68
non-fresh samples	62
Overall Accuracy	0.94
Miss Classification Rate	0.05
True Positive Rate	0.97
False Positive Rate	0.08
Specificity	0.91
Precision	0.92

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