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Fish Species Identification Techniques: A Review

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Abstract

Fish species identification process is still problematical and time consuming, so automated fish identification is important. The performance of various fish identification techniques is compared depending on pre-processing, number of significant characteristics and identification correctness. The reason for writing this review stems from the importance of fish for humans as food and as a wealth which support the economy of countries. Therefore, it is necessary to shed light on fish and how to distinguish the beneficial and harmful ones, discover and identify fish diseases, and so on, which contributes in building a knowledge base available to all. The aim of this paper is present a review on various fish species identification techniques; pre-processing operations, features extraction methods, recognition/classification techniques and databases. This review will be helpful for beginner researchers, it can be used as a starting point for new fish species identification approaches.

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1. Introduction

Aquatic organisms' classification was important process. It can be beneficial for understanding marine ecosystem. It helps us to evaluate the change of environment pollution, marine environment and climate. The evolution of marine biodiversity still poorly evaluated or unknown. Video techniques have been widely used for observing underwater habitat and macro fauna, nevertheless fish species recognition from underwater video for estimating fish profusion take limited interest from the researchers [1].

Fish are among the most important aquatic organisms, it is essential part of human resource particularly as food, there are many types of fishes that vary in shape, lifestyle, size, color, quality and price. There are more than 30,000 types of fish worldwide so it is unworkable to recognize each one by looking at their shape. Fish species can be classified into two types: freshwater fish and saltwater fish, the two types differ in: size, structural adaptation and physiology [2].

Manual classification is laborious, time-consuming, tiresome and requires experience, therefore, it is necessary to design an automated fish identification system able to provide reliable and accurate results. Some challenges like noise, distortion, segmentation fault, overlap, luminance, and image background subtraction includes cases like: conflicting lighting, colors shifting and existence of sediments in water faced fish identification system [3].

At the present time, notwithstanding its agricultural and commercial value, fish identification is considered as a laborious and multifaceted task because of the resemblance in shape, color, texture and size of fish species also fish may appear in different orientations, scales and curved body shapes [4] that's why fish classification system need strong and significant features.

Fish classification or identification system based on two types of features: shape-based features which extracts the shape information of fish, it describes the whole fish likes: fish color and fish texture, the second type is the geometric-based features which describes the local features like: length of fish anal fin, length of mouth, angle of fish head, length of caudal fin and angle of eye-end mouth [5].

This review presented description and discussion for pre-processing steps, features extraction techniques and fish classification algorithms to answer the following questions:

- What pre-processing steps are being applied to achieve high performance of the fish identification system ?.
- What techniques are being applied to extract relevant, robust and significant features ?.
- What algorithms are being utilized to identify various fish images which differ in size and shape accurately ?.

This review is organized as the following: section two explores the fish species identification system; section three discusses the datasets used for fish species identification system; section four concludes this review.

2. Fish Species Identification System

Fish species identification system includes three main steps: 1) pre-processing, 2) characteristics extraction, and 3) recognition/classification.

2.1 Pre-processing:

The main process for improving system, it performed before feature extraction process. The pre-processing of images

contains different operations like: transforming an input image to a grayscale image [6], image scaling, contrast adjustment, removing noise [7]. Morphological operations were used to exclude undesirable shapes from input objects, sometimes morphological operations are performed on input image in order to acquire the binary image from the input image [8]. Combination of image processing techniques such as image enhancement and segmentation can used to improve fish classification system [9], images pre-processing such as rotation, reflection, histogram, equalization, translation and gaussian blurring, data enhancement process was performed on distorted copies of existing images which led to improvement of the work of the system through expand the data set [10]. A gain gaussian blur method was used to blur input image, it used to reduce noise followed by such operations: binary masking of image, flood fill operation (sometimes known as a seed fill), boundary extraction using the sequential grass-fire algorithm [11]. Cropping fish image, edge detection and cut out 512×512-pixel size sub-image was used in [12]. Object detection is an important operation that used to identify and detect the image object, a technique called (you only look once) was used [13] so the system has the ability to classify each image without pre-filtering. Morphology operations in [14] were used in order to separate the background and objective area then boundary detection operation was performed to obtain image contour. Many pre-processing methods such as: ROI process and cropping process were the most convenient because it detects fish proprieties accurately. In [15] image enhancement operations such as: dark channel prior and histogram equalization were used with object detection and segmentation operations such as: high-dimensional color transform, region principal color-based saliency detection and saliency detection via graph-based manifold ranking. Fish images were obtained on a static white background then preprocessed by these steps: converting to binary image, converting to grayscale image, edge detection by applied canny filter and finally filling the inner sides of edges [16]. The pre-processing process is necessary in order to increase and enhance the readability of the fish image. The pre-processing operations give the characteristics extraction stage more accurate, dependable and has a more considerable influence on classification and recognition efficacy.

2.2 Feature extraction:

In these step significant and important characteristics were extracted from image samples. Sometimes an extracted feature may be inaccurate or not relevant, so more effective techniques are demanded in order to find substantial image characteristics. Shape characteristics were extracted from input image, the morphology of the head region of the fish image was more important than tail region [8], another work [17] based on shape features to extract relevant proprieties from fish image,14 shape features were extracted from input image which collected from open fish markets. Shape of fish was used to extract important features of fin and fish body like: length of anal, caudal, pelvic, pectoral and dorsal fin [18]. In [6] features vector was extracted from body of fish based on single value decomposition [19], which was a very useful method in linear algebra, the fish image was divided into (15) blocks, the features were extracted from all parts of the image in order to compose feature vector. Color based method is another descriptor which was used in [16], the input fish image was in hue, saturation and value components color space, it used to extract seven statistical features, so 21 significant characteristics were obtained from each part of image. Scale invariant feature transform was a powerful characteristics detection method, it used to depict image and disclose local characteristics in input image, it was descriptor that was used for recognizing, tracing, locating, and ROI extracting of the input images [20]. Many researchers were used the combination between features (the shape and texture, the texture and color and so on) in order to enhance the accuracy of fish identification. Combination of extracted texture features, shape features and color features were extracted from three different fish classes [21]. Six categories of attribute vectors were formed in [12] based on statistical characteristics, wavelet-based characteristics and color characteristics. Scale invariant feature transform and gray level co-occurrence matrices were used in [15] to classify fish underwater, SIFT used to extract invariant and significant features from images, so it can be used to carry out reliable object matching, GLCM is the most used method in the field of texture analysis applications, it extracts relevant features by extract second order statistical texture features [22]. Robust feature extraction methods were used in [23], GLCM was used to extract 24 attributes, 39 attributes were extracted based on angle and distance tools and 2 attributes were extracted based on statistical measurements. Feature extraction process transform the input data to a data comprises the distinctive key points, this key point will most purposefully represent the information that is essential for classification and analysis. The results show that shape features and the composite features are reliable features for identification fish types, combination of texture and color characteristics became widely used in fish types identification, the features extraction based on semblance includes the gray texture features, color features are susceptible to noise and scale.

2.3 Recognition/classification:

Recognition/Classification is the last stage of the fish species identification system, fishes are categorized by the classifier into their species. Many researchers have evolved a variety of fish classification and recognition systems in order to: use by the fishing industry, observe the behavior of fish and assist in fish sorting and counting.

Artificial intelligence is the branch of computer science that make computers solve hard problems like humans. There are many methods and algorithms of artificial intelligence:

- **Neural network and convolution neural network:** Neural networks are an effective tool for image

classification, object recognition, forecasting, statistical analysis and data clustering. Neural network classified into: 1) feedforward networks which its connection is forward (there isn't connections between the neurons on the same network layer or previous neurons). 2) the radial basic function which have an input layer and an output layer, it can be used for image classification, control systems and regression. 3) perceptron and multilayer perceptron networks which are the earliest and simplest models, it is a linear model that separating data into two different classifications. 4) recurrent neural networks which are a model designed to process consecutive data, the data was moved forward and loop it backwards to previous steps, the layers between the input and output layers are recurrent. 5) A modular neural network which contains a number of components that work together, it can be used to performed difficult tasks [35].

Convolution neural network is a category of neural network, it depended on the convolution kernels or filters which help in extracting the relevant and significant characteristics from the input image, the most advantage of convolution neural network is learn the filters automatically. Convolution neural networks use few preprocessing, receive any type of data as input compared to other techniques of image classification [36].

- **Machine Learning and Deep Learning:** Machine learning is a part of artificial intelligence, it has ability to build a model depended on training data and inform the machine how to perform complex tasks (learning isn't needed), it is widely used in computer vision, military, speech recognition and protection of network [37]. Deep learning is a part of machine learning which depended on artificial neural networks with impersonation learning. It divided into: supervised, semi-supervised, unsupervised and reinforcement deep learning. Deep learning used in cases: fields need great experience (medical decisions, speech recognition, and understanding the language), where the solution of problem constantly changes over time, where problem size is very large [38]. Table 1, was summarized each research:

Table 1. Various studies of fish species identification techniques.

Fields	Reference	Techniques	Accuracy
Fish classification	[6]	A feed forward neural network	94%
	[8]	Deep learning	92.8%
	[9]	Image processing techniques	96.67%
	[10]	Convolutional neural network	Not reported
	[12]	Multi-class support vector machine	Not reported
	[15]	Sift, pca and glcm	Not reported
	[16]	Nearest neighbor algorithm	86%
	[17]	Machine learning algorithm	98%
	[18]	Support vector machine	78.59%.
	[21]	Genetic algorithm with tabu search and a back-propagation algorithm	82.1% for back-propagation, 87% for GTB
	[23]	Ma-b algorithm and back propagation algorithm	90% for MA-B algorithm 82.25% for back propagation algorithm
	[24]	Deep convolutional neural networks	80.58%
	[25]	Multi-level residual network	99.69%
	[28]	Neural network	Not reported
	[32]	Convolutional neural networks	96.55%.
	[33]	The transfer learning technique	90.53% for SoftMax classifier, 95.37% for Google Inception v3"and"SVM classifier
	[34]	Deep learning techniques	Not reported
Recognize/ classify invasive fish species	[29]	Convolutional neural networks	Not reported
	[31]	A statistical classification meta-algorithm	98.9%
Fish recognition	[26]	Deep convolutional neural networks	85.59%
	[30]	Fourier transform and discriminant analysis	90%
Detect and classify fish	[13]	Convolutional neural networks	Not reported
	[27]	Convolutional neural networks	90% and 92% for detection and classification
Fish detection / recognition	[11]	AI techniques and computer vision	90.9% for CNN, 87.08 -98.67% for SURF

3. Database Description

In fish identification domain, no criterion scientific standard dataset compared to other domains and it's one of the restrictions faced the researchers. The researchers were used several datasets, some of researchers based on their self-collected images. Table 2 describes database for each research.

Table 2. Fish identification systems databases description.

Reference	No. of images	No. of Families or Species	Images acquired methods or database
[6]	36	18 species	Cannon power a14000 hd digital camera
[8]	60	1 class	Bright field microscopy imaging
[10]	178	8 species	Not reported
[12]	90 of each class	6 species	Nokia n8-00 smartphone camera
[15]	20000	15 species	Fish4knowledge database
[16]	112	6 species of one family	Not reported
[17]	1520	38 species	Samples were collected from: - markets and supermarkets in island in coastal regions. -central fish market of Port Louis
[18]	150	2 families	Not reported
[21]	500	24 families	Fish-base. Global information system on fishes. Retrieved from, https://www.fishbase.se/home.htm; 2019
[23]	400	24 fish families	Global information system (gis) on fishes
[24]	6918	35 species	The bureau of fisheries and aquatic resources (bfar) regional office no. Viii.
[25]	100	8 species	-Fish-gres database - Fish4- knowledge database
[28]	18,000	18 species	Fishnet dataset
[32]	22437	4 species	Underwater videos (frgt dataset)
[33]	10937	23 species	Fish4knowledge database
[34]	1647	16 species	Underwater video imagery captured off the coast of western Australia

4. Challenges and Future Trends

Number of researchers using convolution neural network and deep learning to improve the accuracy of classification by modified number or nodes or layers [8,11,24,27,32], the challenging to find out the ideal values and valid number of nodes and layers. It is necessary to have sufficient information for choosing correct values for number of epochs, learning rate. Thus, in future automatic optimization researches can be relied on for specifying ideal values.

Most of researches based on methods that classified fishes outside of water, some of researches depend on video datasets that created in the unrestrained underwater environment [32,34]. An extra effort needs to be made on the underwater fish classification to confront the turbidity of water and the confusion of background. Classification performance can be improved by enhancing the monitoring of underwater fish.

Researches [18,21,26] need to increase number of samples for training and testing to improve classification performance.

5. Conclusions

This paper provided an inclusive overview of pre-processing operations, characteristics extraction, classification/recognition algorithms and datasets for fish identification field. Classification of underwater fish is highly complicated and burdensome task. Early techniques for fish types identification were carried out in controlled circumference only. Most of the researchers attempt to identify the fish images based on: the off-line fish images, natural environmental conditions and databases in [15,21,23,25,28]. So, there was no need to use image pre-filtering. The results show that the use of multi-level residual network [25], machine learning algorithm [17], SURF [11] achieved high accuracy with 99.69%, 98% and 98.67% respectively. Maximum number of classified fish species was 38 species [17]. This review will be beneficial for food industry field, marine scientists, agriculture domain and it can be a starting point for other authors since it presents classification/recognition techniques, accuracy of each technique (as shown in Table 1), number of samples, fish species or family's numbers, and images acquired methods or database (as shown in Table 2), new researchers can use this review and make a good comparison between their results and the previous results.

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