

A Method of Fish Classification Based on Wavelet Packet and Bispectrum

^{1,2} Qiao ZHANG, ¹ Feng XU, ^{1,2} Tao WEN, ^{1,2} Tianze YU

¹Institute of Acoustics, Chinese Academy of Sciences,
No. 21, North 4th Ring, Beijing, 100190, China

²University of Chinese Academy of Sciences,
19A Yu-Quan-Lu, Beijing, 100049, China
Tel.: 010-82547661, fax: 010-82547669
E-mail: zhangqiao314@163.com

Received: 13 November 2013 /Accepted: 28 January 2014 /Published: 28 February 2014

Abstract: The complex structure of fish and multispecies composition complicate the analysis of acoustic data. Consequently, it is difficult to obtain a highly accurate rate of classification by using current approaches. A method of fish classification based on the wavelet packet and bi-spectrum is proposed in this paper. To verify this method, firstly, an *ex situ* experiment has been performed with three kinds of fish: Crucian carp (*Carassius auratus*), Yellow-headed catfish (*Pelteobagrus fulvidraco*) and Bluntnose black bream (*Megalobrama amblycephale*). The backscattering signals of these fishes are obtained. Secondly, the wavelet packet decomposition of backscattering envelop is done, and the energy of main frequency bands which is reconstructed from each node are calculated. Thirdly, the bi-spectrum of envelop which is constructed using the backscattering of main frequency band in order to filtering the high frequency noise, is extracted as the additional feature. The sub-band energy of wavelet packet and the bi-spectrum are combined as the characteristic indicator to describe the fish feature. Finally, three kinds of fish are successfully classified by the RBF support vector machine classifier. The results reveal that the proposed method has a highly accuracy rate of classification at fish with different shapes. Copyright © 2014 IFSA Publishing, S. L.

Keywords: Fish classification, Feature extraction, Wavelet packet, Bi-spectrum, Support vector machine (SVM).

1 Introduction

With the marine resources demand increasing, the exploitation of fish resources has been paid more attention. Fish resources survey and assessment are the bases of reasonable exploitation of marine fish resources, which needs the effective fish classification methods urgently. Compared with the traditional trawling method, acoustic way takes advantage of efficiency, convenience, harmless, and sustainable observation, etc.

Researchers have conducted lots of works on the fish discriminating technology based on acoustic methods [1-5]. The identification of fish individual plays a crucial part in the identification of fish shoals. Recently, the broadband sonar-based system was involved in most of the fish discriminated approaches, other than measuring the multi-frequency target strength of single fish in situ. Kulinchenko et al. [6] classified the Pacific Halibut, Rockfish and the bottom successfully using the echo shape and echo spectrum obtained from the broad

sonar. Broadband acoustic echoes, collected from shortnose sturgeon, three non-sturgeon fish and the river bottom, were classified successfully by normalizing the frequency response spectra (Brundage et al.) [7]. The spectra of broadband echoes were also applied in discriminating the mixed fish species of alewives, rainbow smelt and bloaters, and predicting the species composition (Rogers et al.) [8]. However, there is hardly any related research on interior species.

Fish is a complicated scatterer due to its shape (cylindrical or spheroid), deformation (curvature of the fish body and swimbladder) and components (scale, flesh, bone, fat and swimbladder) [9]. It is hard to get the characteristics reflecting the nature of target in practice, and the classified result is always unsatisfactory.

This paper introduces a fish classification method by combining the wavelet packet decomposition and the bispectrum. The wavelet packet decomposition of fish backscattering envelop is done, and the energy of main frequency bands which is reconstructed from each node are calculated. Then, the bispectrum of envelop which is constructed using the backscattering of main frequency band in order to filter the high frequency noise, is extracted as the additional feature. The sub-band energy of wavelet packet and the bispectrum are combined as the characteristic indicator to describe the fish feature in this paper. Finally, the indicators are classified by the SVM classifier.

2. Data Processing

Fish with different shapes differ greatly in their anatomical structures. And the frequency responses of bone, swimbladder, flesh and the fish scale are different too. The scattering of the swimbladder is in the majority of the echo at low frequency, and the contribution of scattering from the bone and scale becomes more important with the increasing of frequency. So the energy distributions of different fish species are different. The wavelet packet decomposition has the excellent analyzed ability in time-frequency domain compared with the traditional wavelet packet sub-band energy calculation, which could be used to identify the signal frequency characteristics without considering the energy distribution of each frequency band. Bispectrum is a most rapidly developing method in modern signal processing, which could provide the phase, energy and the nonlinearity characteristics of the signal. The method of combining the wavelet packet decomposition and the bispectrum features can analyze the energy distribution of the signal in each frequency band and the characteristics in time domain, which improving the classification accuracy. The schematic diagram of the signal processing is shown in the Fig. 1, and the specific steps are as follow.

- 1) Extracting the envelop of the fish backscattering, and moving the echo to the baseband;
- 2) Choosing the appropriate number of decomposition layers according to the echo envelop, and decomposing the signal using wavelet packet;
- 3) Reconstructing each node, and extracting the energy characteristics of the signal in the main frequency band;
- 4) Reconstructing the signal envelop using the signal in the main frequency band, filtering the high-frequency noise to get the reconstructed signal envelop;
- 5) Analyzing the reconstructed signal using the bispectrum, and extracting the bispectrum features;
- 6) Taking the combination of the wavelet packet sub-band energy features and the bispectrum features as the feature for identification, and classifying the targets using the SVM classifier.

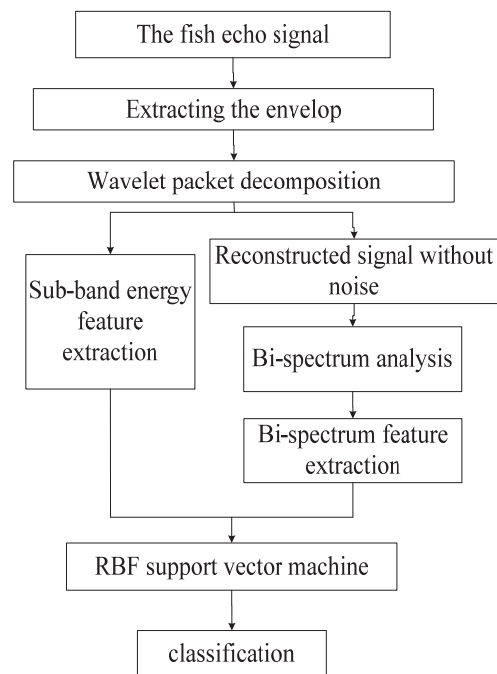


Fig. 1. Schematic diagram of the fish echo signal processing.

2.1. Wavelet Packet Sub-band Energy

Wavelet Packet decomposition is based on wavelet decomposition. It decomposes the low and high frequency of signal simultaneously, achieving evenly division of the signal band with better time-frequency characteristics. The integrity and orthogonality of wavelet packet keep the original signal intact. Fig. 2 shows the sketch map of three layers wavelet packet decomposition.

The fact of wavelet packet decomposition is to make the signal go through the low-pass and high-pass filter group simultaneously, and decompose the

signal into two parts, the high frequency part and the low one, and so on, until the result meets the need.

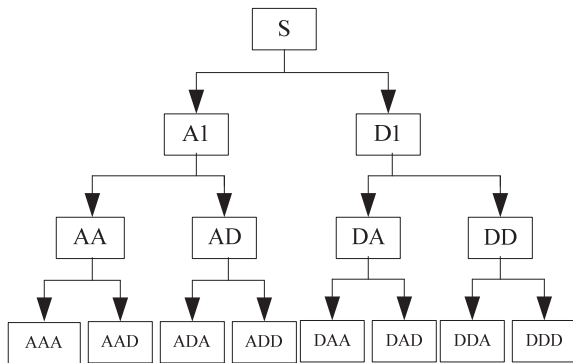


Fig. 2. Sketch map of three layers wavelet packet decomposition.

Let the signal sampling frequency be $2f$. There are 2^j 2^j monospaced frequency bands when j -layers wavelet packet decomposition has been done. The energy of each frequency band can be expressed as

$$E_{j,k} = \sum_{n=0}^{N-1} |x_{j,k}(n)|^2, \quad (1)$$

where $x_{j,k}(n)$ is the amplitude of reconstructed signal $S_{j,k}$. Define: $T = [E_{j,0}, E_{j,1}, \dots, E_{j,2^j-1}]$, and $E_{j,k}' = E_{j,k} / E$, E is the total energy of the signal. Then $T' = [E_{j,0}', E_{j,1}', \dots, E_{j,2^j-1}']$, the feature vector, represents the energy distribution characteristics in different frequency bands of fish backscattering.

2.2. Bispectrum Extraction

High order spectrum is a kind of powerful tool of nonlinear and non-Gaussian signal processing. It could inhibit Gaussian noise and get the information of phase, energy and nonlinearity of the signal. The bispectrum is the lowest and the easiest high order spectrum to deal with, which containing all the characteristics of high order spectrum. The combination of wavelet packet decomposition and bispectrum could improve the classification accurate rate.

The symmetrical areas of bispectrum are shown in Fig. 3.

Bispectrum divides the area into 12 triangles. All the bispectrum could be calculated if the bispectrum of the triangle area $\omega_2 \geq 0, \omega_1 \geq \omega_2, \omega_1 + \omega_2 \leq \pi$ are known.

It's hard to do real time analysis of bispectrum, which is a two dimensional function, due to the huge amount of computation. A one-dimensional section of bispectrum is used to analyze the characteristics of

the signal in application usually. This paper takes the maximum of diagonal and anti diagonal sections of reconstructed fish backscattering envelop as the classification indicators.

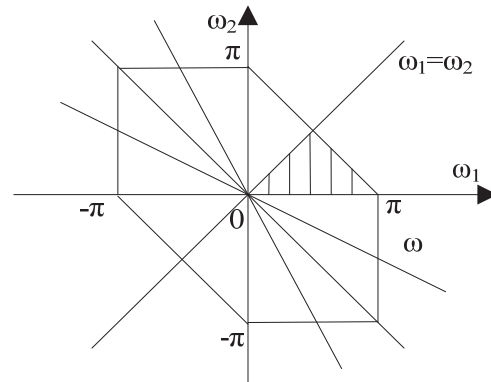
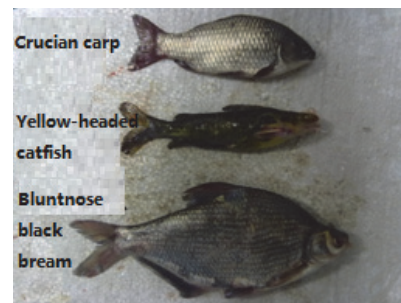


Fig. 3. Symmetric areas of the bispectrum.

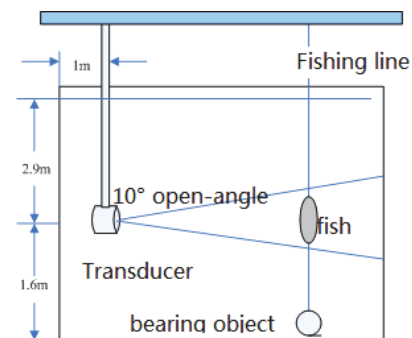
3. Ex situ Experiment and Results

3.1 Ex situ Experiment

The *ex situ* experiment was conducted in an anechoic tank with three kinds of fish: Crucian carp (*Carassius auratus*), Yellow-headed catfish (*Pelteobagrus fulvidraco*) and Bluntnose black bream (*Megalobrama amblycephale*) (Fig. 4(a)). There are three individuals of each species.



(a)



(b)

Fig. 4. (a) Picture of the fishes; (b) Schematic diagram of the *ex situ* experiment.

The fish was immobilized and, while unconscious, hung by fish line with back face to the transducer and head up (Fig. 4(b)). An incident wave of 200 kHz CW signal was generated by a monostatic sonar. The backscattering and envelopes of these fish are shown in Fig. 5. The sampling frequency was 2 MHz. Adjusting the fishing line enable the fish within the opening angle range of the transducer. The distance between fish and transducer was 4 m, satisfied the far field condition.

3.2. Feature Extraction

The frequency spectrum of the fish echo envelopes are shown in the Fig. 6. It is shown that the frequency

of the signal envelop concentrates within 0-15 kHz. Down-sampling processing is done to the signal envelop. Then the wavelet packet decomposition is conducted when the sampling rate reduced to 250 kHz.

There will be few differences between fish species if the number of sub-bands is too small. Nevertheless, the increasing of sub-band number could induce the instability and redundancy of features. The number of layers is 3 to 9 in practical division. Db3 wavelet is used to conduct 6-layer wavelet packet decomposition, and the signal is reconstructed. The reconstructed signal of the former 8 nodes characterizes the signal with frequency in 0-15.625 kHz, which has includes the main information of the fish backscattering envelop.

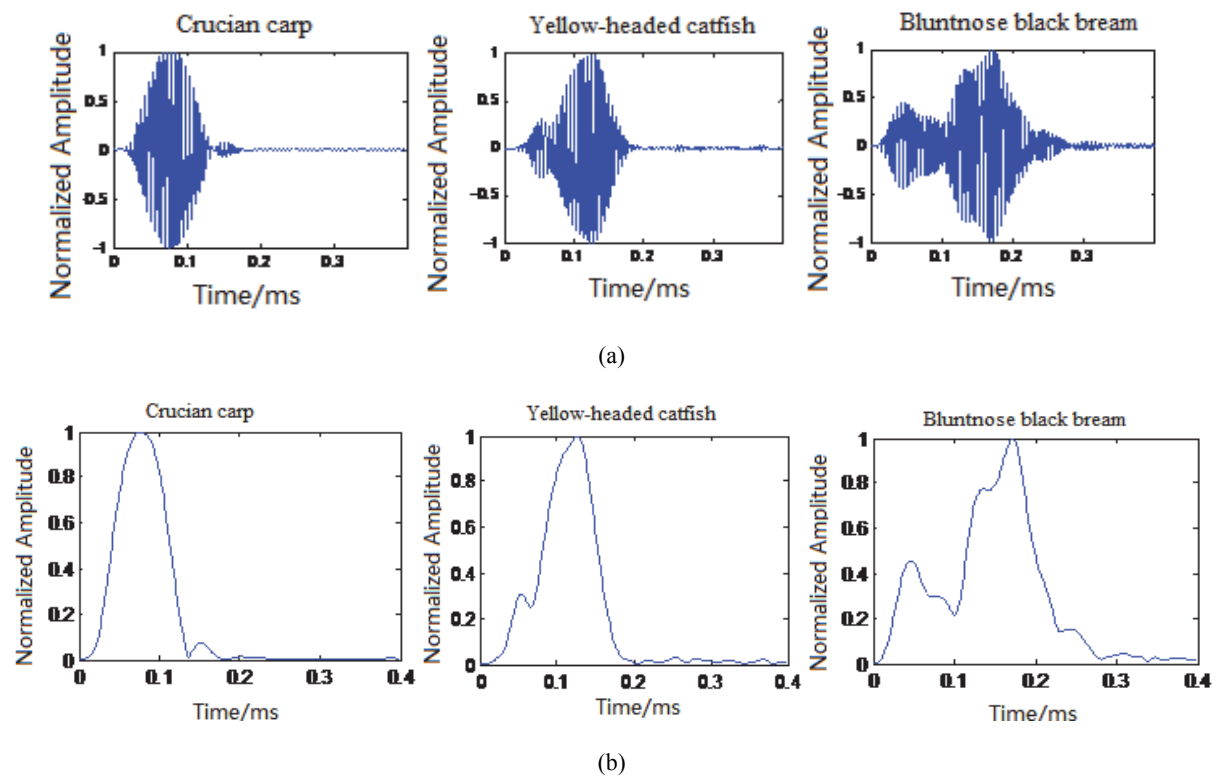
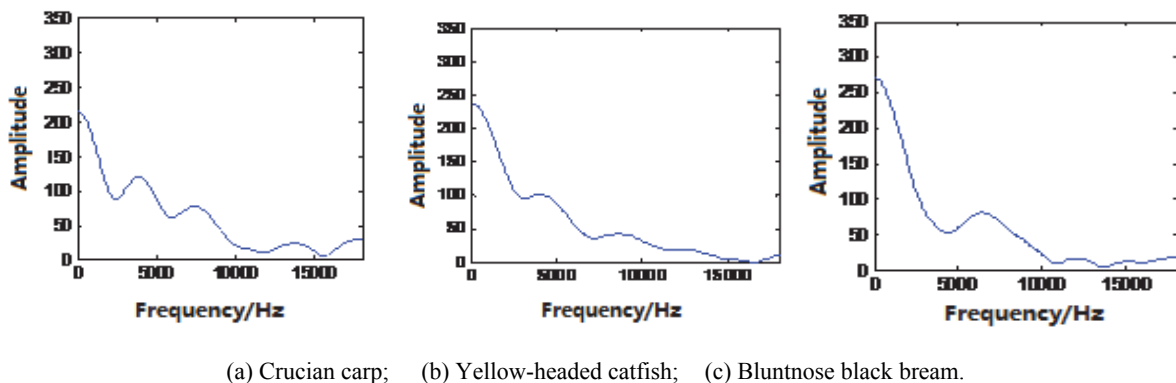


Fig. 5. (a)The backscattering of three kinds of fishes; (b) The envelop of the fishes' backscattering.



(a) Crucian carp; (b) Yellow-headed catfish; (c) Bluntnose black bream.

Fig. 6. The spectrum of the fish envelop signal.

The normalized energy of the signal reconstructed with the former 8 nodes (Equation (1)) can be taken as the feature. At the same time, the fish echo signal is reconstructed with the signals reconstructed by the former 8 nodes. The bispectrum feature is extracted from the reconstructed signal, and the maximum of the diagonal section and the anti-diagonal section is taken as the feature. Finally, 10 features can be used to describe the fish, including 8 wavelet packet sub-band energy features and 2 bispectrum features.

3.3. Classifier Designing

The Directed Acyclic Graph Support Vector Machine (DAGSVM) with Radial Basis Function (RBF core function) was used to classify three types of targets. The research shows that the penalty factor C and kernel function are the main parameters of SVM calibration model, and they have a great impact on the classification result [10]. The parameters C and r are adopted the Grid search algorithm in this paper, with the advantage that the interrelated relationship of mutual restraint between parameters can get the optimal solution faster in the parameter research [14].

3.4. Result

The echo data is separated into two groups. One group is the training sample set with 50 samples and the other is the test sample set with 100 samples. To avoid the occasionality of the classification result, 50 times classifications are conducted. And the average of the 50 classification rates is the final result. Table 1 shows the classification result of wavelet packet sub-band energy feature method and the method of combining wavelet packet sub-band energy feature and bispectrum feature.

As is shown in the Table 1, when the combination of the wavelet packet sub-band energy feature and the bispectrum feature is employed, the highest recognition rate is still for the Crucian carp, reaching up to 92.9%, and the average identification rate attains 87.98%. The result reveals that higher classification rate is obtained taking the combination of the wavelet packet sub-band energy feature and the bispectrum, resulting from multi-aspect characteristics of the fish backscattering are obtained.

4. Conclusion

A fish identification method based on combining the wavelet packet sub-band energy and bispectrum is proposed. The *ex situ* experiment is conducted on three kinds of interior fish. The result shows that the substantial characteristic of the fish can be demonstrated better by combining the wavelet packet sub-band energy feature and the bispectrum. The

proposed method can be used to classify different shapes of fish, and a higher classification rate is obtained compared with the wavelet packet sub-band energy.

Table 1. Result of classification.

Feature Type	Classification rate %			Average classification rate %
	Crucian carp	Bluntnose black bream	Yellow headed catfish	
Wavelet packet sub-band energy	88.6	79.85	80.52	82.99
Wavelet packet sub-band energy & bi-spectrum	92.9	86.1	84.93	87.98

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