Sonar Signal Classification using Neural Networks

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Abstract

One of the most important topics in the sonar sound data processing is proposing a powerful classifier to detect the sound source. In this paper we propose a classifier with proper accuracy. First, proper features should be extracted from sound data; Features could extract from time or frequency domains. Whenever fastness is important, time features are most effective. Otherwise, frequency domain features can be used. According to the importance of fastness in sonar sound source detection, in this paper, performance of features such as autocorrelation, partial autocorrelation and linear prediction code which are time domain features compare with each other. After we select proper feature we design a powerful classifier to classify sonar sound; to do this we implement probabilistic neural network and test it with these features; In order to have high accuracy for sonar sound detection.

Keyword: Neural Network, Partial Autocorrelation Coefficient, Autocorrelation Coefficient, Classifier

1. Introduction

Marine vessels classification is one of the most importance discussions in sonar processing. Of course, extracting suitable features is one of the major needs in sonar classification. Sonar sound data divide to active and passive classes. Sounds such as motors of ship's sounds and the sound of the sea creatures even the sounds of sea waves are belong to passive sonar class. But active sonar is similar to radar. In active sonar signal, Returned signals used to monitoring the environment, so using the passive sound signals is useful to design a sonar classification. In this paper, PNN [1]used as classifier who has following advantages [1]:

1- Rapid training
2- Guaranteed convergence
3- Incremental training capability

But PNN has a disadvantage which is spread parameter selection. The good performance of PNN depends on the proper selection of the spread parameter [2].

2. Related work

For decades, the trained people classified and recognized the class of marine vessels by listening to their radiated noise [3]. With development of AI [2]and hardware, using intelligent systems that are more reliable, and faster replaced with old classification's method. Using the second order autoregressive power density spectrum poles can make good discriminate features in recognition of high and low speed diesel [4]. Also Using of averaged spectral information during the classifier designing improves significantly the efficiency of the classifier [5].In addition, FIRNN[3] is very well suited to the task of detection and classification in real acoustic sonar signals[6].

[1] Probabilistic Neural Networks
[2] Artificial Intelligence
[3] Finite Impulse Response Of Neural Network

3. Experimental Methods

In this paper, different features named, LPC[4] , ACF[5], PACF [6] proposed in order to have a better classification. Ever three features are time domain and have been extracted from fifteen orders.

3.1. Feature extraction

3.1.1. ACF

This feature which proposed in this paper is almost accurate in sonar classification. Interval ranges for this coefficient are [-1,1]. 1 shows complete correlation and -1 shows non-complete correlation. ACF can be computed with equation (1).

$$r_k = \frac{\sum_{i=1}^{N-k}(x_i-\bar{x})(x_{i+k}-\bar{x})}{\sum_{i=1}^{N}(x_i-\bar{x})^2} \quad (1)$$

K is order of feature extraction, x is the sonar sound data, $\bar{x}$ is the mean of sonar sound data. r_k is a vector with a dimension of 1*k.

3.1.2. PACF

This feature which proposed in this paper is really accurate in sonar classification. PACF can be computed with equation 2.

$$\pi(\tau) = corr\left(X_\tau - \hat{E}(X_\tau | X_{\tau-1},...,X_1), X_0 - \hat{E}(X_0 | X_1,...,X_{\tau-1})\right) \quad (2)$$

τ is the order of feature extraction. X is the sonar sound data. $\hat{E}$ is expectation value. $\pi(\tau)$ is a vector with a dimension of $1*\tau$. Interval ranges for this coefficient are [0,1]. 0 shows non-linear relation between two variables. But it doesn't mean independence of them. 1 shows complete linear relation between two variables.

[4] Linear Prediction Code
[5] Autocorrelation Function
[6] Partial Autocorrelation Function

3.1.3. LPC

This coefficient uses in signal processing very much, and It is time domain .LPC can be computed with equation (3).

$$\begin{bmatrix} r(1) & r(2)^* & \dots & r(p)^* \\ r(2) & r(1) & \ddots & \vdots \\ \vdots & \ddots & \ddots & r(2)^* \\ r(p) & \dots & r(2) & r(1) \end{bmatrix} \begin{bmatrix} a(2) \\ a(3) \\ \vdots \\ a(p+1) \end{bmatrix} = \begin{bmatrix} -r(2) \\ -r(3) \\ \vdots \\ -r(p+1) \end{bmatrix} \quad (3)$$

Which r(1),r(2),…,r(p) are estimations of ACF. a(2),a(3),…,a(p+1) are LPC coefficients. Notable point is that a(1)=1. So using a(1) is not useful in classifier designing.

3.2. Used classifier

Several types of neural networks are used for classification, but PNN is usually preferred. PNN is a feed-forward neural networks with supervised learning which uses bayes decision rule and Parzen window[2]. This neural structure has three layers who involve input layer, hidden layer and output layer. Length of the input layer is equal to input vector. Number of the last layer neurons is equal to number of the classes. This structure works based on bayes decision theory. Equation (4) shows how bayes theory does classification [2].

$$p(x|\omega_i)P(x|\omega_j) > p(x|\omega_j)P(\omega_j) \quad (4)$$
$$j = 1,...,c \text{ and } j \neq i$$

Where, $x=\{x_1,x_2,…,x_d\}$ is the 1*d features vector, and $p(x|w_i)$ and $p(w_i)$ are d-dimensional conditional PDF [7] and prior probability obtained from the training data for i'th class.

4. proposed method

According to previous session we examine PNN classifier with different features in order to gain a better accuracy and performance. In this paper we proposed a method named PL method in which PNN

[7] Power Density Function

used as classifier and PACF and LPC coefficient combination used as our feature. PL method compares with other method in session 5.

5. Results and Discussion

In this part we compare different features with each other in order to select a good combination of features named PL method and after that we compare PL method with proposed method in Farrokhrooz and Karimi paper in which AR model coefficient using yule-walker method and six feature of mean value of normalized PSD, Median value of normalized PSD, The frequency corresponding to the maximum value of PSD, Ratio of the maximum value of PSD to the total power, Number of frequency bins whose PSD values are greater than 0.15* maximum PSD value and at last Maximum frequency whose PSD value are greater than 0.15* maximum PSD value are extracted.

. It should be noted the sound data files used in this paper is from two kinds of moving float, a submarine and a surface ship. So there are two classes which named zero and one in target matrix. 16 one second sound files used as training data, which portion of ever class has been 8 sound files. And 20 one second sounds files used as test data which portion of ever class has been 10sound files. Now It is turn to observe the result of each feature.

Figure 1 shows the performance of LPC. It is obvious that this feature has not lead to a good classifier.

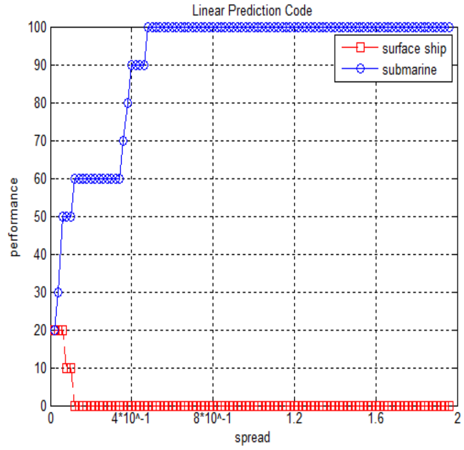

Fig. 1 This figure shows LPC performance

Figure 2 shows ACF performance. Using ACF has been lead to a better performance in compare with LPC.

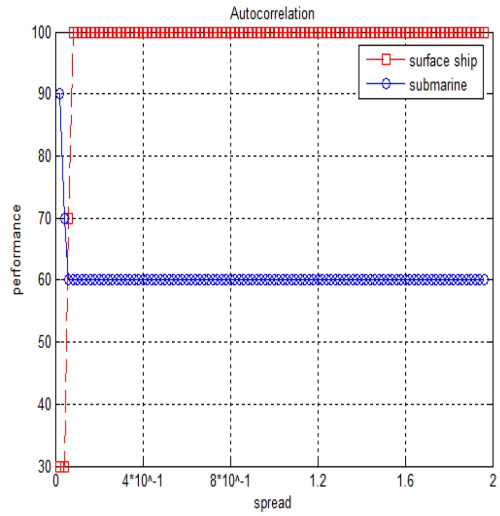

Fig. 2 This figure shows ACF performance

Figure 3 shows the acceptable performance of PACF coefficients. It is observable; classifier has reached to a good performance in some range of spread value.

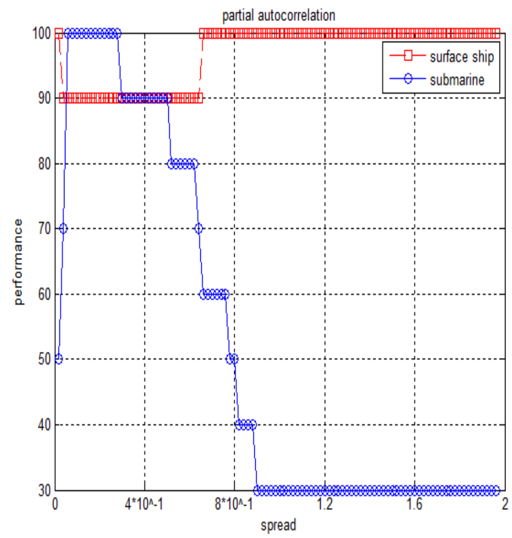

Fig. 3 This figure shows PACF performance

Figure 4 shows result of PL method. It is obvious, the combination lead to a powerful classifier with the wide range of spread value which cause to a good result.

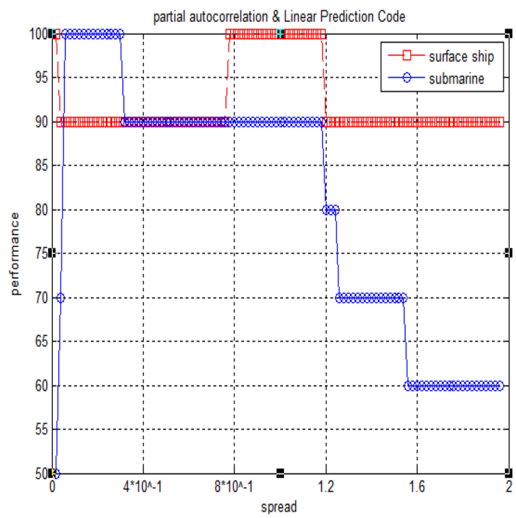

Fig. 4 This figure shows PACF& LPC performance

Figure 5 shows the result of PACF & ACF combination. Classifier has led to a good result, But with narrower band versus LPC & ACF combination.

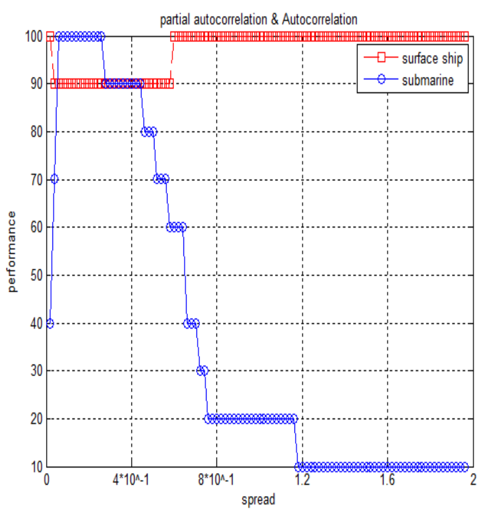

Fig. 5 This figure shows PACF&ACF performance

Figure 6 shows the result of proposed method in farrokhrooz and karimi paper.

As you can see, PL method improves accuracy and performance significantly versus this method.

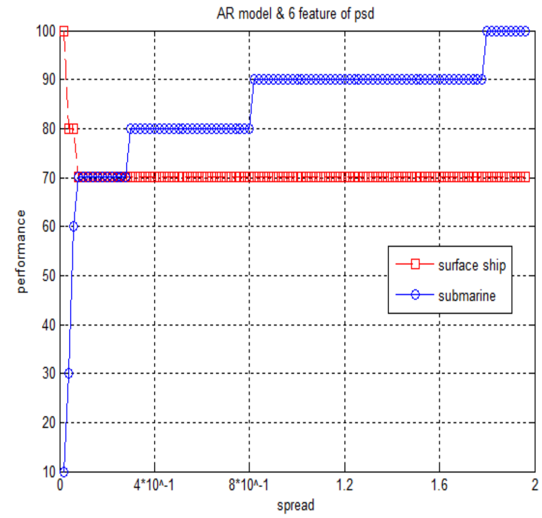

Fig. 6 This figure shows AR coefficient and 6 features extracted from PSD performance.

6. Conclusion

In this paper we proposed a method with a hybrid features in order to increase accuracy in sonar sound detection. Accuracy of PL method in the wide range of spread value shows that PACF and LPC combination can make a powerful classifier in sonar detection systems.

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