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Multi-Static Target FusionREcognition method Based. Bi-Spectrum Feature Prediction

Hongwen Wang , Leyuan Jin

University. Chinese Academy. sciencesBeijing100049

Abstract: Bi-Spectrum Feature of target are abstract and the Method Based on Feature indication is used to conduct multi-Static tar-get recognition.The target recognition conditional probability is obtained through the Bayes rule.And the formula is simplified.The prediction feature of the last node is obtained by BP(Back Propagation)Neural Network,And the prediction error probabilistic is calcu-related using the Gaussian Mixture Model.Then the result multiple by the recognition probability of each former receiver to obtain the conditional probability of the target type.The procedure is rated for every target,And the target type response to the maximum probability is the type of target to be identified.Multi-Static simulation experiment is conducted in Alibaba,And the above method is hired to identify the targets.Compare with the Mono-Static system,The recognition rate of the improved method innovation-ses by above 10% under the condition of certain signal-To-Reverberation Ratio.

Keywords: Multi-Static Sonar System,Target Recognition,Features Prediction,Error Mapping,Bi-Spectrum Feature

1. Introduction

In the underwater Security System of Large Scale Waters, in the past, only the backscatter information of the target was used to identify the underwater target..The final recognition result depends heavily on the recognition performance of the target in a given pose, which is greatly influenced by the change of the target pose. It is difficult to obtain a stable recognition result..In the multi-base sonar network detection system, sonar can simultaneously use the forward direction of the target.,Lateral,Compared with the single-base sonar system, the backscatter information can get more new and available target information in a single frame..Mu

Research on Multi-base underwater target recognition is rare..The traditional multi-sensor fusion method often ignores the correlation between nodes, and the application effect in Multi-base sonar system is not ideal..Currently, there are few articles focusing on Feature Extraction and Recognition of Multi-base underwater targets..AI Xiaofeng and others [1.,2.Based on the research of One-Dimensional Range Profile of radar ballistic targets, a method of extracting the characteristics of One-Dimensional Range Profile of targets under bistatic is proposed, but it is not applied to multi-base target recognition..J m.R.AZIMI-SadjadiEt al [3.] Put forward the kind of use based on multi-angle after to scattering information of decision-making level Fusion Recognition Methods prove the comprehensive use multi-angle information than single angle recognition has higher of recognition rate, but this a kind of Methods ignore the continuous adjacent the angle of mutual correlation.Jaime SalazarEt al [4] Put forward the kind of use prediction network and error mapping multi-angle Target Recognition Methods of six of different shape of target the recognition and traditional of decision-making level Fusion Recognition technology compared recognition rate

improve.3%-6%.But literature [4] Use of only is target in different angle on the after to scattering information this paper this methods of based on put forward the based on prediction characteristics and error mapping of more base Target Recognition Algorithm, extraction the target in different split share structure angle on the one-dimensional distance like the double spectrum characteristics the recognition.

1. More base Target Recognition Principle

More base sonar system is by apart certain distance and can coordination work of a group sonar unit[5]System in a single (or more a) sound source produce sound waves respectively deployment in don't base[6]To the receiver receive target of ECHO.Bistatic sonar is a kind of the most simple of more base sonar system sound source,Target and Receiver not the same article linear on.Corresponding,"Single Base sonar"Is refers to launch and receive unit infinite close to when the situation.In more base sonar target detection when sound source the emission pulse of scattering echo is each sonar node receive the sonar

Node extraction of target characteristics have obvious difference.Figure1Is more base sonar configuration schematic diagram.Figure1More base sonar configuration schematic diagram1.1Based on Characteristics Prediction of Multi-base Target Recognition Methods

Set stay recognition target categoryC_K(KFor the target label)Extraction of the firstIA sonar node of target characteristics vectorX_I.To has three a sonar receive node of more base sonar system as an example more base feature-Level Fusion Recognition of the final results is calculation A conditions Probability$P(C_K| X_{I-1}X_{I-2})$.Which,$X_IX_{I-1}X_{I-2}$Respectively representative adjacent receive node on the characteristics vector.According to Bayesian formula this probability formula can said into such (1).

In different of more base sonar system configuration can in receive node get different of characteristics vector.For example if get characteristics vectorX_{I-2}Hypothesis next the characteristics of the node VectorX_{I-1}Main rely on inC_KAnd and a characteristics of the node VectorX_{I-2}Not so can (2)-In

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StyleC_KThe have (7/).

$P(C_K| X_{I-1})P(C_K| X_{I-2})P(X_I| C_KX_{I-1}X_{I-2}) >P(C_J| X_{I-1})P(C_J| X_{I-2})P(X_I| C_JX_{I-1}X_{I-2})$ (7/)

BecauseX_IIs Continuous Random Variable its distribution is with probability density distribution to said in formula (7/)In with conditions Probability Density$P(C_K| X_{I-1})$

$P(C_K| X_{I-2})P(X_I| C_KX_{I-1}X_{I-2})>P(C_J| X_{I-1})P(C_J| X_{I-2.})P(X_I| C_J,X_{I-1.},X_{I-2.})$To replace the conditional probability$P(C_K| X_{I-1.})P$

$C_K| X_{I-2.})P(X_I| C_K,X_{I-1.},X_{I-2.})>P(C_J| X_{I-1.})P(C_J| X_{I-2.})P(X_I| C_J,X_{I-1.},X_{I-2.})$Finally, get the target recognition result$K$The expression of a class (8.)Shown.

$P(C_J| X_{I-2.})P(X_I| C_J,X_{I-1.},X_{I-2.})$It is difficult to calculate directly and consider replacing or converting it in other ways.Before using

$P(X_I| C_K,X_{I-2.},X_{I-1.})$.In this way, the probability density of the prediction error$P(X_I| C_K,X_{I-2.},X_{I-1.})$Replace$P(X_I| C_K,X_{I-2.},X_{I-1.})$Completion (8.)Calculation.Choose hereBPNeural network predictor for feature Prediction.

1.2. Error mapping based on Gaussian Model

In the above analysisBPThe neural network predictor gets the prediction data of the next node..Sets the error data between the predicted and true values$E =\{E_{1.},E_{2.},... E_D\}$(DDimension Data).The probability density of the prediction error can be used instead (8.)Calculation.The method we take here is to first assume that the prediction error follows a distribution model, then get the distribution parameters of the model by training the data, and finally bring the test data into this distribution model, probability Density of test data.Normal distribution is one of the most thorough models of probability distribution, which has been widely studied in continuous probability density functions..

Let the error data between the predicted value and the true value obey the multivariate normal

distribution.E~$N_M(\mu_E$,Sigma),MAs characteristic dimension.Through training

2. Feature Extraction

Feature extraction is the key link of target recognition, and the effectiveness of Target Feature Extraction and selection is directly related to the correctness of the classification results of target recognition..High-resolution one-dimensional Range Profiles of targets (High Range Resolution Profile,HRrP)It reflects the sonar scattering cross-sectional area distribution along the sonar line of sight of the target in a certain sonar angle of view, reflecting the relative Geometric relationship of the scattering points..Therefore, the high-resolution range profile sample contains important structural features of the target (size,Recognition and classification of targets are of great value..

Limited by the accuracy of sonar distance measurement,HRrPUsually intercepted from the echo data by a distance window,A vector with a certain degree of redundancy inside the object. Therefore, the position of the object in the vector is uncertain, also known as the translation sensitivity of the high resolution range image..In order to avoid the influence of this factor on recognitionHRrPShift Invariant high-order spectral characteristic direction

Quantity.High-order spectrum is a powerful tool to deal with Nonlinear Non-Gaussian signals..Compared with the spectrum and power spectrum, the high-order spectrum can suppress the Gaussian noise,

Because bispectrum is a two-dimensional function, it requires a large amount of calculation and is not suitable for real-time analysis of long data..In the application, we often use some one-dimensional slice of Bispectrum to analyze the characteristics of the signal..In order to reduce the characteristic dimension, the diagonal slice of bispectrum is selected as the characteristic quantity of bispectrum..Select this article

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Use the direct method to calculate the bispectrum characteristics [10].

3. Pool experiment and Data Processing

3.1 Experiment Design

In order to verify the effectiveness of the proposed method and avoid the acoustic compatibility problem in Multi-base sonar, a simple multi-base simulation experiment is carried out in the anechoic pool..The multi-base is configured as one-stop and multi-stop. The target characteristics at different split angles are measured, and the scattering point features are extracted for recognition..Experiment layout as shown in Figure2.Shown.The transmitting transducer and the target are fixed, and the receiving transducer is connected to the rotating arm, so that the target echo signal at any split angle can be obtained..The experimental results are consistent with the actual data obtained from the Multi-collector multi-base sonar configuration, and do not need to use multiple hydrophone for measurement at the same time, which greatly saves the experimental cost..The vertical Open Angle of the transmitting transducer is approximately10 °Can effectively avoid the water surface and underwater reverberation interference.Receive node isBk8105Hydrophone.Split corner expressedSoR.Figure3.Defining the value of split Angle.

The signal is chirp (Linear Frequency Modulation,LFM)Signal, center frequency80 kHz, Bandwidth is40 kHz.Four kinds of targets were selected for testing.,Underwater Robot,Water-filled balls and solid marble columns.The dimensions of each target are as follows:Diver's height172, Carrying the diameter of open breathing Cylinders18 cmThe height is40 cm;The length of the robot,Kuan,Gao separately60 cm,38 cmAnd28 cm;Ball diameter of Water Injection40 cm;The diameter of the marble column is10 cm, Length is37.5 cm.Experimental objectives are shown in Fig.4.Shown.In order to keep the attitude of the four targets unchanged during the rotation of the arm,The balls and marble columns are suspended in the water by a fixed rope. The marble and underwater robots are in a positive and horizontal position underwater..The breastman maintains stability underwater by holding a carbon rod connected to the driving wheel, the forward and horizontal direction is perpendicular to the line between the launching end and the Target Center..

3.2. Feature Extraction

Hydrophone at Split corner-90 °~90 °In the direction, the target echo is sampled at a sampling interval10 °.Figure5.Is in0 °Get in the direction

Target Bispectrum.

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Where the Signal Sampling RateF_SFor400 kHz, The selected Fast Fourier Transform (Fast Fourier Transform,FFT)PointsNFor256, Corresponding

The resulting frequency resolution is F =^{FS}= 1562.5Hz.Yutu5.It is known that the Bispectrum of the envelope of the one-dimensional Range Profile of the target is concentrated in0-40 kHzWithin,

Corresponding number of pointsM =^{40000}= 25.6..TakeM = 26.Only extract the bispectrum diagonal slices of this Part, and get4.Class objectives at different split angles

On the one-dimensional distance profile of bispectrum slice characteristics as shown in Fig.6.Shown.

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Slave chart6.It can be seen that the diagonal slice features of the water injection sphere have little change in each split angle, which is basically consistent..Judging from the maximum amplitude of the bispectrum Diagonal Slice features of multiple sonar nodes of the target, the maximum amplitude of open divers is mostly distributed in0.2.-0.3.The maximum amplitude of the underwater robot is mostly distributed in0.1.-0.15Among them, the maximum amplitude of marble columns is much0.25-0.35Between.

Therefore, from the above analysis, we can see that the bispectrum slice features extracted from the four types of targets at different split angles have their own distinct characteristics, so the extraction of One-Dimensional Range Profile bispectrum slicing features can be very good to distinguish the above four types of targets..In the recognition process, not all

Select where10The characteristic component that dimension contributes to Recognition.

3.3. Prediction Error Analysis

According to the formula (8.)This paper usesBPNeural network is used to predict the target features of sonar nodes..

(1.)Training session:

Before the training data will beN-1.Characteristics of the sonar nodesBPNeural Network input sample, SectionNCharacteristics of the sonar nodesBPOutput sample of neural network, setting the initial value of the Network;

According to input sample get network output calculation output layer unit of error,

If error meet threshold requirements so training end; if don't meet requirements so along the network back spread this error and on each layer connection coefficient ongoing correction until meet requirements get training network parameters.

(2)Recognition stage:

Will test data of beforeN-1A sonar the characteristics of the node asBPNeural Network of input sample;

Will input sample into training getBPNeural Network in get different input sample under of prediction results.

To robot target as an example Figure7/Is use3A sonar node of target

Characteristics of the first4A sonar the characteristics of the node the prediction get of results.Which,'*'Said Stay prediction node real of characteristics vector,"Said test data for open divers of characteristics vector,'-'Said test data for Underwater Robot of characteristics vector,'O'Said test data for ball of characteristics vector,"Said test data for marble cylindrical of characteristics vector.From figure7/In can see for four class target prediction get of characteristics vector and actual characteristics vector is basic agreement of show that useBPNeural Network of unknown sonar the characteristics of the node vector the prediction of results is right.

3.4 More base underwater target recognition process

Based on Characteristics Prediction of Multi-base underwater target recognition algorithm calculation process are as follows:

Assume multi base Sonar System in totalNA sonar node extraction more base sonar system in each sonar node get of target one-dimensional distance like the double spectrum slice characteristics get each target of more base characteristics vector;

UseBPNeural Network Classifier calculation beforeN-1A sonar node of likelihood probability;

Use beforeN-1A sonar node of target characteristics vector of last a sonar the characteristics of the node vector the prediction and calculation and actual

Characteristics vector of error;

Calculation get of error vector of mean and variance get error of distribution parameters;

To calculate the recognition target double spectrum characteristics of prediction error distribution and are put into each target of Distribution Model get recognition characteristics sequence in each target model under the conditions probability density;

Will steps Get the results and to calculate the recognition target of observation sequence in a given model under the likelihood probability judgment stay recognition target

Type.

Comprehensive the Based on Double Spectrum Characteristics Prediction of Multi-base target fusion recognition algorithm process as shown in Figure8Shown in.

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3.5. Recognition result

In the actual multi-base sonar system, the layout of Multi-base sonar is often related to the detection range and terrain,19The possibility of such a dense arrangement of nodes is very small.In order to be more close to the actual application scenarios, this paper uses a four-terminal multi-base sonar layout to verify the proposed algorithm..Because the test site of this paper is the anechoic pool, the interference signal is very small, and the actual application scenarios such as lakes,Reverberation signal is an important interference source due to the complexity of underwater acoustic channels in marine environment..In order to make the experimental data closer to the real situation, the reverberation signal with appropriate power is added into the echo signal, and then the sample signal with reverberation signal is extracted and classified..For the four targets mentioned above, each target gets100Group echo samples as training sets100Group echo sample as Test Set.In order to prevent accidental recognition results, for each class of target to be identified, carry out Recognition processing.30Times, Will30Average of sub-classification results as the final recognition result.

1.The recognition accuracy and false alarm rate of the single base sonar are obtained by only using the backscattering characteristics of the target..

In the multi-base sonar experiment, the configuration of the Four-terminal multi-base sonar system is selected as0 °,20 °,40 °And80 °(Angle Definition3.).4.The target echo on the sonar node is0 °,20 °,40 °The target feature on the node is80 °After prediction, the correct rate of Target Recognition is2.Shown.

According to the formula (7.)To change the order of sonar node selection0 °,20 °,80 °The target feature on the node is40 °After prediction, the correct rate of Target Recognition is3.Shown.

From the results shown above, compared with the single-base sonar system, the fusion recognition rate of the Multi-base sonar system has been significantly improved, the Fusion Recognition Rate of Multi-base targets using one-stop and four-stop is higher than that of single-base targets.

10%Above.For Robots and ball targets, the ratio of confidence20dbWhen the recognition rate is close100%.After changing the order of selected sonar nodes, the recognition rate of the four targets is still higher than that of the single base.

It will also affect the result of Multi-base target fusion recognition..Among the four types of targets, the recognition accuracy of robots and balls is relatively high. Compared with balls, the false alarm probability of robots is also relatively high..Multi-base Fusion Recognition Method is not very obvious to reduce the probability of false alarm.5dbAfter multi-base Fusion Recognition method is used, the false alarm probability of Sphere Target even improves

5%.Therefore, how to reduce the target false alarm rate in the background of strong reverberation is the focus of the follow-up work..

4. Closing remarks

In this paper, multi-base Fusion Recognition Algorithm Based on bispectrum feature prediction is proposed for underwater multi-base target recognition, the bispectrum features of One-Dimensional Range Profiles of targets on different sonar nodes in Multi-base sonar systems are extracted as the Recognition Feature vectors..Based on the Bayesian formula, the conditional probability formula of Multi-base target recognition is obtained, the conditional probability of the error between the prediction and the actual value is converted to the probability density distribution for calculation, and it is multiplied by the conditional probability of each node before the target recognition..Compared with the Single Node recognition algorithm, this method can improve the recognition rate under certain Signal-to-mixture ratio.10%Above.

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