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RESEARCH ON UNDERWATER TARGET SIGNAL DETECTION AND RECOGNITION PROCESSING ALGORITHM

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Abstract- ***Practical application of underwater target echo signal usually get disturbed a Gaussian noise and non-Gaussian noise, in view of the signal recognition problem, this paper proposes a double spectrum analysis based on wavelet transform domain method of weak signal and D-S data fusion algorithm. Through the study of double spectrum of the wavelet transform domain analysis to the signal processing algorithm, the characteristics of the target signal and noise source signal, a processing method of underwater target signal de-noising was presented. For multiple underwater target recognition, the model of underwater target multi-sensor signal recognition was studied. On the basis of analyzing the principle of D-S method and the fusion of multiple signal recognition, the concrete measures of D-S data fusion reasoning was researched and analyzed. By using the combination of simulation calculation and experiment measures, the results show the signal processing method is correct.***

Index terms: wavelet transforms; the double spectrum analysis; signal recognition; data fusion

I. INTRODUCTION

In underwater target detection system, target echo signal analysis and processing in practical engineering is an important research focus, with the increase of the complexity of the environment, the jamming signal processing effectiveness is becoming more prominent, especially marine underwater target signal processing effectiveness. Due to the influences of marine environment, the underwater object detection sensor output signal contains more complex noise signal, which would bring certain difficulty to the system signal recognition [1]. In order to extract the target signals more accurately, it shouldn't always assumes that the jamming signal is Gaussian, and the target signal as a non-Gaussian noise. Higher order spectrum from a higher order probability structure characterization of stochastic signal, Gaussian noise interference can be suppressed completely in theory, but it is powerless in non-Gaussian noise [2,3,4], and the non-Gaussian noise interferes with the higher order signal spectrum. In the field of signal processing, the method of wavelet de-noising has been more and more widely used. There are many methods of wavelet de-noising: The literature [5,6] proposes the concept of multi-resolution analysis, makes the wavelet transform has the characteristics of the band-pass filter, so can make use of wavelet decomposition and reconstruction method to filter and reduce noise [7]. Reference [8,9] proposed nonlinear wavelet de-noising threshold method; this method has been very extensive applied.

On the basis of signal de-noising, it is still need further on signal recognition to get the real target signal. Signal recognition is usually adopts the data fusion processing method. Multi-sensor target recognition is an attempt to fusion target properties of inaccurate and incomplete information, in order to produce more accurate and complete properties of estimation and decision than the single sensor. In numerous data fusion method, the evidence reasoning is suitable for fusion without a priori information; it relies on the description of the uncertainty, the measurement and combined advantages received widespread attention[10]. Traditional evidence reasoning method is just based on the basic probability assignment function, in the light of D-S evidence reasoning method combined the basic probability assignment function, and the multi-sensor information connection between features does not take into account. However, in many practical applications, there were some correlations various sensor information, this part information don't reflect in the traditional evidence reasoning and don't make full use of the multi-source information [11]. Therefore, in marine underwater target, you need to construct a D -S evidence reasoning method based on the data correlation, in order to enhance the system analysis of multi-source information processing ability and improve the ability of target recognition. Data fusion is a multi-source information processing technology that developed recently. Fusion of multi-sensor target recognition attempts to fuse the information that is imprecise and incomplete about the target attribute of each sensors, then, it can produce more accurate and complete attribute estimation and judgment than the single sensor.

Data association is an information processing technology of multi-source sensor network. Through the analysis and extract of the relationship between multi-source data, the target information can be obtained, which can’t be gotten from a single sensor. In practical application, the correlation information has more important reference value than the information that directs access from sensor, because the single detection system or principle exist some shortcomings and insufficiency, and it is hard to overcome these weaknesses by the sensor itself. Multi-source detecting provides a good way to solve this problem[12,13]. The way of multi-source heterogeneous detection has the principle of complementarities by itself, in this way; the associate information sensors can solve the problem which the original detection system can’t. It provides a broader method and ideas for information fusion technology. D-S evidence reasoning method is based on the detection of independent sensors[14]. In many practical applications, the probability assignment function of each sensor is independent, and they may detect the target at the same time, but their information is related. This information is not reflected in the traditional evidence reasoning, which does not make full use of multi-source information. The establishment of data association method between the sensors will make full use of the related information to improve the system's target recognition probability.

Based on underwater sensor output signal, the double spectrum analysis of wavelet domain signal de-noising processing method and the underwater multi-sensors data fusion processing method of the target signal is researched in this paper.

II. BISPECTRUM ANALYSIS OF WAVELET DOMAIN

A. Multi-resolution decomposition of wavelet transforms

In recent years, wavelet analysis developed into a theory of time-frequency analysis, it has been successfully applied to signal processing fields, such as image compression and coding. The advantages of wavelet transform are for offering a multi-scale analysis method for signal. Based on underwater target detection principle, we can use wavelet transform method to dispose underwater multi-sensors signal. The basic idea of wavelet transform is to decompose the signal f (t) by wavelet function $\psi_{a,b}(t)$ as the base [15]. It is shown by the following formula:

$$W_{a,b}(f)=\int_R \psi_{a,b}(t)f(t)dt \tag{1}$$

In formula (1), wavelet basis function $\{\psi_{a,b}(t)\}$ is passed by a basic wavelet $\psi(t)$ through the translation and scaling generated a set of functions:

$$\psi_{a,b}(t)=|a|^{-\frac{1}{2}}\psi(\frac{t-b}{a}) \tag{2}$$

In the discrete case, the wavelet multi-resolution analysis method is put forward by using S.Mallat. By properly selecting the wavelet function to form the space of orthogonal basis L^2(R) can realize the signal wavelet decomposition, assume that L^2(R) space has a multitier solution analysis $\{V_j\}_{j\in Z}$, the conjugate filters $h(n)$ and $g(n)$ can be generated and the corresponding scaling function $\phi(t)$ and wavelet function $\psi(t)$,they meet for the great scale of equation (3) and (4):

$$\phi(t)=\sqrt{2}\sum_n h(n)\phi(2t-n) \tag{3}$$

$$\psi(t)=\sqrt{2}\sum_n g(n)\phi(2t-n) \tag{4}$$

In (3) and (4), $g(n)=(-1)^n h(1-n)$, The wavelet function can be set:

$$\psi_{j,k}(t)=2^{-\frac{j}{2}}\psi(2^{-j}t-k) \quad j,k\in Z \tag{5}$$

In practice, the wavelet function has constructed orthogonally to make the calculation of wavelet transform more effective,

$$<\psi_{j,k},\psi_{m,n}>=\int_{-\infty}^{+\infty}\psi_{j,k}(t)\overline{\psi_{m,n}(t)}dt=\delta_{j,m}\delta_{k,n} \tag{6}$$

This can prove that the continuous wavelet transform discrete into wavelet transform theoretically, the basic information of the signals will not be lost[16]. On the contrary, due to the orthogonally of the wavelet basis function can eliminate the wavelet space caused by redundant connection between two points. At the same time, the orthogonally also makes the calculation error smaller, time-frequency function transformation results can reflect the nature of the signal.

The basic idea of Mallat multi-resolution analysis $\{V_j\}_{j\in Z}$ is calculate the projection coefficient signal f (t) in space $\{V_j\}_{j\in Z}$, the analyzed signal is decomposed into approximation components and detail components of different scales[17]. Set signal approximation components and detail components respectively:

$$A_j^k f =< f,\phi_{j,k}(t) > \tag{7}$$

$$D_j^k f =< f,\psi_{j,k}(t) > \tag{8}$$

So signal decomposition of recursion method can be represented as follows:

$$A_j^k f = \sum_k \tilde{h}(k-2n) A_{j+1}^k f \tag{9}$$

$$D_j^k f = \sum_k \tilde{g}(k-2n) A_{j+1}^k f \tag{10}$$

The signal synthesis algorithm is shown below:

$$A_{j+1}^n f = \sum_k g(n-2k) D_j^k f + \sum_k h(n-2k) A_j^k f \tag{11}$$

After the signal *f (t)* decomposition, all levels of the component corresponding to different frequency constitute a multi-resolution tower structure[18]. Hierarchy of the multiband signal decomposition provides theory basis for underwater target signal decomposition.

B.Bispectrum analysis theory and algorithm

In practical engineering, the most commonly used high order spectrum is the third order bispectrum. Bispectrum analysis is the third order simulants of the signal spectrum analysis for two-dimensional Fourier transform [19].

Assuming that the underwater sensor output signal $x(n)$ is zero and the third order stationary random sequence, its third-order correlation function is given by formula (12).

$$R_{xx}(m_1,m_2) = E[x(n)x(n+m_1)x(n+m_2)] \tag{12}$$

Then its dual spectrum can be defined as follows：

$$B_{xx}(\omega_1,\omega_2) = \sum_{m_1}\sum_{m_2} R_x(m_1,m_2) e^{-j(\omega_1 m_1+\omega_2 m_2)} \tag{13}$$

In order to ensure high order moment and high order cumulate of the existence of Fourier transform, high order moment and high order cumulate are required absolutely.

Bispectrum estimation methods are divided into indirect method and direct method. The direct method is segment the sample data, and then the FFT is used to calculate DFT paragraphs, finally obtaining the order spectrum. In order to reduce the estimation variance, it is necessary to signal to filter. The indirect method after the DFT coefficients of paragraphs, produces multiple modulations by the coefficients, and then estimates the double spectrum of each piece of data [20,21]. In order to eliminate the noise of the underwater target, the direct method is adopted. The direct method of bispectrum estimation algorithm can be summarized, the sensor output discrete quantity x(0), x(1),…,x(*N-1*) as zero mean observation samples, its sampling frequency is f_s . The specific process is as follows:

(1) The given data was divide into K section, each containing M observation samples: $x^{(k)}(0), x^{(k)}(1),..., x^{(k)}(M-1)$, Among them: $k=1,...,K$. The overlap between two adjacent data is allowed here.

(2) Coefficients of computing discrete Fourier transform (DFT):

$$X^{(k)}(\lambda)=\frac{1}{M}\sum_{n=0}^{M-1}x^{(k)}(n)e^{-j2\pi n\lambda/M} \tag{14}$$

In (14), $\lambda=0,1,...,M/2; k=1,...,K$.

(3) Calculation of DFT coefficients of triple correlation:

$$\begin{aligned}&\hat{b}_k(\lambda_1,\lambda_2)=\frac{1}{\Delta_0^2}\sum_{i_1=-L_1}^{L_1}\sum_{i_2=-L_2}^{L_2}X^{(k)}(\lambda_1+i_1)X^{(k)}(\lambda_2+i_2)X^{(K)}(-\lambda_1-\lambda_2-i_1-i_2)\\&k=1,...,K;0\le\lambda_2\le\lambda_1,\lambda_1+\lambda_2\le f_s/2\end{aligned} \tag{15}$$

In (15), $\Delta_0 = f_s/N_0$, N_0 and L_1 should be selected to satisfy the value of $M=(2L_1+1)N_0$.

(4) The given data x(0),x(1),…,x(N-1) of estimation period of bispectrum estimation of average are given by K:

$$\hat{B}_D(\omega_1,\omega_2)=\frac{1}{K}\sum_{k=1}^{K}\hat{b}_k(\omega_1,\omega_2) \tag{16}$$

In (16), $\omega_1=\frac{2\pi f_s}{N_0}\lambda_1, \quad \omega_2=\frac{2\pi f_s}{N_0}\lambda_2$

C. Bispectrum analysis method of wavelet domain

The study of wavelet transform and bispectrum analysis characteristics of the two kinds of signal analysis method can put forward bispectrum analysis method of wavelet domain. The advantage of wavelet transform is that the analysis of non-stationary signal has obvious time-frequency localization, which can effectively analyze the transient information of the target signal. Bispectrum analysis which from the high order probability structure characterization of stochastic signal is a powerful tool for Gaussian signal processing, it can completely suppress Gaussian noise theoretically. In the higher order spectrum, spectrum's order number is the lowest, the processing method is the simplest, at the same time, it contains all the characteristics of the higher order spectrum[22]. Wavelet transform domain bispectrum analysis process is shown in figure 1.

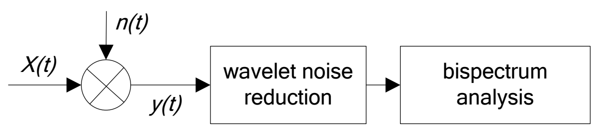


Figure 1 Double spectrum analysis of wavelet transform domain

In figure 1, $X(t)$ is a useful signal without noise, and n(t) is interference noise. The noise can be a Gaussian noise, or a Gaussian noise. When n(t) is the Gaussian noise, it can directly analyze the bispectrum without the wavelet de-noising , because the double spectrum analysis theory can completely suppress Gaussian noise. However, when n(t) contains non-Gaussian noise, the double spectrum is powerless, the useful signal spectrum characteristics would drown in non-Gaussian noise. Therefore, we first process the weak signal wavelet de-noising before the bispectrum analysis in order to eliminate the interference of the non-Gaussian noise.

III.UNDERWATER MULTI-SENSORS SIGNAL RECOGNITION PROCESSING ALGORITHMS

A. Data correlation and evidence reasoning analysis

Established on the basis of the underwater target recognition, in order to obtain the real target signal, we need to identify and the relevant data reason the underwater target detecting sensor network , and provide a reliable identification for underwater detection system. Assuming that $P(X_1)$ and $P(X_2)$ are two independent underwater sensor evidence emerged of target recognition probability, $P(AX_1)$ and $P(AX_2)$ is a probability of the evidence of two sensors and associated evidence. Also determined probability of the target, when the given correlation values appear, namely β_i.

According to the conditional probability, and then

$$P(A|X_1) = P(AX_1)/P(X_1), \quad P(A|X_2) = P(AX_2)/P(X_2)$$

$$\beta_i = P(A) = P(A|X_1)/P(X_1) + P(A|X_2)/P(X_2)$$

$$= [P(A|X_1)P(X_2) + P(A|X_2)P(X_1)]/P(X_1)\,P(X_2) \qquad (17)$$

Make $P(A|X_1) = P(A|X_2) = \lambda$, the formula (17) as follows:

$$\beta_i = \lambda[P(X_2) + P(X_1)] / P(X_1)\,P(X_2) \qquad (18)$$

In （18）, λ can be obtained through the engineering practice.

According to (17) and (18), because of underwater detection sensors with independent probability assignment function and sensors associated independent from each other, β_i can be used as a independent judgment evidence, which based on the D-S evidence reasoning. In this way, the sensors system can obtain $p+q$ evidences, q is the number of relevance evidence. And in practice, the relevance evidence is more important than a single point of evidence, it can greatly improve the efficiency of the use of multi-source data[23].

Assuming that the sensors have independent probability assignment function, and the sensors associated with each other independently, so the system of q associated criterion can be directly through the laws of D-S evidence reasoning synthesis. The associated determined evidence β_i is from the output information to fusion information. β_i is independent with each other, which compared with the original sensor output information, so β_i and the original sensor criterion cannot directly synthesis with the laws of the D-S evidence reasoning. At the same time, β_i must be alone in the light of D-S evidence reasoning rule of synthesis.

Underwater target detection system used multi-sensor to structure measurement platform, it would make every sensors has interrelated with each other, this physical or logical system design makes the output of multi-source sensors exist a certain relationship, which is mainly manifested in the time domain specific synchronous or asynchronous logic, it may also display to spatial data particular relevance or waveform space data, especially in the detection system of multi-source heterogeneous sensors, the characteristics of the same target association is determined by the physical properties of the heterogeneous sensor[24]. This relationship can be obtained through theoretical derivation, so do the pre-simulation or test. There are many related factors in the correlation of multi-source sensors' output, some factors appear to support the target recognition, but others are opposite. How to select the correlation factor is a key problem to be solved in engineering practice [21]. The output of multi-source sensors mainly includes image, waveform, data and other information, which exist many correlation factors in it. According to the design of actual detection system, the selection of related factors must be the most beneficial to the determination of the target, and can eliminate all kinds of interference furthest. Effect of multi-sensors association analysis is a complex problem, which needs to analyze the specific problems in practice.

In practical application, for each sensor and the associated sensor can select a specific relational variable value as a quantitative index of the information association, the index can be calculated and obtained through practical test. A selection principle of the index is when the associated variable reaches to the value; the target identification probability is not less than the single sensor's decision probability[24]. Through the ratio of calculation of the practical associated variables value and the specific associated variables value to ascertain that the contribution of target determination about the correlation information, the ratio is called correlation. By calculating the degree of correlation, to revise the target recognition assignment probability of the sensor and to reflect the related information of the sensor identification appears to support or refute. Figure 2 is the correction method of target recognition probability method.

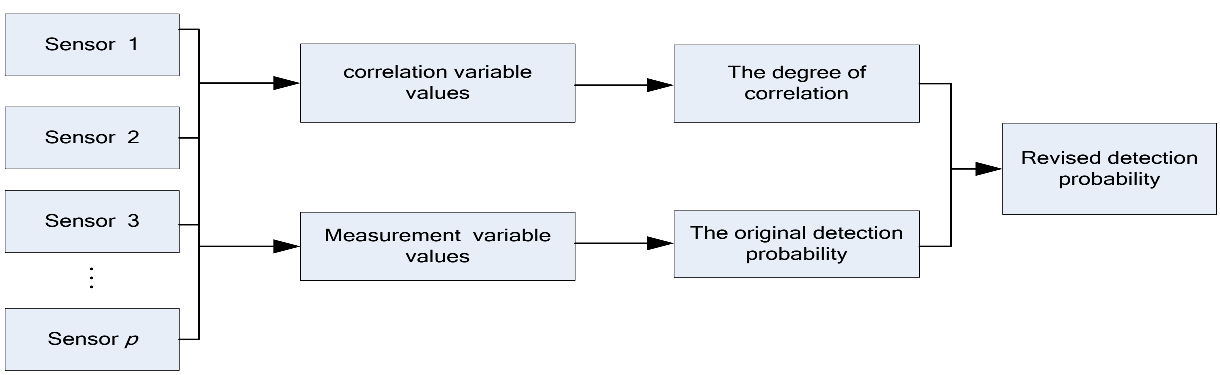


Figure 2. The correction method of target recognition probability

Suppose, a detection system contains P sensors in figure.2, the detection probability assignment of each sensor to target is W_i. The sensor P_i and $q(q \le p-1)$ sensors associated. So, when every association evidences appears, it will support the sensor P_i of target detection probability assignment. Assume that the ratio of correlation information of real measured relevance and the setting relevance is K_i, at the same time, setting the impact factor of related information to be λ_i. According to the relevant information, it can give out the revision value of W_i.

The modified calculation method of W_i can be expressed by formula (19).

$$W_i' = (1+\sum_{i=1}^{p-1}\lambda_i K_i)W_i \tag{19}$$

W_i' is the revision value of W_i. When P_i does not correlate with another sensor, $K_i = 0$.

Sensor modified detection probability assignment still meets the application conditions of D-S evidence reasoning method; it can be synthesized by D-S evidence reasoning synthesis method.

B. Multi-sensors signal fusion algorithm

Assuming that *H* is a collection of underwater detection system, in this collection, assumed that there are mutually independent complete between sensors. *A* collection of all subset has *T*. If H have *n* hypothesis, *T* has 2^n subsets.

Assuming that the number of evidence to support the H is p, for each of the evidence, there is a basic probability assignment function of *M*. *M* is a mapping from *T* to [0,1], at the same time, it will satisfy the following conditions:

$$\begin{cases} M(\Phi)=0 \\ \sum_{A\subseteq\Theta} M(A)=1 \end{cases}, \quad 0 \le M(A) \le 1 \tag{20}$$

Suppose, there are q+1 sensors exist two independent associations, according to the formula (20), the threshold value of correlation probability of target assignment can be calculated, its corresponding basic probability assignment function is M(A). M(A) is a mapping from *T* to [0,1], and meet the D-S evidence reasoning conditions[17,19].

$$M(A) = M_1(A) \oplus M_2(A) = \sum_{X\cap Y=A} \frac{M_1(X)\times M_2(Y)}{K} \tag{21}$$

In formula (21), $K = 1 - \sum_{X \cap Y = \Phi} M_1(X) \times M_2(Y) = \sum_{X \cap Y \neq \Phi} M_1(X) \times M_2(Y)$, $A \neq \Phi$.

After obtaining the *M(A),* the system obtained the two combined evidence reasoning results, as well as the results of the two reasoning according to the conditional probability calculation, and the D-S evidence reasoning to approximate synthesis the combination of evidence reasoning results. Because the value of β_i is with a series of constraints, the two reasoning results exist a certain degree of correlation. But the actual calculation result does not affect the final authenticity of reasoning, and the real target signal characteristic is obtained.

Ⅳ.SIMULATION AND EXPERIMENT ANALYSIS

A. The comparison and analysis of traditional bispectrum estimation and wavelet domain bispectrum estimation

Based on the theoretical research, assuming the original echo signal obtained by sensor of the underwater target detection is $x = \sin(2 * pi * t_1 / 32)$, $t_1 = 1:1024$, and the signal is mixed with noise $y = x + \omega = \sin(2 * pi * t_1 / 32) + \omega$, ω is non-Gauss noise which obeys the Rayleigh distribution. For the traditional bisspectrum estimation of the output of underwater target sensor, it contains the non-Gauss noise under the condition of small and the bispectrum estimation of wavelet domain are shown in figure 3 and figure 4.

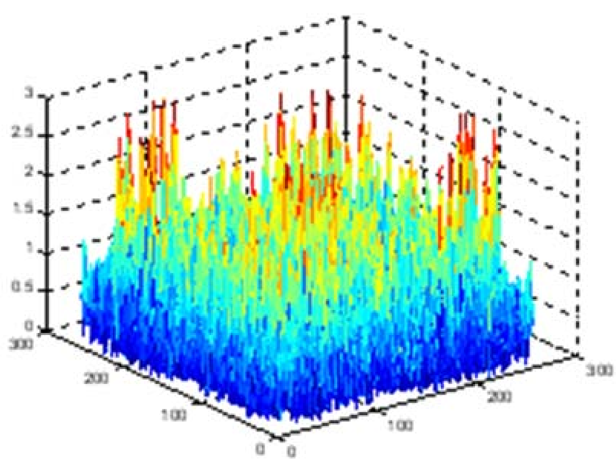


Fig.3 The traditional bisspectrum estimation containing noise signal

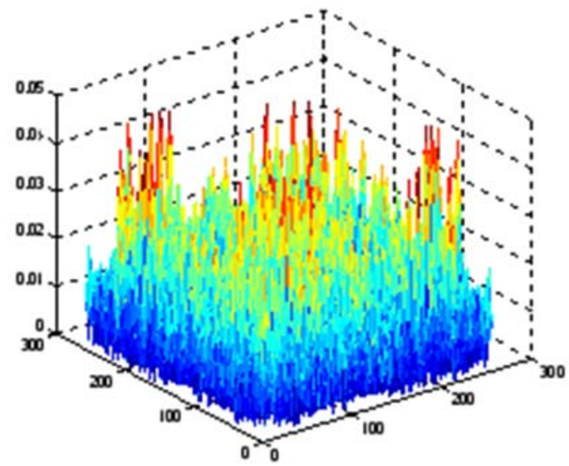


Fig.4 The bisspectrum estimation of wavelet domain containing noise signal

Through the comparison of traditional bispectrum estimation and bispectrum estimation of wavelet domain, we can see from the figure 4 more clearly than Figure 3, the traditional bispectrum analysis in Figure 3 still interfered by non-Gauss noise, in addition to the peak value appeared at characteristic frequencies, the peak value also appeared at other frequencies, it is difficult to detect and pick-up the target signal. However, bispectrum estimation of wavelet domain using the characteristics of wavelet de-noising can clearly identify the frequency peak of target signal.

B.The comparison of traditional bispectrum estimation and bispectrum estimation of wavelet domain when the signal contain non-Gauss noise component

According to the principle mentioned above, the traditional bispectrum estimation which the signal contains non-Gauss noise and bispectrum estimation of wavelet domain are shown in Figure 5 and Figure 6.

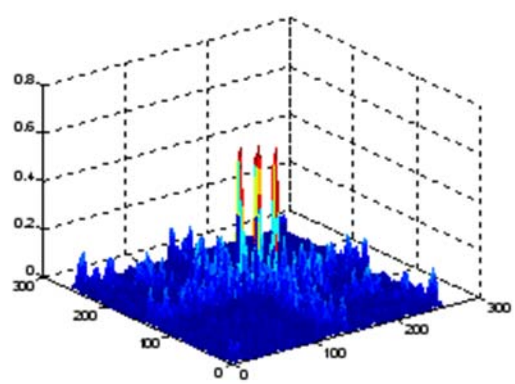


Figure 5. The traditional bispectrum estimation under the non-Gauss noise

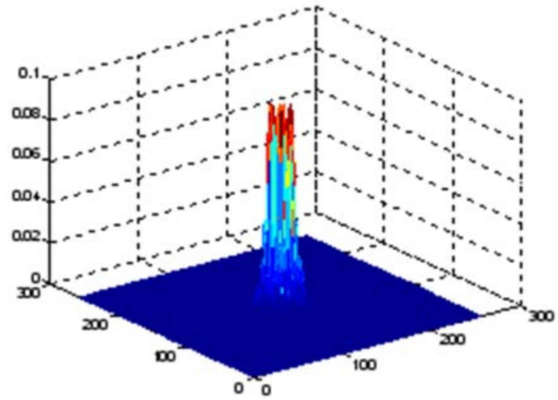


Figure 6. The wavelet domain bispectrum estimation under the non-Gauss noise

Figure 7 and figure 8 are the two two-dimensional distribute of the same noise signal, it is clearly that the distribution in figure 8 is relative steady, which are propitious to target recognition under underwater target detection system.

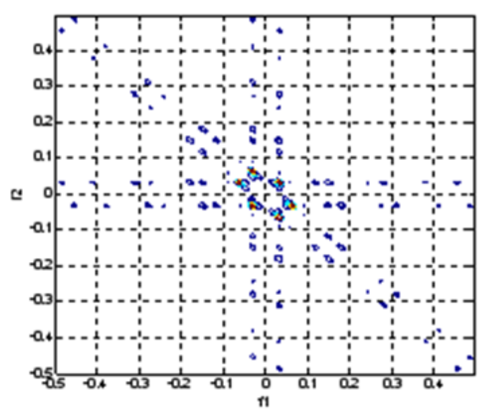


Figure 7 The traditional bispectrum estimation

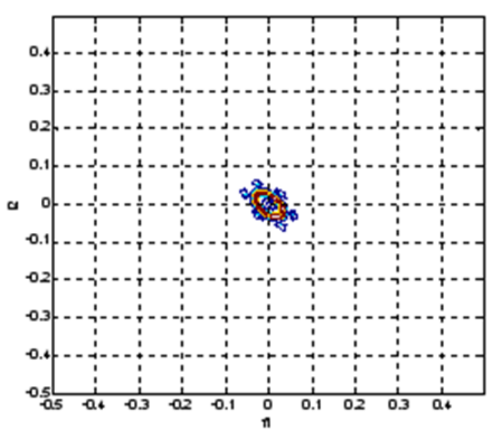


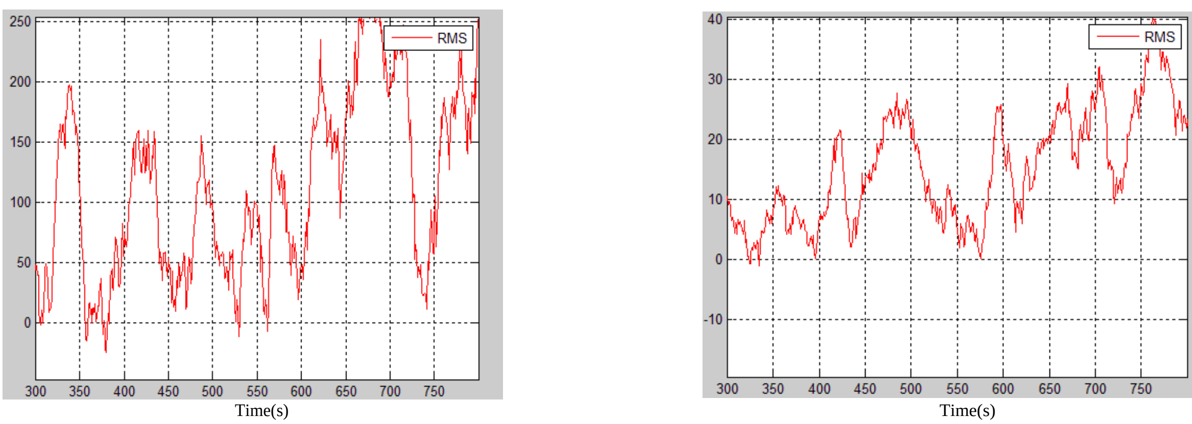
Figure 8 The wavelet domain bispectrum estimation

At the same time, when the non-Gauss noise component increases in two conditions, we can know that the wavelet domain bispectrum analysis is obvious from figure 7 and figure 8. So, the traditional bispectrum analysis interfered by non-Gauss noise, and the bispectrum feature frequency was submerged in non-Gauss noise, it is difficult to distinguish the signal and the noise. The result shows the wavelet domain bispectrum analysis is more superior to the traditional bispectrum analysis of underwater target detection system.

C. The output signal simulation and analysis on underwater target detection signal

To assess the effect on fusion algorithm and signal characteristic in underwater target detection system, we using the MATLAB simulation software to make simulation experiment based on the above theory and analysis.

Firstly, initializing the simulation, the simulation time sets to 1000s, and establishing the standard system initial value: starter (0) and measurement initial value, and generate a signal generator. In order to promote the authenticity of the simulation, the actual moving target should have certain randomness and motor section; and select the actual movement trajectory in 250s. Secondly, we use wavelet domain bispectrum estimation experiment of single sensor data and multi-sensors data, and display the target moving path obtained by single sensor and multi-sensor tracking path. Fig.9 is the simulation results of the toutput signal of sensor.



(a) (b)

Figure 9 the simulation results of output signal of sensor by using wavelet domain bispectrum estimation

Figure 9 (a) is a test of the single sensor data. It can be seen from the Figure 9 (a), the part of measurement error increased dramatically should be the target maneuvering time interval, the error in the 348s and 683s all surpassed 210. Figure 9 (b) is the test of multi-sensor data in underwater target detection. In Figure 9 (b), the measurement error in the 486 s and 764 s respectively achieve the maximum value. Comparing Figure 9 (a) and (b), when the system used a single sensor measurement, the error of the mean square value can reach more than 210, and when the system used multi-sensors measurement, the error of the mean square value is about 32. It is obviously that the multi-sensor fusion can effectively reduce the motor segment error and achieve the goal of fast convergence. So, wavelet domain bispectrum estimation method can improve signal performance, and it is propitious to target recognition.

D. The experimental analysis on data fusion recognition processing

Based on D-S evidence reasoning, if a framework for target recognition is $T = \{M_{1,} M_{2,} M_{3,}\}$, the detection system is designed by four kinds of sensors. According to the formula (17) to (21), we can calculate and analyze the measure data by different multi-sensors detection system.

The basic probability assignment function corresponding to a sampling period is shown in Table 1, which represents the basic probability assignment function of uncertain proposition. There is a correlation between the two groups of sensors corresponding. Table 2 is the target judgment γ probability under the calculation of a given correlation value.

Table 1 The basic probability assignment value of four kinds sensors

Target recognition	M_1	M_2	M_3	T
y_1	0.28	0.21	0.23	0.27
y_2	0.24	0.25	0.15	0.46
y_3	0.15	0.35	0.24	0.44
y_4	0.25	0.12	0.32	0.38

Table 2 Target judgment γ probability under the calculation of a given correlation value

Target recognition	M_1	M_2	M_3
γ_{12}	0.14	0.027	0.019
γ_{34}	0.018	0.024	0.02

In table 2 , Υ_{12} represent sensor 1 and sensor 2 correlation degree, γ_{34} represent sensor 3 and sensor 4 correlation degree. Based on table 1 and table 2, we assemble y_1, y_2 y_3 and y_4 ,and obtain the correlation value. Without considering the correlation information y_1, y_2 y_3 and y_4, the four kinds of evidence synthesis probability can be calculated, the result can be shown in table 3.

Table 3 Four kinds of evidence synthesis probability

evidence synthesis probability	M_1	M_2	M_3	T
y_{12}	0.23	0.34	0.21	0.12
y_{123}	0.27	0.31	0.26	0.13
y_{1234}	0.42	0.39	0.33	0.08

In table 3, y_{12} and y_{1234} is target recognition probability on the sensor 1 respectively with other sensors' evidence synthesis. Such as, y_{12} is sensors 1 and sensor 2 synthesis recognition probability. y_{123} is sensor 3 and y_{12} synthesis recognition probability under certain condition, y_{1234} is sensor 4 and y_{123} synthesis recognition probability under certain condition. Through calculation and analysis, we can calculate target determine probability β_i under the condition of a given relational values based on the formula (18), the value of target determine probability β_1 can be gained, which is show in table 4.

Table 4 target determine probability β_1 and β_2

target determine probability	M_1	M_2	M_3	T
β_1	0.25	0.21	0.22	0.13
β_2	0.31	0.34	0.35	0.16

We combine β_1 and β_2 by using D-S evidence reasoning method, and the probability distribution of four sensors can be obtained after combining, as shown in table 5.

Table 5 The probability distribution by combining β_1 and β_2

probability distribution	M_1	M_2	M_3	T
β_{12}	0.35	0.28	0.22	0.03
y_{1234}	0.38	0.39	0.34	0.09

Based on table 1 and table 5, we can get the total recognition rate distribution of target fusion under four sensors detection system, as shown in table 6.

Table 6 Total recognition rate distribution of four target fusion

total recognition rate distribution	M_1	M_2	M_3	T
P	0.48	0.46	0.22	0.11

Through the comparison and analysis, D-S evidence reasoning method can improve recognition rate. Strong correlation original goal was to improve the probability of detection (such as, the value of M_1 and M_2 respectively from 0.36 to 0.48 and 0.39 to 0.46), conversely, if target signal are not correlation, the target detection recognition rate will weaken (such as, the value of M_3 from 0.349 to 0.22). But, the uncertainty of detection system T from 0.09 to 0.11, the reliability of the detection system improved obviously.

From the whole experiment process, the D-S evidence reasoning method that based on the data association has two cores. First, it is how to get the correlation information from multi-source sensor data. Second, it is how to make full use of the correlation information form a correct judgment for the target. The method mainly is use the application of the correlation function to get the target detection probability and the correlation information. And this method solves the problem of the extraction and application for the correlation information in underwater multi-targets recognition. At the same time, the method effectively combines the D-S evidence reasoning method, and greatly improves the overall detection performance of detection system. Through the simulation calculation and the actual test calculation, combining wavelet transform bispectrum analysis method and D-S data fusion processing method, which can effectively improve the underwater target recognition.

V. CONCLUSIONS

In this paper, according to the characteristics of the underwater target echo signal, combining wavelet transform and double spectrum analysis of their respective advantages, this paper put forward a double spectrum analysis based on wavelet domain target signals. This method takes advantage of the target signal and noise distribution characteristic of wavelet domain, effectively separate the noise from the signal, thus avoiding the non-Gaussian noise interference with bispectrum analysis, so as to eliminate Gaussian noise interference and the non-Gaussian noise interference. Under different intensity noise based on wavelet domain of the double spectrum analysis and the comparison of traditional bispectrum analysis, it can be concluded that double spectrum analysis of wavelet domain is superior to the traditional bispectrum analysis; especially in the case of non-Gaussian noise is very strong. In addition, the D-S data fusion reasoning measurement can effectively improve the recognition rate of underwater target detection. According to the D-S evidence reasoning method, the uncertainty of the system is also greatly reduced, the target signal analysis and identification in this paper provides an important theoretical basis and application value.

VI. REFERENCES

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