Application of a new local enhancement method in sonar image entropy segmentation

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Abstract

In order to solve the problem of false dark areas in the bright areas of sonar images, this paper proposes a sonar image local enhancement method, which is based on the edge detection of the robert operator on the image and uses the row-frequency and column-frequency features to construct One-dimensional histogram, the mapping relationship between the edge detection image and the histogram is established, in which the zero point that appears for the first time on both sides of the most value point is used to determine the threshold value to determine the target bright area, and on this basis, the morphological method is used to achieve Enhancement of the target bright area. Aiming at the problem that the existing entropy segmentation sonar images generally have a lot of noise in the reverberation zone, a fuzzy weighted Tsallis entropy segmentation method is proposed. At the same time, a weight function is introduced to improve the segmentation effect of the reverberation zone. The comparative analysis results show that the entropy segmentation method proposed in this paper is better than the traditional entropy segmentation method in sonar image segmentation.

Keywords: sonar image segmentation; local enhancement; fuzzy entropy; double threshold; weighting function;

1 Introduction

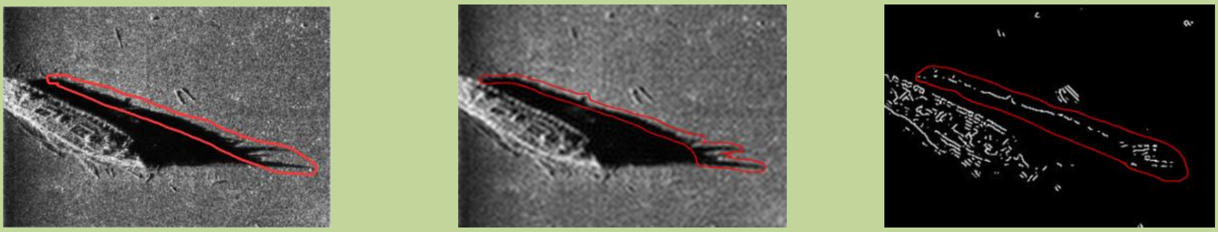
Underwater acoustic technology is an important means of detecting submarine targets, and in many cases the only means [1]. Underwater object search, underwater salvage, underwater construction, intelligent underwater robot navigation and collision avoidance, seabed treasure detection, ocean development and utilization, and marine military activities all involve seabed target recognition [2]. Due to the different reflection intensity of sonar on the seabed target with complex structure, the grayscale of sonar imaging suddenly decreases, and some false dark areas are formed in the bright areas of the imaging. These false dark areas have an effect on the segmentation of the sonar image and are easily misclassified into target dark areas, making automatic target recognition of the sonar image more difficult. It is very important to accurately find the position of the bright area and enhance the bright area for segmentation and recognition of the sonar image.

Entropy segmentation method is an important image segmentation method，In the 1980s, it was widely used in medical, agricultural and other fields [3-6]， The main content of the research focuses on improving the segmentation effect and increasing the speed of the algorithm [7-9].The literature [10] The maximum entropy of the one-dimensional attribute histogram is used to segment the submarine sonar image. This method is suitable for the segmentation of the one-dimensional histogram with a bimodal shape that is not ideal, but it cannot describe the positional relationship between the bright and dark areas of the sonar image. The literature[11] proposes a symmetrical minimum cross Tsallis entropy underwater target sonar image segmentation method based on one-dimensional attribute histogram, which can obtain a good target dark area segmentation effect, but has no obvious advantage in the bright area and reverberation area segmentation effect.The literature[12] proposes a target image threshold segmentation method based on symmetric Tsallis cross entropy and the difference between the background and the target area, which has a good segmentation effect when the target's internal gray distribution is relatively uniform. The literature[13] uses the Lagrange multiplier method to calculate the centroid of the membership function. This method has achieved good results when segmenting infrared images. The literature[14] uses fuzzy entropy to segment remote sensing images to get better segmentation results.The literature[15] uses firefly algorithm for multi-threshold image segmentation, and experiments show that the segmentation efficiency has been greatly improved. Although the methods of these documents[10-15] have achieved good segmentation results in some cases, when applied to sonar images, the reverberation area segmentation effect is poor, and the target bright area is complicated, the false light in the target bright area cannot be darkened. Area is divided into bright areas。

In submarine target sonar image segmentation, the existence of false dark areas inside the target bright area will lead to an increase in the joint probability of the dark area and the reverberation area in the two-dimensional histogram, thus making the reverberation area more noisy in the segmentation results. In order to avoid this phenomenon, the target bright area needs to be enhanced before segmentation. This paper proposes a sonar image segmentation method based on local enhancement and fuzzy weighted Tsallis entropy. Use the robert operator to obtain the edge detection points in the edge detection map. The characteristic of the concentrated number of edge detection points is used to determine the threshold in the row-frequency and column-frequency histogram, so as to locate the target bright area and adopt the form The learning operation enhances the localized image; using the distribution characteristics of the optimal threshold in the two-dimensional histogram, a weight function is constructed to describe the degree of the peak and undulation of the diagonal line and its vicinity. By weighting the total entropy of the image, we obtain The threshold range for better segmentation effect; the fuzzy weighted Tsallis entropy segmentation method combined with local enhancement completes the better segmentation of sonar images, and the segmentation result is close to manual segmentation.

2 Sonar image target bright area localization and enhancement

This article focuses on the research of submarine target sonar image recognition. Figure 1 (a) is the sonar image of the sunken shipwreck, Figure 1 (b) is the result of DCT filtering, and Figure 1 (c) is the result of edge detection by the Robert operator. The part circled by the curve in the figure is the boundary between the reverberation zone and the dark zone.



a) Target original image   b) DCT filtering results   c) Robert edge detection results

Figure 1 Submarine target sonar image

2．1 Bright area positioning preprocessing

In the research, the target image was first DCT filtered, and the filtered image was edge detected by robert operator. The edge circled by the curve in Figure 1 (c) will interfere with the positioning of the bright area to some extent. In order to achieve the purpose of eliminating interference, this paper eliminates the influence of noise by constructing extended images of feature images on both sides of the edges of the dark area and the reverberation area.

The calculation formula of the extended image pixel value of the feature image on the left side of the edge of the dark area and the reverberation area is:

$$Left(i,j)=\begin{cases}\frac{1}{\alpha}\sum_{k=1}^{\alpha} g_f(i,j\text{-}k) & g_e(i,j)=255\text{且}n+1<j<j_{\max}-n\\ 0 & g_e(i,j)=0\text{且}n+1<j<j_{\max}-n\\ 150 & \text{其他}\end{cases} \tag{13}$$

The calculation formula of the extended image pixel value of the feature image on the right side of the edge of the dark and reverberation areas is:

$$Right(i,j)=\begin{cases}\frac{1}{\alpha}\sum_{k=1}^{\alpha} g_f(i,j+k) & g_e(i,j)=255\text{且}n+1<j<j_{\max}-n\\ 0 & g_e(i,j)=0\text{且}n+1<j<j_{\max}-n\\ 150 & \text{其他}\end{cases} \tag{14}$$

Among them, i is the number of rows of the feature image, j is the number of columns of the feature image, is an adjustable parameter, generally takes a positive integer (7 in this article); g_f is the pixel value of the filtered image, and g_e is the pixel value of the edge detection image.

Calculation formula for removing noise by edge detection:

$$\mathrm{Re}\,move(i_1, j_1)=\begin{cases} 255 & 1 < Letf\,(i_2, \mathrm{j}_2) < 80 \text{且} \;\; 50 < Right(i_2, j_2) < 150 \\ 0 & \text{其他} \end{cases} \tag{15}$$

Where $i_1 = i_2$ and $j_1 = j_2$-8.

Comparison of effect before and after noise removal：

a) Image before denoising b) Image after denoising

Figure 2 Comparison of image effects before and after denoising

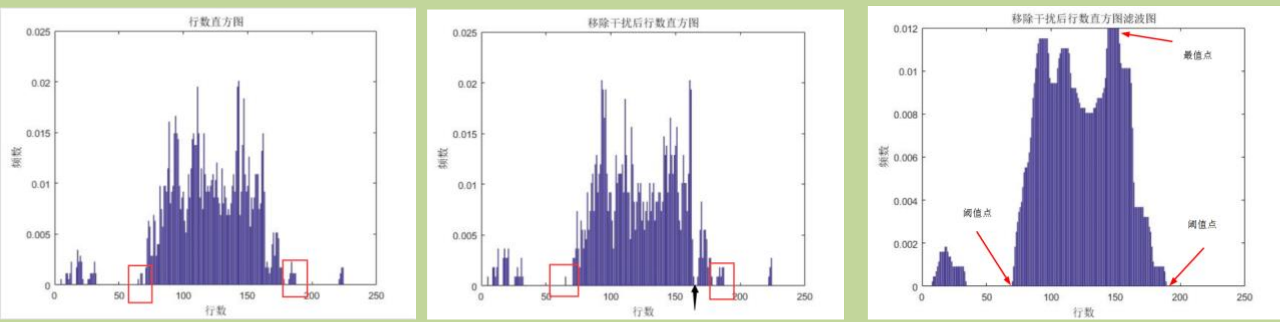
As can be seen from Figure 2b), the noise in the circled part of Figure 2a) is almost all removed, and at the same time, the points with the same features in the internal part of the bright area are mistakenly removed. From the statistical data in Table 1, it can be seen that the number of edge points in the bright area after denoising has been reduced to a certain extent, but the proportion of pixels in the bright area has been increased. Positioning.

Table 1 Statistics of the number of edge points

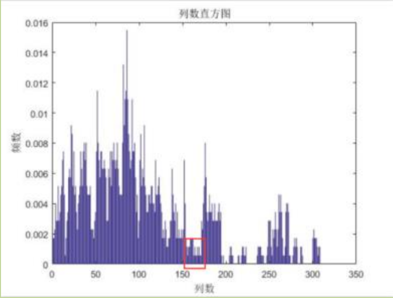
Image	Number of edge pixels	Number of pixels at the edge of the bright area	Bright area ratio
Before denoising	925	568	61.41%
After denoising	567	405	71.43%

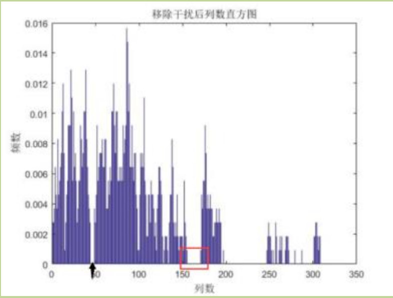
2.2 Localization of bright areas

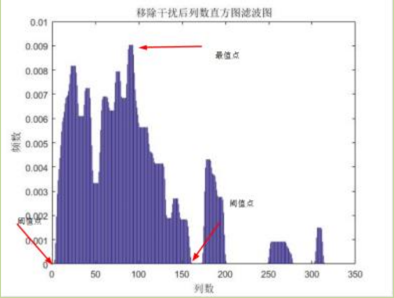
Based on the one-dimensional histogram threshold segmentation method, this paper proposes a local sonar image localization method, which locates the bright area by finding the threshold points of the row histogram and the column number histogram. First, the histogram of the number of rows and columns of the denoised image is counted, and secondly, the mean value is filtered on the histogram. The zero point will not appear in the target bright area corresponding to the filtered histogram. The zero point that appears for the first time on both sides of the most value point is the required threshold point, which locates the area of the target bright area. Figure 3a) and Figure 3d) are the row number histogram and column number histogram before denoising, Figure 3b) and Figure 3e) are the row number histogram and column number histogram after denoising, Figure 3c) and Figure 3f respectively) Are histograms after performing mean filtering on Figure 3b) and Figure 3e), respectively.



a) Line histogram of image before denoising b) Histogram of the number of lines in the image after denoising c) Histogram of rows after mean filtering







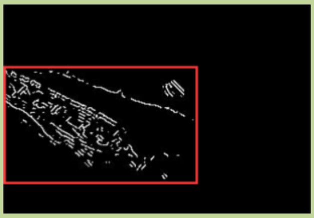
d) Histogram of the number of columns in the image before denoising

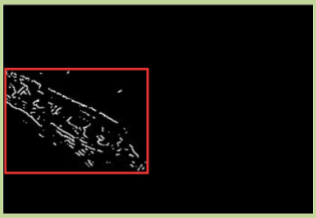
e) Histogram of the number of columns in the image after denoising

f) Histogram of column number after mean filtering

Figure 3 Row number histogram and column number histogram

It can be seen from Figure 3 a) and d) that the histogram of the image before denoising has more noise (rectangular framed). As can be seen from Figure 3 b) and e), through the pre-processing denoising operation, the noise is better removed (rectangular framed), and after removing the noise, a zero point appears inside the bright area (indicated by the arrow). It can be seen from Figure 3 c) and f) that after the average filtering, the zero point inside the bright area is eliminated, that is, the required threshold point (shown by the arrow) is obtained. As can be seen from Figure 4, compared with before denoising, the image positioning effect after denoising is more accurate.





a) Positioning effect before denoising b) Positioning effect after denoising

Figure 4 Comparison of positioning effect before and after denoising

2.3 Bright area local enhancement

In the study, the method of mathematical morphological expansion was used to enhance the expansion of the edge of the bright area. This process also causes the image edge to be expanded to cause edge distortion. Therefore, the expansion operation needs to be constrained. The process is as follows:

1） Line scan the image after edge detection, and mark the most edge points on both sides;

2） Select the Disk operator as the expansion operator, and perform the expansion operation on points other than the line scanning mark points;

3）The results of step 1) and step 2) are superimposed on the DCT filter map to obtain a bright area enhanced image, as shown in Figure 5.

Figure 5　Effect picture after bright area enhancement

3 Two-dimensional fuzzy weighted Tsallis entropy algorithm

Drawing on the idea of the one-dimensional histogram weighted Otsu segmentation method, this paper proposes a method of weighting the two-dimensional fuzzy Tsallis entropy of the image, using the valley weight coefficient and the diagonal weight coefficient to weight the two-dimensional histogram The weight at the trough near the corner line increases. This method not only uses the information at the threshold point on the histogram, but also considers the information about the threshold point neighborhood, so that the selection of the threshold is more in line with the distribution characteristics of the target dark and bright areas.

Let $p_{(i,j)}$ be the joint probability of the two-dimensional histogram of the image (grayscale-neighbor mean), L_1 is the maximum grayscale value of the image, and L_2 is the maximum average grayscale value of the neighborhood, the target dark area, reverberation area, and target bright area The probability distributions are:

$$P_d = \sum_{i=1}^{L_1} \sum_{j=1}^{L_2} p_{(i,j)} U_d \tag{13}$$

$$P_s = \sum_{i=1}^{L_1} \sum_{j=1}^{L_2} p_{(i,j)} U_s \tag{14}$$

$$P_r = \sum_{i=1}^{L_1} \sum_{j=1}^{L_2} p_{(i,j)} U_r \tag{15}$$

The degrees of membership are：

$$U_d = U_{dx} U_{dy} \tag{16}$$

$$U_s = U_{sx} U_{sy} \tag{17}$$

$$U_r = U_{rx} U_{ry} \tag{18}$$

$$U_{dx} = \begin{cases} 1, & i \le a_{1x} \\ 1 - 2 \times (\dfrac{k - a_{1x}}{c_{1x} - a_{1x}})^2, & a_{1x} < i \le b_{1x} \\ 2 \times (\dfrac{k - a_{1x}}{c_{1x} - a_{1x}})^2, & b_{1x} < i \le c_{1x} \\ 0, & i \le c_{1x} \end{cases} \tag{19}$$

$$U_{sx} = \begin{cases} 0, & i \le a_{1x} \\ 2\times(\dfrac{k-a_{1x}}{c_{1x}-a_{1x}})^2, & a_{1x} < i \le b_{1x} \\ 1-2\times(\dfrac{k-a_{1x}}{c_{1x}-a_{1x}})^2, & b_{1x} < i \le c_{1x} \\ 1, & c_{1x} < i \le a_{1x} \\ 1-2\times(\dfrac{k-a_{2x}}{c_{2x}-a_{2x}})^2, & b_{2x} < i \le c_{2x} \\ 2\times(\dfrac{k-a_{2x}}{c_{2x}-a_{2x}})^2, & b_{2x} < i \le c_{2x} \\ 0, & i \le c_{2x} \end{cases} \tag{20}$$

$$U_{rx} = \begin{cases} 0, & i \le a_{2x} \\ 2\times(\dfrac{k-a_{2x}}{c_{2x}-a_{2x}})^2, & a_{2x} < i \le b_{2x} \\ 1-2\times(\dfrac{k-a_{2x}}{c_{2x}-a_{2x}})^2, & b_{2x} < i \le c_{2x} \\ 1, & i > c_{2x} \end{cases} \tag{21}$$

$$b_{1x} = \frac{a_{1x}+c_{1x}}{2} \tag{22}$$

$$b_{2x} = \frac{a_{2x}+c_{2x}}{2} \tag{23}$$

$U_{dy}U_{sy}U_{ry}b_{1y}b_{2y}$ The seeking process is similar and will not be repeated here. The fuzzy Tsallis entropy of these three regions are:

$$S_d = \frac{1-\sum_{i=1}^{L_1}\sum_{j=1}^{L_2}(\frac{p_{(i,j)}}{P_{d(i,j)}})^q}{q-1} \times U_{dx}U_{dy} \tag{24}$$

$$S_s = \frac{1-\sum_{i=1}^{L_1}\sum_{j=1}^{L_2}(\frac{p_{(i,j)}}{P_{s(i,j)}})^q}{q-1} \times U_{sx}U_{sy} \tag{25}$$

$$S_r = \frac{1-\sum_{i=1}^{L_1}\sum_{j=1}^{L_2}(\frac{p_{(i,j)}}{P_{r(i,j)}})^q}{q-1} \times U_{rx}U_{ry} \tag{26}$$

The total two-dimensional fuzzy Tsallis entropy of the image is：

$$S = S_d + S_s + S_r + (1-q)^2 \times S_d S_s S_r \tag{27}$$

The two-dimensional filtered histogram is：

$$
\begin{aligned}
H(i,j) &= h(i-m, j-m) + h(i-m, j-m+1) \cdots + h(i-m, j+m) \\
&+ h(i-m+1, j-m) + h(i-m, j-m+1) \cdots \\
&+ h(i-m+1, j+m) \\
&+ \cdots \\
&+ h(i+m, j-m) + h(i+m, j-m+1) + \cdots + h(i+m, j+m)
\end{aligned} \tag{28}
$$

The weight function is：

$$w(i,j) = 1 - H(i,j) - |i-j| \div 100 \tag{29}$$

m is the neighborhood of the smoothing filter; h is the joint probability of the two-dimensional histogram gray-neighbor mean; w is the weight function. The optimal threshold vector $(a_{1x}a_{2x}b_{1x}b_{2x})$ should maximize the following formula, namely:

$$(a_{1x}a_{2x}b_{1x}b_{2x}) = \arg\max(S \times w(a_{1x}, b_{1x}) \times w(a_{2x}, b_{2x})) \tag{30}$$

4 Analysis of results

1）Split results manually

The research of segmentation algorithm in this paper is carried out according to the requirements of the project "National Natural Science Foundation of China 61616038". In this project, the segmentation of sonar images is required to achieve the effect of white in bright areas, black in dark areas, and gray in reverberation areas. Therefore, in the research of this paper, firstly, the sonar shipwreck image was manually segmented to make the bright area, dark area and reverberation area achieve the best segmentation effect required by the project. The various algorithms in the project research and the algorithms proposed in this paper are all Use this segmentation result as a basis for comparison. The effect of manual segmentation is shown in Figure 6.

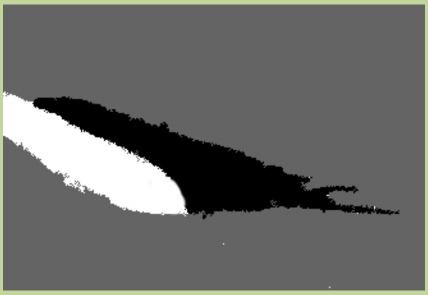
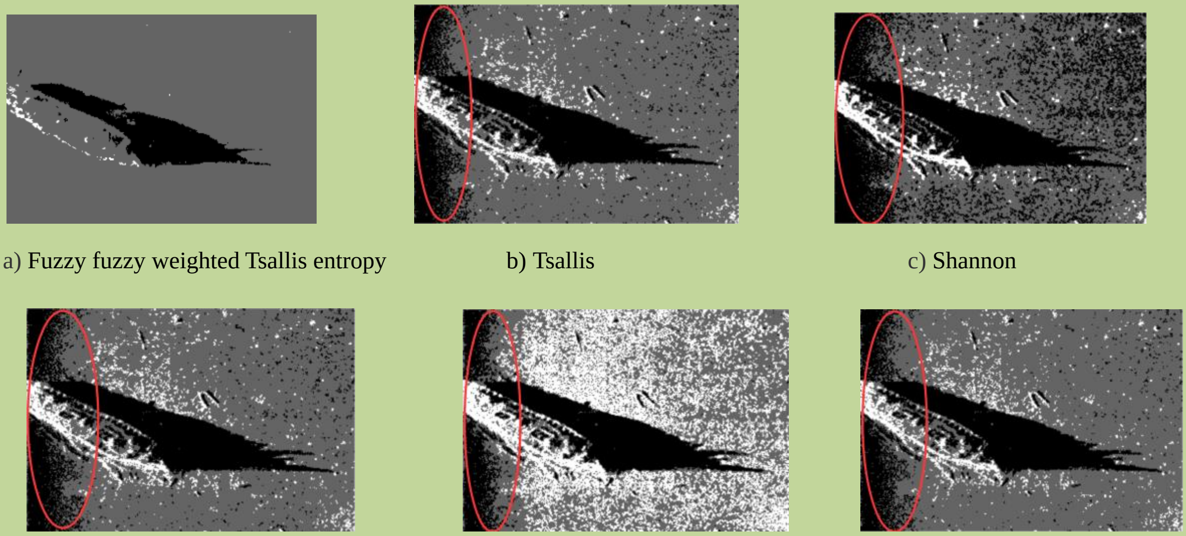


Figure 6 Split image effect manually

2）Split image effect manually

When local enhancement is not used in the segmentation, the segmentation results of the fuzzy weighted Tsallis entropy segmentation method and five classical entropy segmentation algorithms are shown in Figure 7.



a) Fuzzy fuzzy weighted Tsallis entropy　　b) Tsallis　　c) Shannon

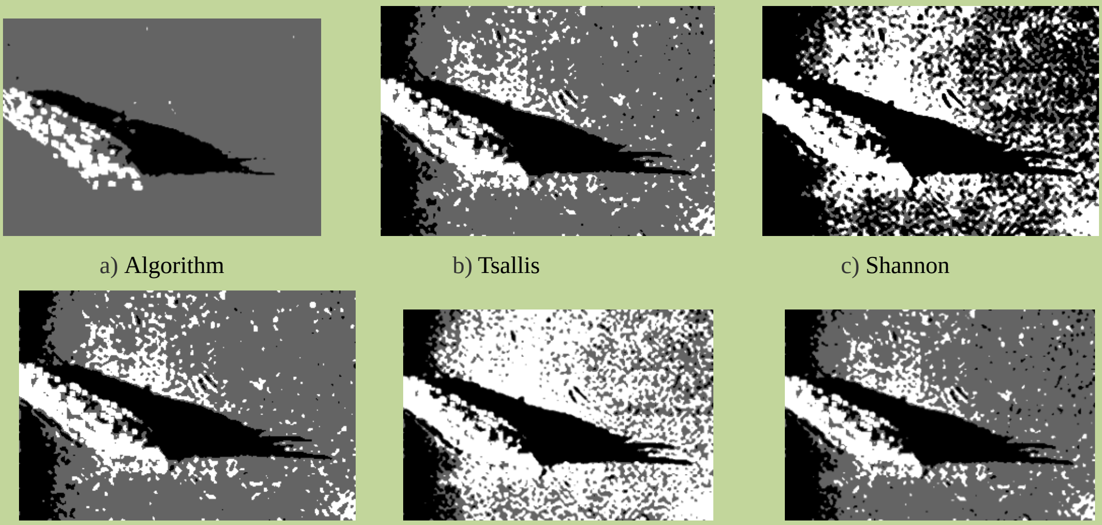
d)　Reny　　e) Exponential　　f) Arimoto

Figure 7 Entropy segmentation effect chart

As can be seen from Figure 7, a large area of black area (the circled part in the figure) appears on the left side of the image segmented by the five classic algorithms. This area is a weak echo signal generated by the seawater around the sonar array transmitter As a result, it is divided into target dark areas and mis-segmentation occurs. The fuzzy weighted Tsallis entropy algorithm introduced in this paper introduces a weight function in the threshold selection process, which better avoids the mis-segmentation of reverberation areas.

3）Locally enhanced segmentation results

Fig. 8 is the segmentation result of applying the local enhancement technique. Compared with the other five classic algorithms, the segmentation effect of the bright area, dark area and reverberation area in the image segmented by this algorithm is close to that of manual segmentation, with clear boundaries, less noise and good visual effect. Compared with the segmentation result in Fig. 7, it can be seen that the target segmentation result after applying the local enhancement technique is significantly better than that before enhancement, regardless of the bright area, dark area and reverberation area.



a) Algorithm　　b) Tsallis　　c) Shannon

d) Reny　　e) Exponential　　f) Arimoto

Figure 8 Locally enhanced segmentation effect

5 Conclusion

Aiming at the needs of sonar image recognition and location tracking of submarine targets, sonar image segmentation is the key. The commonly used entropy method to segment sonar images is difficult to achieve accurate segmentation of the bright, dark and reverberation regions in the target image. This paper proposes a segmentation method for sonar image local enhancement combined with fuzzy weighted Tsallis entropy. The threshold value of the row and column histogram is used to locate the target bright area and enhanced by morphological methods. The enhanced image is fuzzy weighted Tsallis entropy Method for segmentation. In the research of the thesis, the algorithm of this paper is compared with 5 classical entropy segmentation methods. The research results show that the segmentation effect of the proposed algorithm in the bright, reverb and dark areas of the sonar image is superior to the other five classical algorithms, which verifies the effectiveness of the proposed algorithm.

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