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# Image Quality Assessment Method for Underwater Acoustic Communication Based on Digital Watermarking

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***Abstract- This paper proposes a method of reduced-reference image quality assessment based on watermarking algorithm in underwater acoustic channel. By embedding the watermark image into the original one, then delivering the combined image through the channel distortion, the same channel distortion would be exposed to the original and the watermark image. In the receiver,we use the blind extraction methods to recover the watermark image and use the watermark degradation to evaluate the quality of the original one. In this paper,we build three kinds of channels: AWGN channel, Rice fading channel and GB model channel to validate the feasibility of the method which would be used in the underwater acoustic channel.***

**Index terms: Digital Watermark, PSNR (Peak Signal to Noise Ratio), Image Quality Assessment (IQM), UAC (Underwater Acoustic Communication).**

# I. INTRODUCTION

The quality assessment methods can be classified into two types: subjective image quality assessment(SIQA) and objective image quality assessment(OIQA) [1]. SIQA makes the observers evaulating the image quality of the testing image, and then giving the scores. By averaging the scores of all observers, Mean Opinion Score(MOS) of the image would be evaluated. SIQA method can reflect the image quality better, but it was inconvencient for SIQA to be used in engineering application. OIQA aims at providing an automatic and efficient system to evaluate the quality. Based on the existence of source image, OIQA can be classified into: Full Reference(FR), Reduced Reference(RR) and No Reference(NR) [2]. The FR requires the original image information as a reference[3]. The original image is fully available. The RR only requires some features of the original image or statistical information as a reference for assessment. The NR does not need any information about the reference image. In image evaluation system, the widely used FR methods are PSNR and SSIM. They can assess the image quality in some aspects. But in many occasions,such as in a acoustic transmission network, it would be impossible to obtain the original image in the receiving end. So FR method would not be suitable to be used in the communication application. NR method is not reliable and just suitable for evaluating very special image quality. Therefore, the research of RR OIQA method is meaningful [4].

The digital watermarking technique confirms the integrity of the data though embedding the redundant information-watermark into the the original data information [5]. Any ways of malicious destruction and removal hidden information, will also lead to digital products being destroyed, so we can view the damage of the hidden information to assess the damage of the original digital works [6]. Digital watermarking use some strategies to embed the digital information into the original data. According to the position of embedding information [7], we can classify watermark algorithm into spatial domain watermark algorithm and transform domain watermark algorithm. Spatial domain watermark algorithm embeds the watermark information into the original signal in spatial domain, usually including LSB method, COR method. And the transform domain watermark algorithm embeds the watermark information into the transform spatial domain including the DCT domain and wavelet domain. On the other hand, according to the characteristics of watermarking algorithms, the watermark can be classified into: robust, semi-fragile and fragile watermark.

In this paper, we use the watermarking technology in the reduced reference image quality assessment. We embedded the semi-fragile watermark into the host image. In receiver, we can evaluate the quality of the image by studying the changes of the watermark [8]. Different degradation levels of the three underwater acoustic channels had been simulated, and the degradation database had been established. Based on the database, we use the OIQA of the watermark image to evaluate the SIQA of the host image's quality. So that it would be suitable for the method to be used in the underwater acoustic application.

## I. WATERMARKING EVALUATION AND IMAGE QUALITY ASSESSMENT

### a.Watermarking Evaluation Scheme

In this paper, we embedded the watermark into the original image, and through the channel distortion, we use the blind watermark extraction [9] method to extract the watermark in the receiving end. Then, we can assess the quality of the watermark to evaluate the host image's quality. The specific processes are as follows:

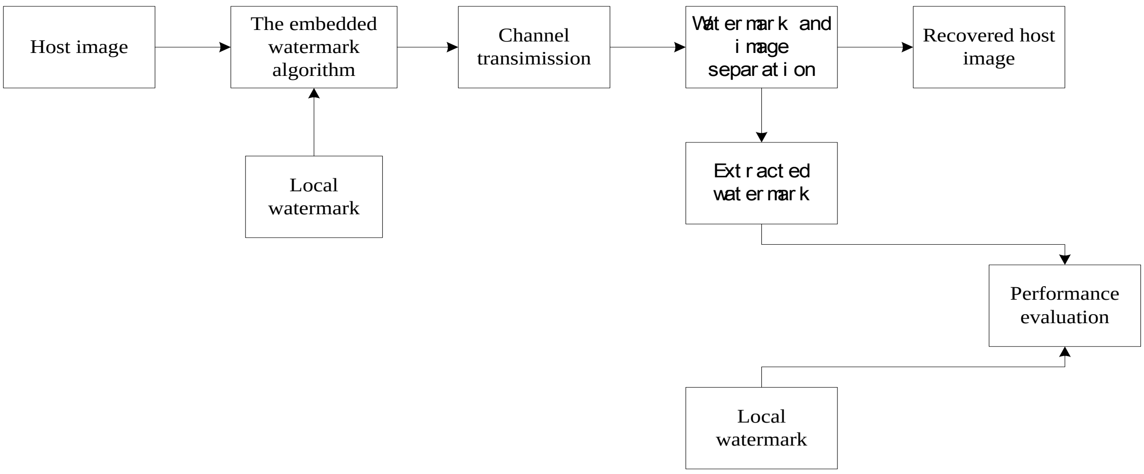



Figure 1. The flow chart of the assessment

### b.Image evaluation index

b.i Subjective image evaluation index

As the human visual system is the image processing terminal, the reasonable method to evaluate image quality is based on subjective evaluation. In the subjective image quality assessment methods, Mean Opinion Score(MOS), that is, the average subjective scores method, is commonly used. It is through different observers for image quality evaluation to get the subjective scores and normalize the score to represent the image quality. It generally has five standards: excellent, better, good, bad, worse [10]. Subjective evaluation criteria are shown in the table1.

Table 1: Subjective evaluation rating

| Level | Damage | Quality |
|---|---|---|
| 5 | Not detectable | Excellent |
| 4 | Perceptible，not boring | Better |
| 3 | Slight boring | good |
| 2 | Boring | bad |
| 1 | Very boring | worse |

b.ii Objective evaluation index

For usual occasions, after we obtain the original images and the reconstruction images, the mean square error(MSE) and peak signal to noise ratio(PSNR) are used to assess the quality of the reconstruction image, they are traditionally objective image quality assessment methods based on the statistical properties. They are the simple mathematical statistics difference between the original image and the reconstruction image.Assuming the image size is M×N,I(x,y) represents the original image, $\hat{I}$ (x,y) represents the distortion image.The expression for MSE and PSNR can be expressed as (1) and (2):

$$MSE = \frac{1}{MN}\sum_{x}\sum_{y}\left[I(x,y)-\hat{I}(x,y)\right]^2 \tag{1}$$

$$PSNR = 10\log_{10}\frac{m^2}{MSE} \tag{2}$$

The value m is a pixel which can achieve the maximum value, for 8 bits, m=255. Generally speaking, MSE is a measurement of the difference between images, and PSNR is a measurement of the image faithful reconstruction or the similarity of the distortion image and original image. The two formula is direct, strict, and simple to calculate. These advantages make them be widely used. But we also notice that the two methods are based on the per-pixel difference to compare the difference of the images. They treat the per-pixel in the same way. So they are the limited approximation of the human vision feeling.

In addition, ZHOU Wang team put forward the SSIM method. This method is demonstrated by comparing the original image and the distortion image's structure characteristics to the assessment, without the error merging. Assuming that x and y represent the two comparison signals, defines the luminance signal comparison function, contrast ratio function, structure similarity function, as (3).

$$l(x,y)=\frac{2u_x u_y + C1}{u_x^{\ 2} + u_y^{\ 2} + C1} \tag{3}$$

Among them, C1 is a constant for the $u_x^{\ 2} + u_y^{\ 2}$ may be very small.

$$c(x,y)=\frac{2\sigma_x\sigma_y + C2}{\sigma_x^{\ 2} + \sigma_y^2 + C2} \tag{4}$$

Among them, C2 is the same with the C1, $\sigma_x$ and $\sigma_y$ represent x and y standard deviation respectively.

$$s(x,y)=\frac{\sigma_{xy} + C3}{\sigma_x\sigma_y + C3} \tag{5}$$

$$\sigma_{xy}=\frac{1}{N-1}\sum_{i=1}^{N}(x_i-u_x)(y_i-u_y)\ , \tag{6}$$

$$SSIM(x,y)=\frac{(2u_x u_y + C1)(2\sigma_{xy} + C2\ )}{(u_x^{\ 2} + u_y^{\ 2} + C1)(\sigma_x^{\ 2} + \sigma_y^2 + C2)} \tag{7}$$

ZHOU Wang apply the SSIM index into the evaluation of the image quality through two steps. First, we implement the SSIM method in a small window of the image. Second, we average all of the local value of SSIM to get the MSSIM to evaluate the image quality.

$$MSSIM(X,Y)=\frac{1}{M}\sum_{j=1}^{M}SSIM(x_j,y_j) \tag{8}$$

Among them, X,Y represents the original image and the distorted image respectively, $x_j$ and $y_j$ represent the j number local window contents,M is the number of local window.

This paper will use SSIM and MOS values as the basic assessment index after the image distortion. we use the SSIM index to assess the recovered watermark quality and MOS value to the recovered host image quality. And then we draw the curve between the recovered watermark and recovered host image to make a qualitative description of the watermark quality change and the covered image quality change. And finally we can talk about the feasibility of the RR method using watermark.

## II. ASSESSMENT APPROACH BASED ON WATERMARK

In the image quality assessment of this paper, we use the embedding watermark as the reference to evaluate the host image. There are some points for attention in embedding the watermark. Firstly, The watermark embedding should follow the invisibility principle, that is, the watermark embedding should keep a certain invisibility while maintaining certain robustness. Secondly, the watermark embedding and extraction of the whole process should be blind, that is, we don't use the original image information in the extraction process. Thirdly, the watermark embedding should follow the comprehensive principle, namely the watermark embedding should try to distribute to the whole host image space. Based on the above requirements, the PSNR of the embedded image should exceed 30dB to guarantee the invisibility. In this paper, we use COR spatial method and DCT transform method to embed the watermark,and compare the two methods in embedding.

### a. COR spatial embedding method

To embed the watermark in the spatial domain, it is easy to solve and have a less calculation of volume. The principles of the COR watermark embedding are as follows: First, we segment the covered image into 8×8 blocks [7], each block is a basic unit for the watermark sequence. Second, select predetermined two value watermark pattern, using several watermark pattern as the embedded watermark. Third, we generate the PN sequence of the watermark. The specific process is using a fixed seed to produce the same length, minimum correlation of two PN sequences to represent the two value watermark, and embed the PN sequence into the each 8×8 blocks. Fourth, after the channel distortion, the received image is also divided into 8×8. After this, we use the fixed seed to produce the PN sequence, and then correlation detection for every block, comparing the corresponding correlation values between two PN sequences and the 8×8 values. At last, decide the each block's representation of value '1'or '0', and recover the watermark.

b. DCT Transform domain to embed the watermark

To embed the watermark into the image's transform domain, we have to make a dct transform of the image. So the algorithm is more complex, but the basic processing step is the same as the COR spatial domain embedding method. As follows: First, We segment the covered image into 8×8 blocks, each block is a basic unit for the watermark sequence, and then for each block, we get the DCT2 transform.Second, select predetermined two value watermark pattern, using several watermark patterns as the embedded watermark. Third, We generate the PN sequence of the watermark. The specific process uses a fixed seed to produce the same length, minimum correlation of two PN sequences to represent the two value watermark, and embed the PN sequence into the each 8×8 DCT coefficients. Fourth, after the channel distortion, the received image is also divided into 8×8, and dct2 transform for each block. After this, we use the fixed seed to produce the PN sequence, and then correlation detection for every block, comparing the corresponding correlation values between two PN sequences and the 8×8 DCT coefficients. At last, decide the each block's representation of value '1'or '0', and recover the watermark. We research the two ways of embedding in this paper. Next, we will illustrate which method will get a better result for embedding through different materials.

## III. DEGRADATION RESOURCES DATABASE

In this paper, we choose 10 pieces of materials(256 x 256) as the original host images, the materials involving the characters and scenery. So the range is wide. And we design four different kinds of watermarks for embedding,size 20x50, just as figure 2 had shown.

(a) Watermark-I (b) Watermark-II (c) Watermark-III (d) Watermark-IV

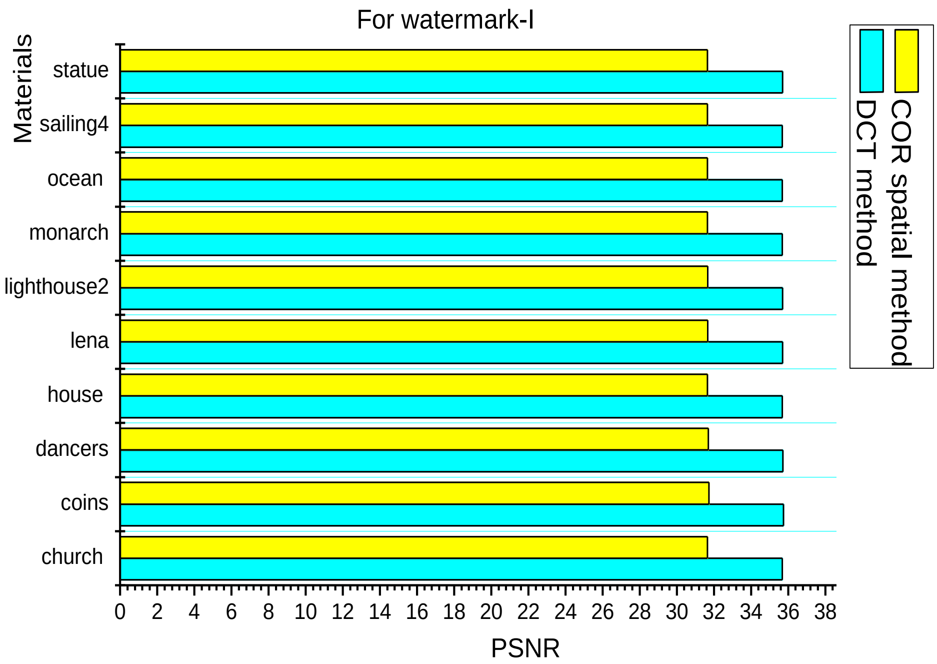
Figure 2. Watermark Image Types

(a) Material church (b) Material lena

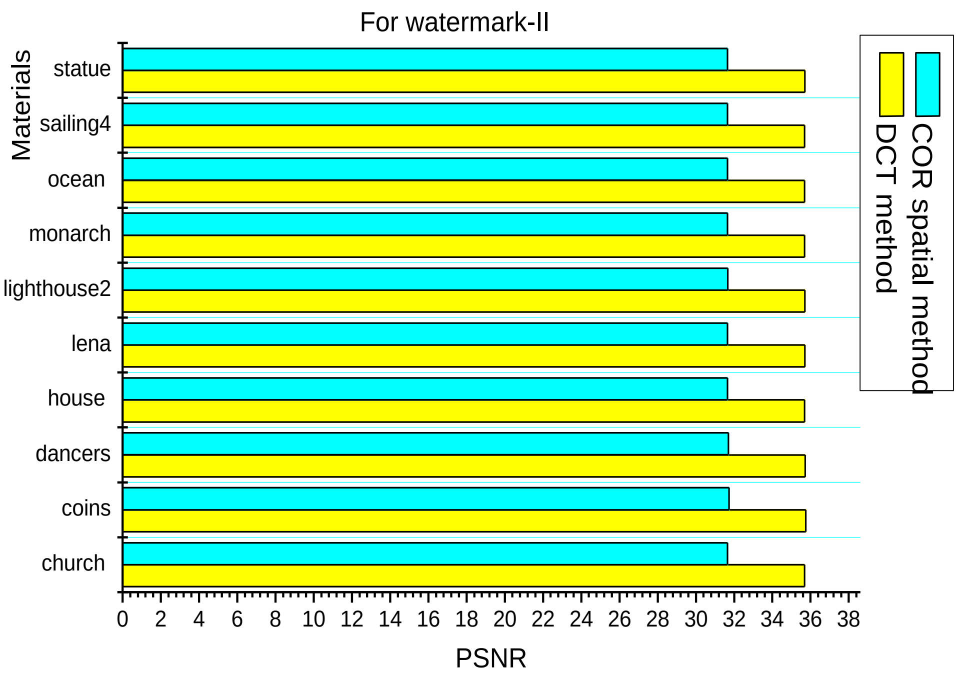
Figure 3. Image Types Of The Materials

A. Effects of Embedding Method

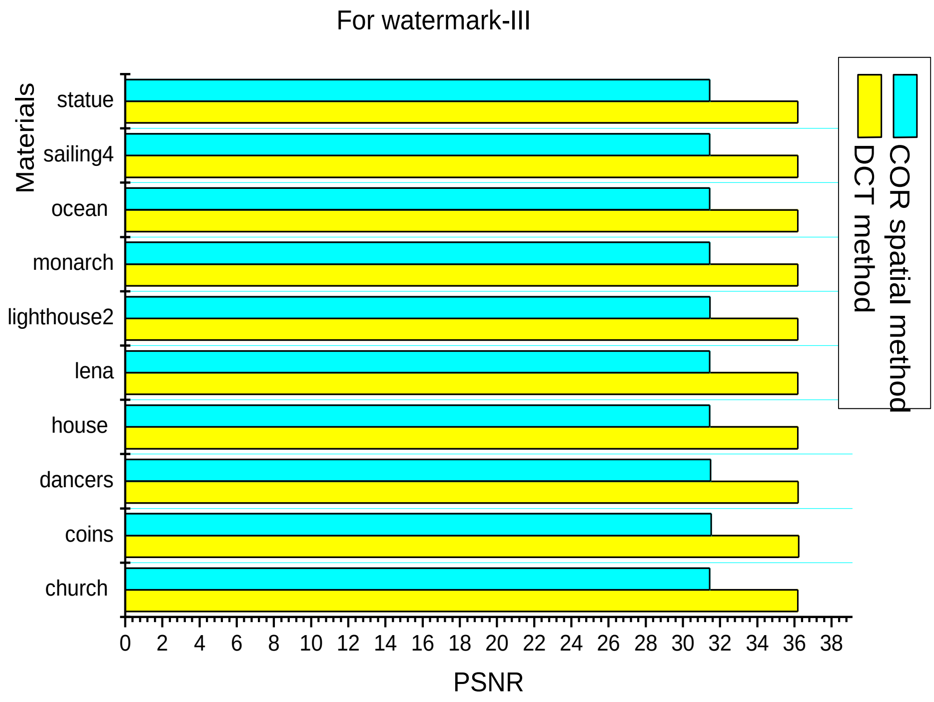
We use COR method and DCT method to embed watermark into the ten host images. And we calculate the PSNR value of the watermarked image to decide which method is better one. The figure 4 are four kinds of watermarked image’s PSNR statistical graphics using the two methods.



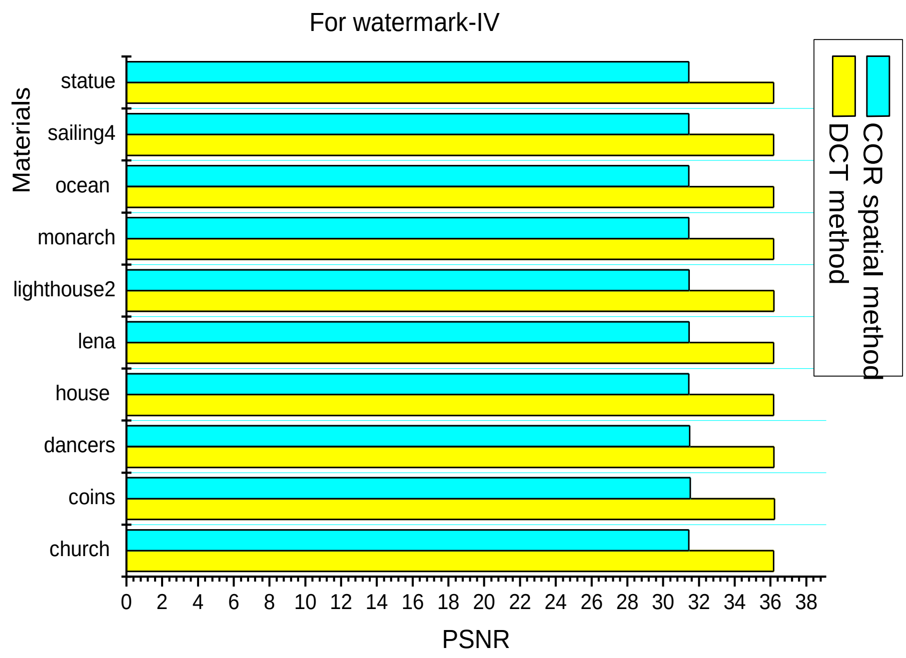

(a) PSNR of two methods for watermarkI




(b) PSNR of two methods for watermark II




(c) PSNR of two methods for watermarkIII




(d) PSNR of two methods for watermarkIV

Figure 4.PSNR Of Two Methods For Four Watermark Types

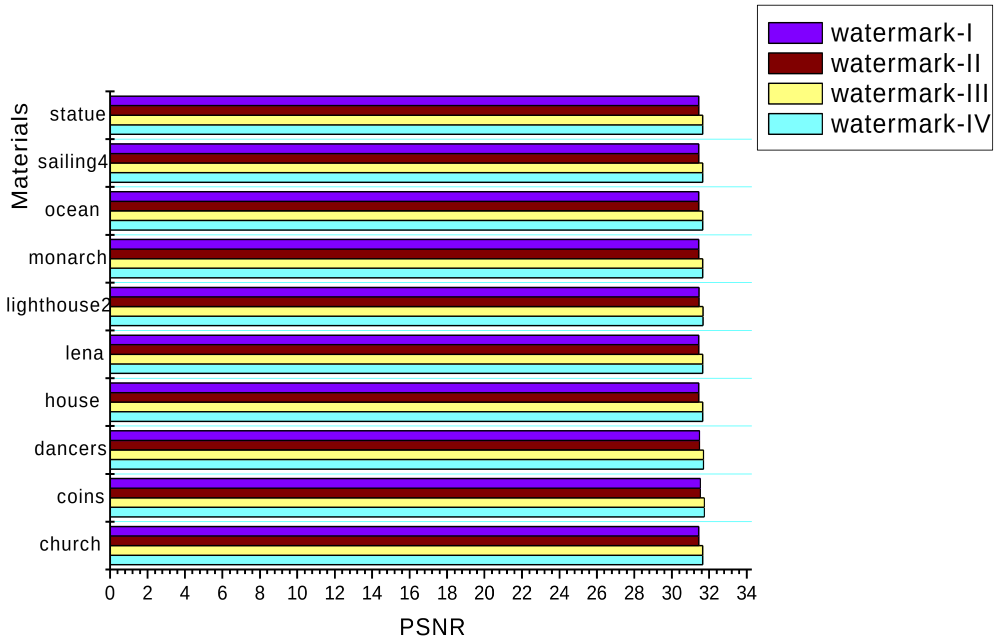



Figure 5. PSNR histogram of Image after Watermarking

For four types of watermark, the PSNR of watermarked image using two methods all exceeds 30dB, that means two kind of embedding methods both maintain certain invisibility. However, we also can see that the DCT method has a greater PSNR value than the COR spatial method. So the DCT method are more invisible for embedding. The DCT method will be chosen in the following embedding in this article. In addition we can get the watermarked image's PSNR statistical graphics for four types of watermark using the same DCT method. As follows in Fig.5, watermark I and watermark II get the same effect for embedding. Watermark III and watermark IV get the same effect for embedding. But the watermark III and watermark IV are better than the watermark I and watermark II, so the watermark III and watermark IV are better choices. In this paper we will choose the watermark III as the watermark for embedding in the DCT method to build the degradation database.

b.The degradation levels of different channels

According to the results above, the DCT method and the watermark III get a better results for embedding. Two images are the materials embedded watermark III with DCT method just as figure 6 had shown. The PSNR values about the two images are 36.1767 and 36.1805. It maintains a relatively good invisibility.

(a) Church embedded the watermark III

(b) Lena embedded the watermark IV

Figure 6.The Image Of Embedding Watermark

The image degradation model of channel is Gauss white noise, Rician Fading channel and Gilbert-Elliot Model. Gauss white noise [11] degradation may directly be through MATLAB software's imnoise function to achieve. Rician Fading channel is based on LABVIEW software platform. We set the Rician channel's frequency deviation for 100HZ, and we use Root shaping filter, the Alpha is:0.5,the filter length is 8. Furthmore, we set the symbol rate of 40k, using 2-PSK modulation to modulate the source. We change the Rician channel parameter K value to change the effect on the image. GB-model simulation channel is a kind of network packet loss simulation. We can set the packet loss rate to study the influence of the GB-model channel [12]. Now we define the Gauss channel, Rician channel degradation and GB-model channel degradation ,just as table 2 shown. The higher Gauss noise level, Rician noise level and Gilbert-Elliot Packet Lost Rate level is, the worse of the quality of image.

Table 2: Deterioration grade table

| **Type** | **L1** | **L2** | **L3** | **L4** | **L5** | **L6** | **L7** | **L8** | **L9** | **L10** |
|---|---|---|---|---|---|---|---|---|---|---|
| Gauss Noise | 0.005 | 0.01 | 0.015 | 0.02 | 0.025 | 0.03 | 0.035 | 0.04 | 0.045 | 0.05 |
| Rician Noise K | 5 | 2.5 | 0 | -2.5 | -5 | -7.5 | -10 | -12.5 | -15 | -17.5 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gerbort-Elliot | 1% | 2% | 3% | 4% | 5% | 6% | 7% | 8% | 9% | 10% |


Figure 7. The Image Of Recover and watermark in Gauss Level-2


Figure 8. The Image Of Recover and watermark in Rician Level-3


Figure 9. The Image Of Recover and watermark in Gilbert-Elliot Model Level-4

Each image will be through the three channel degradation. At the receiver end, we extract the watermark using blind extraction method [13]. After the separation between watermark and the host image, we can see the degradation of the recovered host image. Figure 7 to Figure 9 show the effects in Gauss, Rician Channel and Gilbert-Elliot Model. We can also obtain figure of the subjective image score(MOS) for the recovered image lena under the three channel degradations. we can see that with the increasing of the noise level, the MOS value decrease, just as figure 10 had shown.

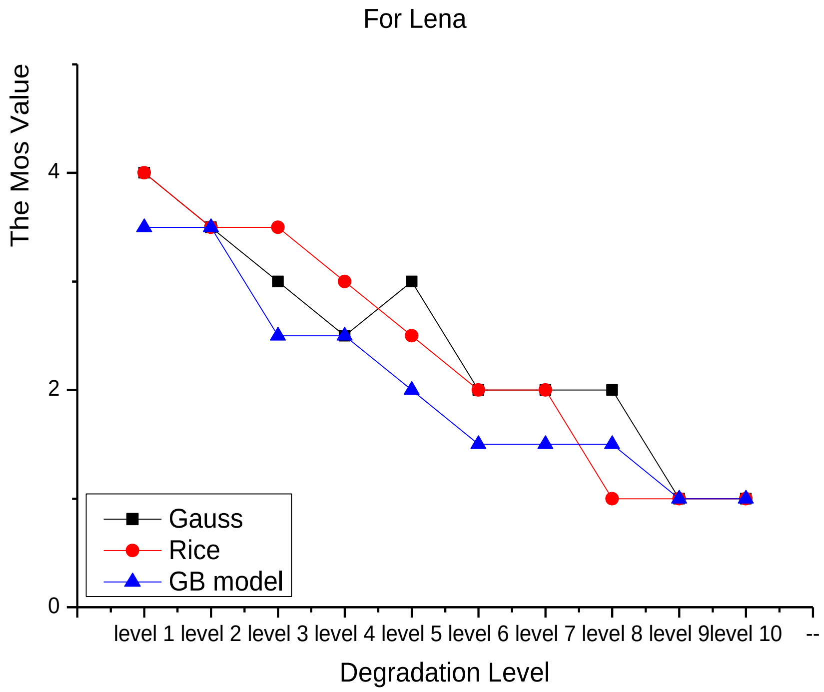



Figure 10. The MOS value of recovered Lena image

## IV. EXPERIMENTAL RESULTS AND ANALYSIS

In this paper, we obtain 10 pictures's database under different level degradations in three channels. We set the recovered watermark's SSIM as the horizontal coordinate. We set the recovered host image's MOS as the vertical coordinate, using Logistics fitting. From Fig.11, we can see that the recovered watermark's SSIM increase with the recovered Host image's MOS. To a certain extent, the change of watermark's quality and the change of host image's quality are synchronous. The curves we can use frequently used 3 evaluation indexes in reference2 to assess the objective prediction and subjective evaluation's consistency .

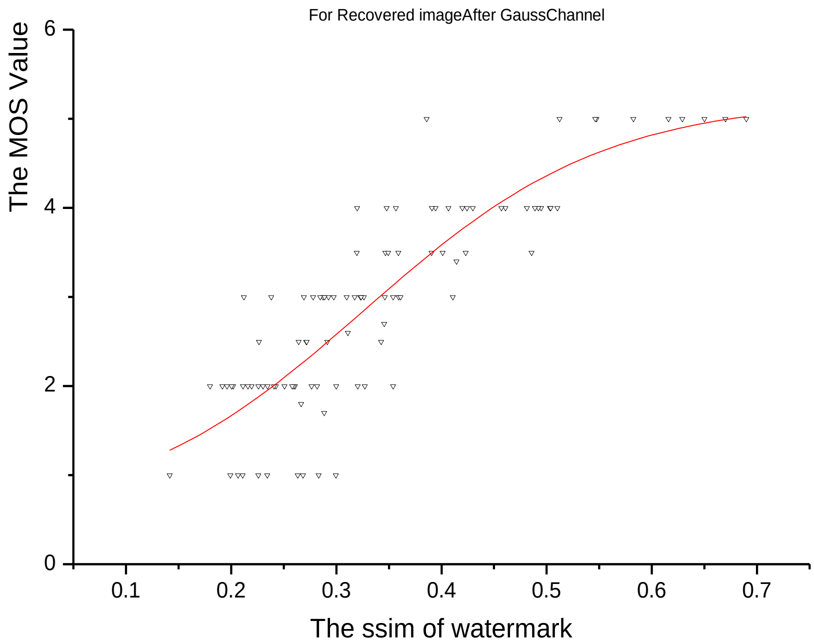
(1) the correlation coefficient between the recovered watermark SSIM and recovered host image's MOS(Pearson correlation), reflects the accuracy of the objective measure's prediction, the value is between [0,1], the performance is better with the value close to 1.

(2) Spearman rank order correlation coefficient reflects the objective measure's monotonicity, its absolute value ranges from 0 to 1, the closer to 1 the value is, the better the

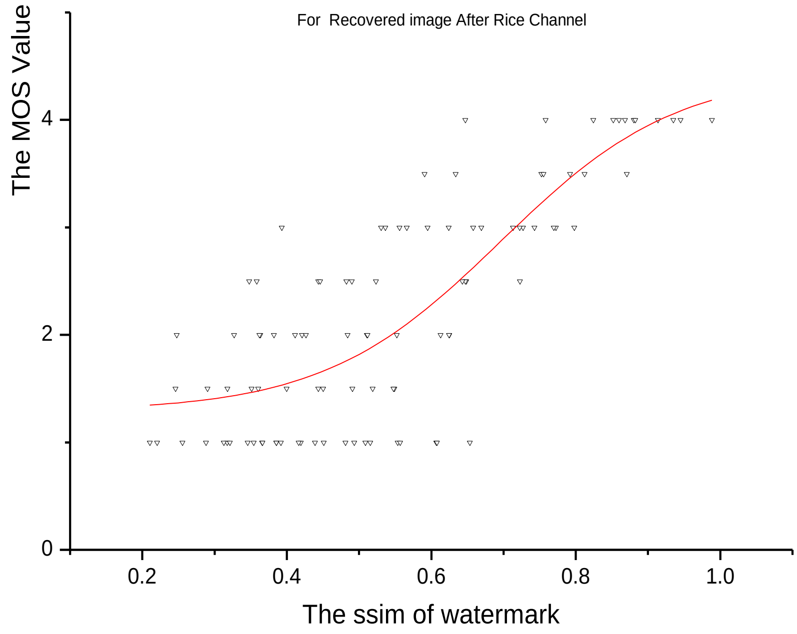
performance is.

(3) Outlier Ratio after the nonlinear regression analysis, reflects the objective measure's consistency, the value are between [0,1], the closer to 0 the value is, the better the performance is.

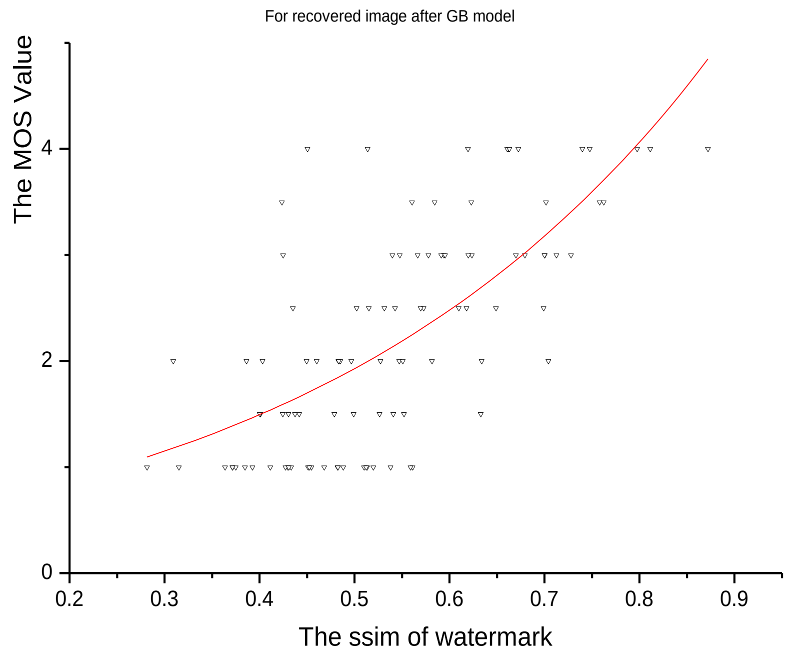
These indexes' value are shown in the table 3. whatever it is Gauss, Rician Fading Channel or G-B model channel, the MOS values of recovered host image and the SSIM values of recovered watermark are basically monotonicity and consistency. In addition,under the Gauss channel, the values of three indexes are higher than the Rice channel and GB model channel, so it means its monotonicity and accuracy are better.




(a) Under Gauss channel




(b) Under Rician channel




(c) Under G-B modul channel

Figure 11. Host Image's MOS vs. Watermark's SSIM

under three kinds of channels (Gaussian, Rician, G-B Model).

Table 3: Experimental data

| **Channel type** | **Pearson** | **Spearman** | **OR** |
|---|---|---|---|
| Gauss | 0.8231 | 0.8615 | 0.38 |
| Rice | 0.7876 | 0.7435 | 0.42 |
| GB | 0.7017 | 0.6983 | 0.48 |

## V. CONCLUSIONS

In this paper, we put forward a method that can assess the image quality based on digital watermarking technology in underwater acoustic channel. We used a blind detection method for watermark extraction. Four kinds of watermarks had been tested using COR and DCT embedding method. And by this watermarking method, it would be possible for us to evaluate the original image’s quality. Three kinds of channel had been used for the simulation, and the metric (Peason, Spearman, and OR) we used had shown that the method would be acceptable to be used.

## VI. ACKNOWLEDGEMENT

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