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LDPC-CM-UEP in the application of digital image watermarking technology

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ABSTRACT

Digital image watermarking is a kind of information hiding technology. Due to high demand of secretiveness and reliable transmission for the secret message in information hiding technology ,the paper adopts the unequal error protection of LDPC coding modulation (LDPC-CM-UEP) scheme to apply to digital image watermarking technology, the code words which the watermark information is encoded by LDPC code to generate are divided into two parts.The two parts respectively make use of two different QAM high-efficient modulation modes, so that the watermark information as important bit gets very strong protection. The simulation results show that this scheme improves the spectrum utilization rate of the system on the premise of guaranteeing robustness and imperceptibility of the watermark, thus improving the transmission quality of digital image watermarking system.

Key words: LDPC code; digital image watermark; coding modulation; unequal error protection

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INTRODUCTION

In recent years, with the rapid development of computer network communication technology and computer network communication technology and multimedia technology, digital watermarking as an important branch of information hiding technology is extensively studied, and made great contributions to themultimedia data authentication and information security[1].Digital image watermarking technology make use of visual redundancy which HVS (Human Visual System) form to multimedia image data to add invisible mark (watermark) into the digital information by signal processing without affecting the normal use of original data, so as to achieve the purpose of copyright protection [2]and information hiding[3-4].

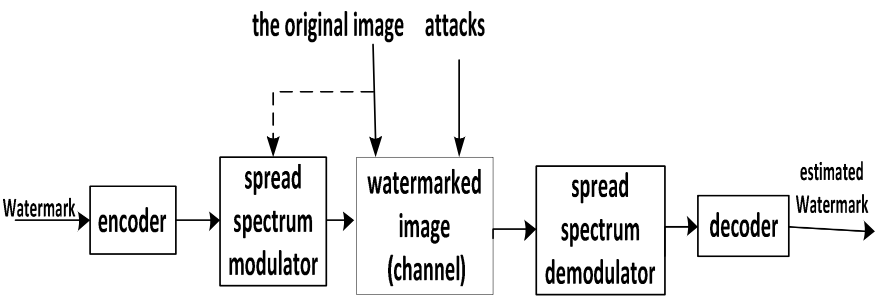

Fig. 1: The equivalent channel mode of digital image watermarking system

The model of digital image watermarking system is similar to digital communication system model [5](as shown in Fig.1), many researchers have introduced LDPC code (Low Density Parity Check Code) as the channel coding into digital watermark system, because LDPC code is the closest Shannon limit among the channel error correcting code known,so that the watermarking can be well protected from noises or attacks. Although LDPC code has the better error correction performance since it adopts traditional coding and BPSK modulation in digital image watermark system , but the system bandwidth and the quantity of watermark information are more enormous, reducing the transmission efficiency of thewatermark. So it is very necessary to introduce the scheme of LDPC channel coding with high performance in the digital watermark system.

In view of existing situation that mobile communication system is more and more high requirements for the data transmission rate, many researchers combine multiple modulation schemes with channel coding [6], greatly improving the system spectrum utilization rate.Meanwhile it can get better BER(Bit Error Ratio) performance. LDPC-CM (LDPC Coding Modulation) combines LDPC coding with MQAM modulation,and the codewords are mapped to the MQAM constellations which can improve the performance of the system on the premise of neither widening bandwidth nor reducing transmission rate of the effective data.LDPC-UEP(Unequal Error Protection) is that the transmission error rate of the important information bits being as low as possible by using LDPC code, and the transmission error rate of the minor information bits is not high.

Based on this, this paper proposes the LDPC-CM-UEP scheme to be applied into the digital watermarking system [7-8].The watermarking information is encoded with LDPC code to receive the codewords,and they are divided into two parts, which were mapped to the different QAM modulation constellation coordinate to form the unequal error protection.While ensuring the watermark information imperceptibility and robustness,the scheme can improve the transmission rate of the system and the transmission quality of the watermarking system.

LDPC CODE

LDPC code is a kind of linear block code, first proposed by Gallager in 1962[9]. Because of the limited computing ability, it was discovered by people until 1999 that its performance is very approaching to the Shannon limit. It has been widely used in many important fields such as deep space communication [10],optical fiber communication ,helicopter satellite communication[11] and so on, and attracts increasing attention in the field of mobile communication.

A. The Encoding Algorithm of LDPC Code

In contrast with the traditional block code, the greatest advantage of LDPC code is that its parity check matrix H is a sparse matrix which is almost composed entirely of zero elements, namely the number of elements"0" is far more than the number of elements"1" in the parity check matrix. The number of non-zero elements in each column is called the column weight, the number of non-zero elements in each row is called the row weight in the matrix H .In order to meet the requirements of the sparsity and decoding, the row weight and the column weight are very small number to be compared with the code length, and the number of overlapping between two arbitrary column does not exceed 1.

After constructing a $m \times n$ dimensionof H , H makes use of the Gauss elimination method to obtain a generating matrix $G = \left[P_{k\times(n-k)} \; I_{k\times k} \right]$,(where k is the length of the information sequence, the square I is theidentity matrix).The known information sequence is mapped to obtain the code words c , $c=[t,u]$, by the formula $c = uG$,where t is redundancy bit, u is information bit.

B. The Decoding Algorithm of LDPC Code

LDPC decoding algorithm in general adopts traditional beliefpropagation(BP) decoding algorithm in probabilistic domain, because the algorithm is a parallel, so the decoding speed is higher. In traditional digital watermarking communication system the code word c_i becomes the transmitted information $x_i = (-1)^{c_i}$ by BPSK modulation, and then through the AWGN channel, $y_i (i = 1, 2, \cdots, n)$ is received the information sequence. Finally, obtain the estimates of the code words $\hat{c}$ according to y . LDPC decoding process can be divided into three steps:

1). Initialization

Calculate the prior probability of informationbits.The initial information of BP decoding is

$$q_{ij}(0) = \frac{1}{1+e^{-2y_i/\sigma^2}} \tag{1}$$

$$q_{ij}(1) = 1 - q_{ij}(0) \tag{2}$$

(Where $q_{ij}(b)$ is the probability of the outside probability information which variable nodes transmit to check nodes being judged as b).

2). Transmit and update the iterative information.
The check nodes and variable nodes information can be normalized because the transmitted information between check nodes and variable nodes is the probability information,thus updating the information of the check bits and the information bits by iteration.

3). Thesoft-decision decoding
Receive the estimates of the code words $\hat{c}$ according to the soft decision decoding. If the syndrome gets "0",namely $H\hat{c}=0$,the decoding is successful to terminate the iteration, otherwise the iteration continues until it reaches the maximum number of iterations.

THE WATERMARKING SCHEME BASED ON LDPC-CM-UEP
The model of digital image watermarking system based on the LDPC-CM-UEP scheme (as shown in Fig. 2) is mainly divided into four parts: LDPC coding modulation of watermarking information, embed the watermark, extract the watermark and LDPC decoding of multiple modulation.

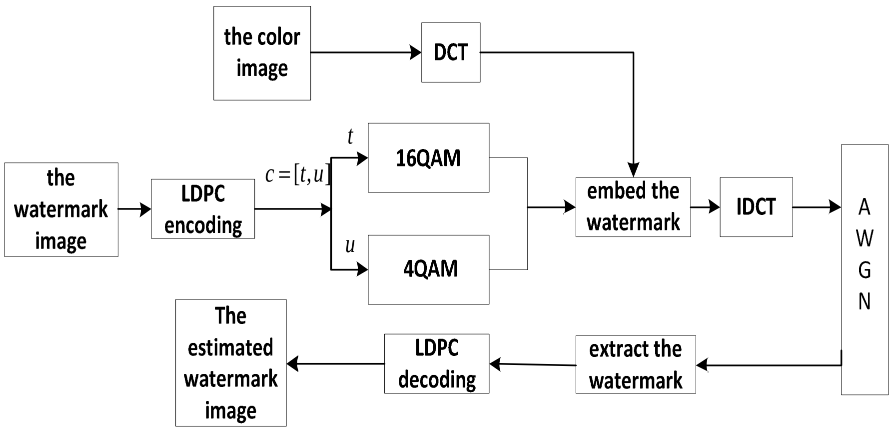

Fig. 2 :The watermarking system model diagram based on the LDPC-CM-UEP scheme

A.LDPC Coding Modulation (CM) of Watermarking Information
The codewords $c=[t,u]$ can be obtained by the encoded information of the binary watermark image. Then the information bits are mapped to the 4QAM signal constellation and the redundant bits are mapped to the 16QAM signal constellation by using Gray Map. The information bits can get better protection because the BER by using 4QAM modulation is lower than one by using 16QAM modulation [12],thus realizing the unequal error protection. Thenuse the pseudo random sequence to spread spectrum (SS), finally getting the watermark sequence which is totally encoded. SS refers to use pseudo random sequence as spread-spectrum codes on the transmitted signal to expand the spectrum, so that the channel bandwidth can far exceed the required information transmission bandwidth. Use the same spread-spectrum codes to dispread, which can restore the original data at the receiving end [13]. The seed of the pseudo random sequence can be set by own, this paper is set to 99 as the key of the watermarking system. If you do not know the key, you cannot detect and extract the watermark, thus enhancing the imperceptibility of the watermark.

B. Embed the Watermark
This part is the most important part in a watermarking scheme and must meet the two most fundamentalrequirements under the condition of fixed watermark size, imperceptibility and robustness [14]. According to the extensive of the application of color image and the practicality of the scheme, this paper chooses the 24 bit true-color image as the original carrier image [15]. It is divided into 8×8 blocks, each block goes through the two dimensional discrete cosine transform (DCT) [16], and then the watermark informationby LDPC coding modulation is embedded in DCT mid-frequency coefficients, the formula is as follows:

$$BLOCK = BLOCK(1+a\cdot K) \quad (3)$$

(Where $BLOCK$ represents the DCT mid-frequency coefficient; a represents the watermark information; K

represents the watermarking intensity, where K is satisfied $K > 0$.The watermarking intensity of K can affect the imperceptibility of theembedded image watermarking).

Then go through IDCT transform DCT coefficients after being embedded the watermark go through IDCT transform, and making the corresponding adaptive vision masking calculation, thus the watermarked image is obtained.

C. Extract the Watermark

The process of extracting the watermark andembedding the watermark are quite the contrary.After the watermarked image and the original carrier image are divided into 8×8 block,they is transformed by IDCTto make the difference, and divide by the intensity K, then using the key for dispreading to obtain the watermarking information which is embedded before.

D. LDPC Decoding of Multiple Modulation

The codewords cannot be directly normalized because they are converted into symbolic information after they are mapped to the MQAM constellation. In order to reduce the complexity [17], every bit of information need to be obtained from the symbolic information, which can perform binary iterative decoding. The 4QAM constellation can be regarded as a subset of the 16QAM constellation.Go through BP decoding algorithm by the LDPC decoding algorithm for Mary modulation [18]. Receive the estimates of the watermark $\hat{u}$ according to the following formula,

$[H_t, H_u]\times[p, d]^T = 0$ (4).

SIMULATIONRESULTS

This paper selects the color image of 256×256 pixels "lena.bmp" as the original carrier image, the watermark image is the standard BMP image which is the size of 32×16, the watermarked image and the extracted watermark image by MATLAB simulation(as shown in Fig.3). The LDPC code length is 1024, the code rate R is $1/2$.Theencoding algorithm uses the Mackay 1A method to get the check matrix H.Its column weight is 3, the row weight is evenly distributed as possible, and amaximum of 6.The maximum iterative decoding number is 100.Set $K = 0.1$(where K is the embedment intensity).

Fig. 3: the simulation diagram based on LDPC-CM-UEP scheme

1). Theembedment intensityof K

The peak signal to noise ratio (PSNR) is the ratio of signal energy and the noise energy, which is used to measure the noise of the watermarked image. The watermark information is larger, the PSNR value is smaller,consequently reducing the imperceptibility. In order to having nice imperceptibility, the PSNR value should be greater than 38dB. The calculation formula of PSNR is as follows:

$$PSNR = 10\log\frac{M^2 f_{\max}^2}{\sum_{x=1}^{M}\sum_{y=1}^{M}[\hat{f}(x,y) - f(x,y)]^2} \quad (5)$$

(Where $M*M$ represent the size of the original carrier image, $f_{\max}$ is the maximum pixel value in the image, $\hat{f}(x,y)$ represents the pixel values of the watermarked image, $f(x,y)$ is the pixel value of the original carrier image).

According to the ratio curve of PSNR and the embedment intensity of K in the LDPC-CM-UEP scheme (as shown in Fig.4) can be obtained, the PSNR value is 38.9511 when the embedment intensity is 0.1,which the watermark have good imperceptibility.Therefore the embedment intensity in MATLAB modulation is chosen to 0.1 in order to take into account the robustness and the imperceptibility of the watermark.

With increasing the embedding strength of K , the noise Patternis more obvious in the embedded watermark image(as shown in Fig. 5).

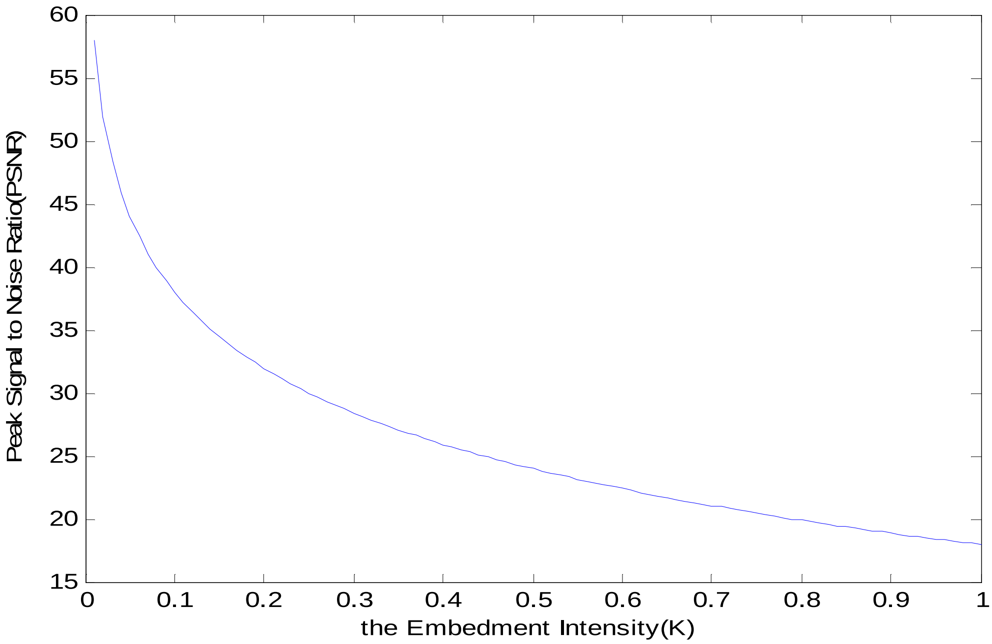

Fig. 4: The relationship curve between PSNR and the embedding strength K

(a) $K = 0.1$ (b) $K = 0.2$

(c) $K = 0.4$ (d) $K = 0.5$

Fig. 5 :Changes of noise pattern under different embedding strength

2). Thespectrum availability ratio of η

The formula of the spectrum availability ratio η is as follows:

$\eta = R1bM$ (6)

(where R is the rate of LDPC code) .

Set $R = 1/2$ .For the BPSK modulation, $M = 2$, so $\eta = 0.5$ bit/s/HZ, so η respectively is 1 bit/s/HZ and 2 bit/s/HZ for the 4QAM and 16QAM modulation. Therefore the mean of η in the LDPC-CM-UEP scheme is 1.5 bit/s/HZ, which improve 1 bit/s/HZ as compared with η in the BPSK modulation (as shown in TABLE□) .

TABLE□.The Watermark Embedding Effect Under Different Schemes

K	$K = 0.2$	$K = 0.5$
LDPC		
LDPC -CM -UEP		

3). Theperformance against JPEG compression

JPEG compression as a kind of image compression is the most common, which can lose part of image information. The quality factor Q (0 ~ 100) value is greater, the degree of JPEG compression is smaller, so the image quality is better.

The BER curves of LDPC-CM-UEP scheme and the conventional LDPC encoding and BPSK modulation scheme are applied to digital image watermarking system under the JPEG compression (as shown in Fig.6) are compared, it can be concluded that when Q is 0 ~ 60, the BER of LDPC-CM-UEP scheme is a little lower than one of the LDPC encoding and BPSK modulation scheme,BER had little difference; when Q is 60 ~ 100, theperformance of LDPC-CM-UEP scheme is better.SoLDPC-CM-UEPscheme can guarantee that the watermark have a good ability of robustness.

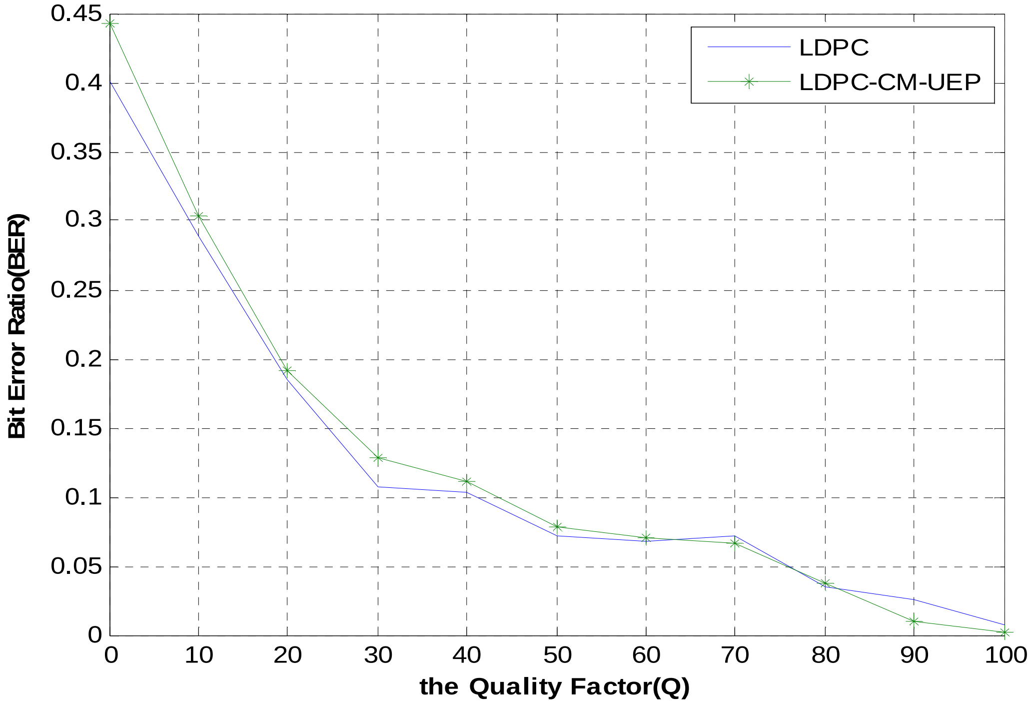

Fig. 6 :The BER curve under the JPEG compression

CONCLUSION

The LDPC-CM-UEP scheme in the application of the digital image watermarking system can ensure good robustness and imperceptibility of the watermark, and improve the spectrum ratio, only minimal loss of BER in the system, thus improve the transmission quality of the system. The scheme makes LDPC code in the application of digital watermarking technology to be more practical and extensive,and lay the foundation for the application of high efficient modulation and unequal error protection in the digital watermarking system.

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