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An Improved Algorithm of SPIHT based on the Human Visual Characteristics

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***Abstract*—**Because of excellent properties, people has paid more attention to SPIHI algorithm, which is based on the traditional wavelet transformation theory, but it also has its shortcomings. Combined the progress in the present wavelet domain and the human's visual characteristics, we propose an improved algorithm based on human visual characteristics of SPIHT in the base of analysis of SPIHI algorithm. The experiment indicated that the coding speed and quality has been enhanced well compared to the original SPIHT algorithm, moreover improved the quality of the transmission cut off.

***Keywords*—**Lifted wavelet transform, SPIHT, Human Visual Characteristics.

I. Introduction

THE wavelet transformation has obtained the good effect in the imagery processing aspect by its ability of time-frequency analysis and removing correlation. From 1980s last stages, Mallat first introduced fast wavelet transformation to image processing, and the wavelet transformation obtained the widespread popularization in the image compression domain. A. Said and W. A. Pearlman's embedded coding method (SPIHT algorithm) is an advanced method in image coding domain, which is considered one of the most advanced in the field of image transform coding method by the international community. The method takes the zero tree structure as its foundation, after a series of measures, such as set definition, set division. It effectively completes the coding process. The SPIHT algorithm doesn't need any data training, supports the multi- coding rate, and has higher Signal-to-Noise and better quality of the recovered image. The overall performance surpasses the EZW algorithm, which is proposed by J. M. Shapiro [2]. But the theoretical analysis and the experimental results indicate that this algorithm also has some insufficiencies, the manifestation is: In the fast wavelet transformation process, the convolution operation with the huge image data seriously reduces the coding speed. It will reduce the processed image quality (specially is low bit rate) that the algorithm doesn't sufficiently consider the Human Visual Characteristics (HVC). It needs using additional three list sets LIS (list of insignificant sets), LIP (list of insignificant pixels), and LSP (list of significant pixels) to store the coded node and assembly. Because of its greater demand for memory, it is hard for the hardware realization.

In order to overcome this deficiency, people proposed a lot of improved methods on its foundation [7]-[10]. This paper presents a new image coding algorithm, which can overcome the deficiencies SPIHT by changing the order of SPHIT output bitstream and taking the measure of considering the HVC based on the SPHIT compression. The proposed improvement of SPIHT is highly efficient image compression algorithm, and its image quality is superior to the original complex SPIHT, has broad application prospects.

II. Lifting Wavelet Transformation

Now, when the actual digital picture uses the integer to express, by the traditional wavelet filter output result is the decimal but is not the integer, the wavelet transformation in this time cannot realize any distortion reconstruction, moreover computable complexity to be high is disadvantageous to the hardware realization. Sweldens and so on proposed Lift Scheme which is one of methods that constructs compactly supported biorthogonal wavelet, which was called "the second-generation wavelet"[3][4]. This method favors the hardware realization, can carry on the fast original position operation, does not need external storage space, computation complexity is lower and easy to reversible transformation, the wavelet coefficient obtained is the same as with which is obtained by using the tradition wavelet transformation. Filter based on lifting scheme is composed of simple filter sequence. Show through Fig. 1, it can be implemented by the three steps: Split, Predict, and Update. The Fig. 2 shows the reversible transformation.

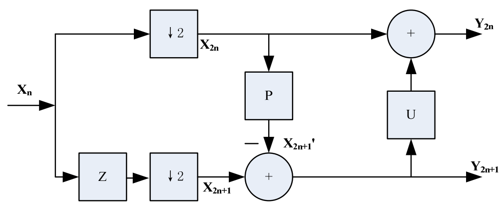

Fig. 1 Wavelet Transformation based on Lifting Scheme

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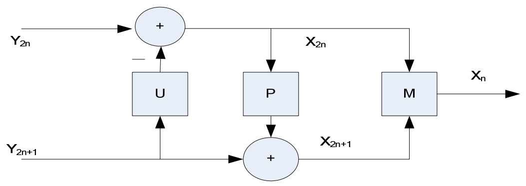

Fig. 2 Reversible Wavelet Transformation based on Lifting Scheme

According to the odevity of the input signal's ordinal number, the split divides the signal into following two groups:
According to the odevity of the input signal's ordinal number, the split divides the signal into following two groups:

$$X_0^0(n)=X(2n);X_1^0(n)=X(2n+1) \quad (1)$$

Predict: the filter P functions to the even signal ($X_0^0(n)$) and obtains the forecast value ($X_1^p(n)$) of the odd signal, then get the prediction error ($X_1^1(n)$) by the method which subtracts the forecast value from the odd signal:

$$X_1^1(n)=X_1^0(n)-X_1^p(n) \quad (2)$$

Update: Filter U functions to odd signal forecast error, obtain the even signal (X00(n)) forecast value (X0p(n)) , then use even signal for matching the signal to carry on the adjustment:

$$X_0^p(n)=\sum_k u_k X_1^1(n-k);X_0^1(n)=X_0^0(n)-X_0^p(n)... \quad (3)$$

In Formula (2) (3), K value scope separately corresponds to rank of the filter P and U.

III. Human Visual Characteristics

Recent years, from the observations of person's visual phenomena and the research of physiological and psychological vision, people have discovered the effect of vision masking. If we can make full use of the effect of vision masking in the image coding process, permit a bigger actual distortion under the same condition in the subjective sensation distortion, we can use the lower bit rate to maintain the subjective quality of the image unchanged. The research indicated that: (1) the person eye is very sensitive to information distortion of the image fringe area; (2) the person eye quite is sensitive to information distortion of the image smooth area; (3) the person eye is insensitive to information distortion of the image texture area. Because sensitive degree of person's eye to the area which are fringe area, smooth area and texture area in the image is different, it means that there are differences in the importance of image information among the three kinds of different regions (from image coding aspect). Therefore we can give the wavelet coefficient to the different visual weighted value according to the image information of the three different kinds of regions (in sensitive area wavelet coefficient multiply by bigger visual weighted value). This method can guarantee transmitting the most visual important coefficient first, and enhancing quality of the recovered image further. This method can guarantee transmitting the most important coefficient in the visual firstly, in order to further improve the image restoration quality. Introducing human eye visual characteristic (HVC) comprehensively and Entrusting the different visual weight to the wavelet coefficient have to complete the below primary mission:

(1)Divides high frequency belt of the wavelet image into different sub-block Bk (k=1,2... S).

(2)According to the certain classified rule, divides the above sub-block into even slide block, texture block and edge block, its process is: Calculates entropy value and variance of each image sub- block Bk (k=1,2... S), the entropy value smaller sub-block should be the even slide block. But the bigger entropy value of image sub- block is the texture block or the edge block. The texture block correspondence variance is smaller, the edge block correspondence variance is bigger, Select the appropriate entropy threshold value and the variance threshold value. Obtain the corresponding edge block, even slide and the texture block.

(3) Determine different visual weighted value of the wavelet coefficient of the edge block, smooth slide and the texture blocks. In order to simplify the visual weighted value selection process, this article first divides the image into the following three kinds (Table I):

Texture image (Mandrill), its characteristic is the biggest proportion in the Texture block of the image

Edge image (Barbara), its characteristic is the biggest proportion in the Edge block of the image

Smooth image (Lena): its characteristic is the biggest proportion in the Smooth block of the image.

TABLE I
Different Block of the Image

Image block	Texture image(Mandrill)	Edge image(Barbara)	Smooth image(Lena)
Texture	48.9	10.3	7.4
Edge	29.2	54.9	43.2
Smooth	21.9	34.8	49.4

IV. SPIHT

SPIHT is a wavelet-based image compression coder. It first converts the image into its wavelet transform and then transmits information about the wavelet coefficients. The decoder uses the received signal to reconstruct the wavelet and performs an inverse wavelet transform to recover the image. SPIHT and its predecessor(the embedded zero tree wavelet coder) were significant breakthroughs in still image compression in that they offered significantly improved quality over vector quantization, JPEG, and wavelets combined with quantization, while not requiring training and producing an embedded bit-stream. SPIHT displays exceptional characteristics over several properties all at once [6].

SPIHT is a method of coding and decoding the wavelet transform of an image. By coding and transmitting information about the wavelet coefficients, it is possible for a decoder to perform an inverse transformation on the wavelet and reconstruct the original image. The entire wavelet coefficient does not need to be transmitted in order to recover the image. Instead, when the decoder receives more information about the original wavelet transform, the inverse-transformation will yield a better quality reconstruction (i.e., higher peak signal to noise ratio) of the original image. SPIHT generates excellent image quality and performance due to several properties of the coding algorithm. They are partial ordering by coefficient value, taking advantage of redundancies between different wavelet scales and transmitting data in bit-plane order. Following a wavelet transformation, SPIHT divides the wavelet into spatial orientation trees Fig. 3.

SPIHT codes a wavelet by transmitting information about the significance of a pixel. By stating whether or not a pixel is above some threshold, information about that pixel's value is implied. Furthermore, SPIHT transmits information stating whether a pixel or any of its descendants are above a threshold. If the statement proves false, then all of its descendants are known to be below that threshold level and they do not need to be considered during the rest of the current pass. At the end of each pass the threshold is divided by two and the algorithm continues. By proceeding in this manner, information about the most significant bits of the wavelet coefficients will always precede information on lower order significant bits, which is referred to as bit-plane ordering. Within each bit-plane data is transmitted in three lists:

The list of insignificant pixels (LIP), the list of insignificant sets (LIS), and the list of significant pixels (LSP).

In addition to transmitting wavelet coefficients in a bit-plane ordering, the SPIHT algorithm develops an individual order to transmit information within each bit-plane. The ordering is implicitly created from the threshold information discussed above and by a set of rules which both the encoder and decoder agree upon. Thus, each image will transmit wavelet coefficients in an entirely different order. Slightly better PSNR are achieved by using this dynamic ordering of the wavelet coefficients.

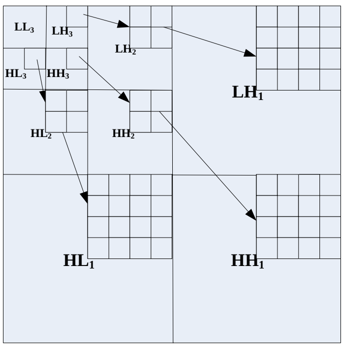

Fig. 3 Zerotree in a 3-level decomposition

V. Algorithm in this Article

In the SPIHT each stage, output bit stream includes all bits which are created in the sorting process and refining process. In some stage, changing bitstream output order [5] can improve the truncation transmission the image quality, but the simply change certainly cannot enhance the non-truncation transmission the image quality. Combined above introduced Lifted Wavelet Transform and HVC, we can simultaneously improve these two aspects (truncation and non-truncation) the picture quality. The algorithm of changing bit stream output sequence SPIHT was called MSPIHT (Modified SPIHT). In the reality the image that we see is the color image, because human visual Characteristics color sensitivity is much lower than bright sensitivity. Here we use gray image which gives the integrity the process:

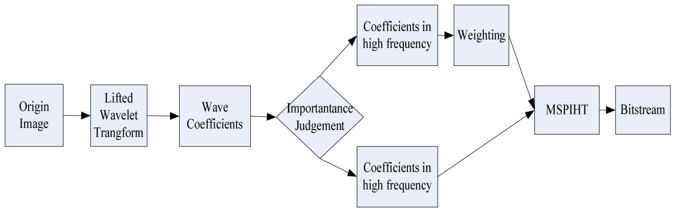

Fig. 4 Our coder block diagram

From the Fig. 4, we can see that this image compression code algorithm mainly includes 3 parts: (1) Carrying on the primitive image to the fast promotion wavelet transformation (2) According to human eye visual characteristic, Entrusts the different visual weight to the wavelet coefficient of the wavelet image in the high frequency inner tube (3) Carries on the compression code using revision symbol stream output order MSPIHT.

VI. Experiment Results and Conclusion

We use the computer: CPU P4 2.8G, RAM 56MB, Operating System Windows XP (Simplified Chinese), Experimental environment MATLAB 7.0 (Simplified Chinese). We take LENA as the experimental object and use the objective evaluation standard PSNR to take this paper evaluation criterion. The experimental data is as follows:

TABLE II
EXPERIMENTAL RESULTS IN 256×256 IMAGE SIZE

	First phase	Second phase	Third phase	Fourth phase	Fifth phase	Sixth phase	Seventh phase
Original SPIH	14.489	15.566	18.373	22.612	30.712	34.153	35.005
Reference [5] source	14.489	16. 724	21.031	23.774	32.501	34.153	35.005
This paper	15.039	18.063	23.457	27.197	33.568	35.855	37.379

REFERENCES

[1] A. Said,, W.A. Pearlman. 1996,*A new, fast, and efficient image codec based on set partitioning in hierarchical trees.* IEEE Trans. Circuits Syst. Video Technol.6 (3), 243-250.
[2] J. M. Shapiro, *Embedded image coding using zero trees of wavelet coefficients*,1996 IEEE Transactions on Signal Processing, 41(12):3445-3462 .
[3] I. Daubechies, W. Sweldens.1996, *Factoring wavelet transforms into lifting steps"*. Technical report, Bell Laboratories, Lucent Technologies.
[4] A. R. Calderbank,I Daubechies,W Sweldens. B. L. Yeo, *Wavelet transforms that map integers to integers.*1996, Technical report, Department of Mathematics, Princeton University.
[5] Chun-Liang Tung, Tung-Shou Chen A *New Improvement of SPIHT Progressive Image Transmission.* 2003, Proceedings of the IEEE Fifth International Symposium on Multimedia Software Engineering.
[6] SPIHT Image Compression: Properties of the Method. [Online].Available: http://www.cipr.rpi.edu/research/SPIHT/spiht1.html
[7] Lin WK, Burgress N. *Low memory color image zerotree coding*. In: Proceedings of the 32nd Asilomar Conference on Signal, Systems and Computer. 1998. 231~235.
[8] Wheeler W, Pearlman W. A. *SPIHT image compression without lists*. 2000, Proceedings of the IEEE ICASSP 2000.
[9] Song Xiao Fang Zhang Chengke Wu *A New Robust Multiple Description Coding Method Based on Region of Interest .*2003, Proceedings of the17 th International Conference on Advanced Information Networking and Applications (AINA'03).
[10] Debargha Mukherjee and Sanjit K. Mitra, *Life Fellow, Vector SPIHT for Embedded Wavelet Video and Image Coding.*2003, IEEE Transactions on Circuits and Systems For Video Technology, Vol. 13, No. 3, March.

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