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Multi-Wavelet Domain Reconstruction of Lost Blocks in Wireless Image Transmission

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Abstract

A fast scheme for multi-wavelet domain interpolation of lost image blocks in wireless image transmission is proposed in this paper. Instead of using common retransmission query protocols, the lost block is reconstructed in the multi-wavelet domain using the correlation between the lost block and its neighbors.

The algorithm suggests that each tile is decomposed using a single level 2-D DMWT (2-Dimension Discrete Multi-Wavelet Transform) instead of decomposing the tile into three level 2-D DWT(2-Dimension Discrete Wavelet Transform), as stated in the JPEG2000 standard. It can be easily seen that the reconstruction procedure is very simple because it only requires knowing the 2-D DMWT of the surrounding tiles. Finally, it requires only to average the corresponding decomposed tiles.

Keywords: multi-wavelet, lost blocks reconstruction, wireless transmission.

اعادة تركيب المقاطع المفقودة من الصور المرسلة لاسلكياً باستخدام مجال المويجة المتعددة

الخلاصة

في هذا البحث تم أقتراح مخطط سريع لاسترجاع اجزاء الصورة المفقودة عند ارسالها لاسلكيا باستخدام مجال المويجة المتقطعة بدلاً مِنْ أستعمالَ بروتوكولات إستفسار إعادةَ الإرسال المشتركة فقد تم أسترجاع الجزء المفقود من خلال الارتباط مع الاجزاء المجاورة للجزء المفقود.

يقترح في الخوارزمية تحليل كل جزء من أجزاء الصورة باستخدام مرحلة واحدة الى مجال المويجة المتعددة المتقطعة ذات البعدين بدلا من تحليلها باستخدام ثلاث مراحل من مجال المويجة المتقطعة ذات البعدين كما هو معمول بالنظام القياسي JPEG 2000 . ويمكن ملاحظة سهولة خطوات الطريقة المقترحة في استرجاع الاجزاء المفقودة وذلك لأنها فقط تحتاج الى معرفة تحليل الأجزاء المجاورة للجزء المفقود باستخدام مرحلة واحدة من مجال المويجة المتعددة المتقطعة ذات البعدين. وبعد ذلك يتم أخذ المعدل للأجزاء التي تم تحليلها.

INTRODUCTION

In common operation of the JPEG2000 still image compression standard [1], the encoder tiles the image into blocks of n x n (n being a power of 2 pixels) calculates a 2-D DWT (2-Dimension Discrete Wavelet Transform), quantizes the transform coefficients and encodes them using arithmetic coding. In common wireless scenarios, the image is transmitted over the wireless channel block by block. Due to severe fading, entire image blocks can be lost. Chang reports that average packet loss rate in a wireless environment is 3.6% and occurs in a bursty fashion [2].

Error resilient channel coding schemes (e.g., Forward Error Correction) use Reed Solomon codes

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or convolutional codes to reconstruct the lost portion of the bit stream, sacrificing some useful bandwidth in the process. This method, which is designed for a fixed bit error rate (BER), cannot completely prevent loss of data when the BER is unknown, as in most practical cases [2].

The common techniques to recover the lost block are grouped under Automatic Retransmission Query Protocols (ARQ). ARQ lowers data transmission rates and can further increase the network congestion, which can deteriorate the packet loss [3]. Instead, it is shown in this paper that it is possible to satisfactorily reconstruct the lost blocks by using the available information surrounding them. The location of lost data, i.e., lost image blocks, is known in common wireless scenarios. The proposed scheme is tested with a variety of images and simulated block losses. It is shown that reconstructions have acceptable visual quality, high SNR, and a low computational cost. Purely decoder based error concealment in baseline JPEG coded images has been demonstrated in the image domain and in the DCT domain. Various studies have successfully used the wavelet framework for texture synthesis [4], reconstruction of edges, which are distorted during compression [5], and enhancement of edges, which are blurred during interpolation [6].

V. DeBrunner et al, provide a survey of commonly used error control and concealment methods in image transmission [7]. Image domain methods use interpolation [8], or separate reconstruction methods for structure and texture [9]. Most transform based methods, notably those described for MPEG-2 video [10] and earlier for DCT-JPEG images [8], assume a smoothness constraint on the image intensity. These methods define an object function, which measures the variation at the border between the lost block and its neighbors, and then proceed to minimize this object function. Z. Alkachouch and M. Bellanger [11] describe a different DCT based interpolation scheme, which uses only 8 border pixels to reconstruct the 64 lost DCT coefficients.

THE PROPOSED ALGORITHM

In common operation of the JPEG2000 still image compression standard, the encoder tiles the image into blocks of n x n (n being a power of (2) pixels (normally 8, i.e., 8×8 blocks), calculates a 2-D DWT into three levels, quantizes the transform coefficients and encodes them using arithmetic coding. So, in this paper, instead of using 2-D DWT, it is proposed to use a 2-D DMWT (**2-Dimension Discreate Multi-Wavelet** Transform).

The 2-D DMWT decomposes each tile into low frequency components (L_1L_1, L_1L_2, L_2L_1, and L_2L_2), and high frequency components (L_1H_1, L_1H_2, L_2H_1, L_2H_2, H_1L_1, H_1L_2, H_2L_1, H_2L_2, H_1H_1, H_1H_2, H_2H_1, and H_2H_2).

So once the missing block has been detected, the reconstruction of lost blocks includes the following steps (it is assumed that the low frequency components have already been received correctly):-

1) The tiles that are at the top (T), bottom (B), right (R), left (L), right-top (RT), right-bottom (RB), left-top (LT), and left-bottom (LB) are taken.

2) The 2-D DMWT for T, B, R, L, RT, RB, LT, LB are found.

3)The high frequency components are found by averaging the corresponding high frequency components from the eight surronding tiles

A flowchart of the proposed algorithm is shown in Fig.(1).

ADVANTAGES OF MULTI-WAVELET TRANSFORM OVER WAVELET TRANSFORM

For best performance in image compression, wavelet transforms require filters that combine a number of desirable properties, such as orthogonality and symmetry. However the design possibilities for wavelets are limited because they can not simultaneously possess all of these desirable properties. The relatively new field of multi-wavelets shows promise in removing some of the limitations of wavelets. Multi-wavelets offer more design options and hence can combine all desirable transform features [12].

Because of the above, the author in [12] suggested to use multi-wavelet instead of wavelet in image compression. He proved that it is possible to support a low resolution video stream from the original stream which is a desirable feature for mobile telephone video transmission where the display screen is very small and adapts well to low resolution images. The other interesting feature is the ability to adapt the quality to the required bit rate through the use of some quantization factor. This feature is also desirable for INTERNET transmission at very low bit rates.

So, it is required to find a new technique to reconstruct the lost blocks using multi-wavelet and to benefit the above features to make if for the algorithms used to reconstruct the lost block.

SIMULATION RESULTS

There are three methods to find the 2-D DMWT [12], depending on the type of preprocessing, these are:-

1) Repeated Row Preprocessing,
2) Critically-Sampled, and
3) Fast algorithm.

a) Repeated Row Preprocessing (RRP)

Fig.(2) shows an 8×8 simulated lost block and its corresponding reconstructions. It can be easily seen that the reconstruction is perfect using the subjective human display.

b) Critically-Sampled (CS)

Fig.(3) shows an 8×8 simulated lost block and its corresponding reconstructions. It can be easily seen that the reconstruction is good using the subjective human display.

c) Fast Algorithm (FA)

It is found that the performance of reconstruction using the fast algorithm for finding the 2-D DMWT is the same as the criticaly sampled method. So the figures obtained are the same as those obtained in Fig.(2).

EVALUATION TESTS OF THE RESULTS

The commonly used objective measure is the Signal to Noise Ratio (SNR). The error between an original and reconstructed pixel values is defined as [13,14]:

$$error(x,y)=O(x,y)-R(x,y)$$

where O(x,y) is the pixel value at position (x,y) of the original block and

R(x,y) is the pixel value at position x, y of the reconstructed block.

The Total Error (TE) between the original and reconstructed block of size (M*N) is defined as [13,14]:

$$TE = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} O(x,y) - R(x,y)$$

The SNR metric considers the reconstructed block R(x,y) to be the "signal", and the error to be the "noise". So SNR can be defined as [14]:

$$SNR = 10\log_{10}\left(\frac{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}(R(x,y))^2}{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}(O(x,y)-R(x,y))^2}\right)$$

For a comparison between RRP, CS, and FA, Table (1) shows that RRP gives the best performance among them, while CS and FA give the same performance because the multi-wavelet values are the same using CS and FA with a little difference from that obtained for RRP.

Finally comparing the proposed algorithm, i.e., using DMWT instead of using DWT, the obtained results are compared with the reconstruction algorithm presented by A. H. Hadi [15] as shown in Table (1). It shows that the reconstruction algorithm presented using RRP and CS (or FA) gives better performance than using the 2-D DWT.

CONCLUSIONS

Since there is no control over the fading channel, there is no prior information about the relative locations and number of blocks that can be lost in the process. It is noted that before transmission of the blocks, a packetization scheme is applied so that a bursty packet loss during transmission is scattered into a pseudorandom loss in the image domain. Therefore, consecutive image blocks are rarely lost and the reconstruction scheme can use the neighborhood of the lost block for reconstruction.

In this paper, an algorithm for reconstruction of lost blocks using the 2-D DMWT is presented. The algorithm suggests that each tile is decomposed using a single level 2-D DMWT instead of decomposing the tile into three 2-D DWT levels, as documented in the JPEG2000 standard. It can be easily seen that the reconstruction procedure is very simple because it only requires to know the 2-D DMWT of the surrounding tiles. After that, it requires only to average the correspoding decomposed tiles. It is assumed in this paper that the low frequency components are received correctly.

It is also found that the 2-D DMWT that uses RRP gives the best performance among the proposed scheme and the previously reported work.

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Table-1- Comparison between the proposed multi-wavelet algorithm with the previously wavelet algorithm

2-D DMWT (Single Level)				2-D DWT (3 Levels)	
Block Type	SNR for RRP (dB)	SNR for CS (dB)	SNR for FA (dB)	Block Type	SNR (dB)
L_1H_1	30.332	21.232	21.232	H_0	18.612
L_1H_2	22.836	17.328	17.328	V_0	18.559
L_2H_1	30.668	25.970	25.970	D_0	18.868
L_2H_2	27.687	20.158	20.158	H_1	18.205
H_1L_1	27.616	20.002	20.002	V_1	19.957
H_1L_2	29.545	21.277	21.277	D_1	16.561
H_2L_1	21.738	14.817	14.817	H_2	12.158
H_2L_2	24.657	19.800	19.800	V_2	12.739
H_1H_1	42.426	31.206	31.206	D_2	21.559
H_1H_2	33.181	27.585	27.585		
H_2H_1	33.769	23.767	23.767		
H_2H_2	28.406	26.300	26.300		

where H_0, V_0, D_0, H_1, V_1, D_1, H_2, V_2, D_2 are the high frequency components of the 3-level 2-D DWT

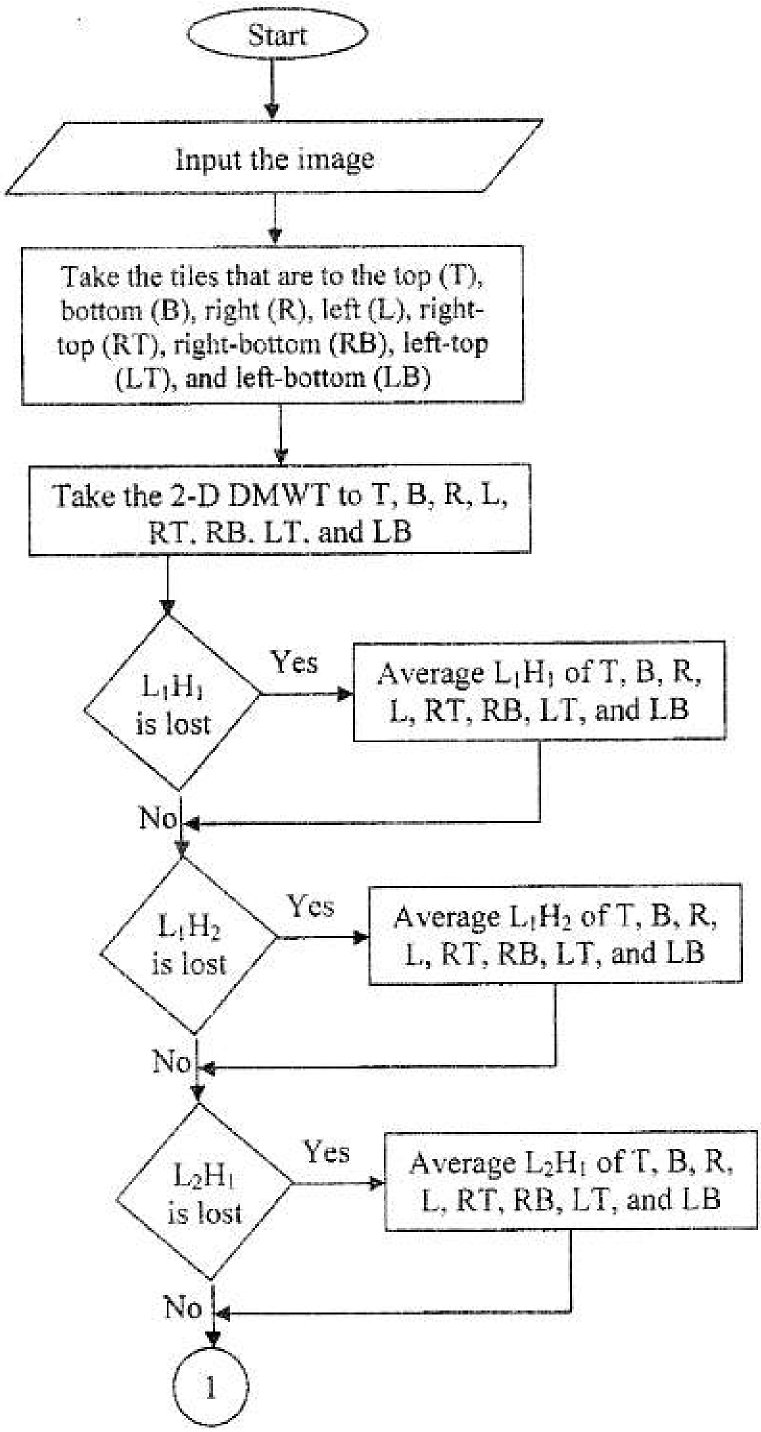
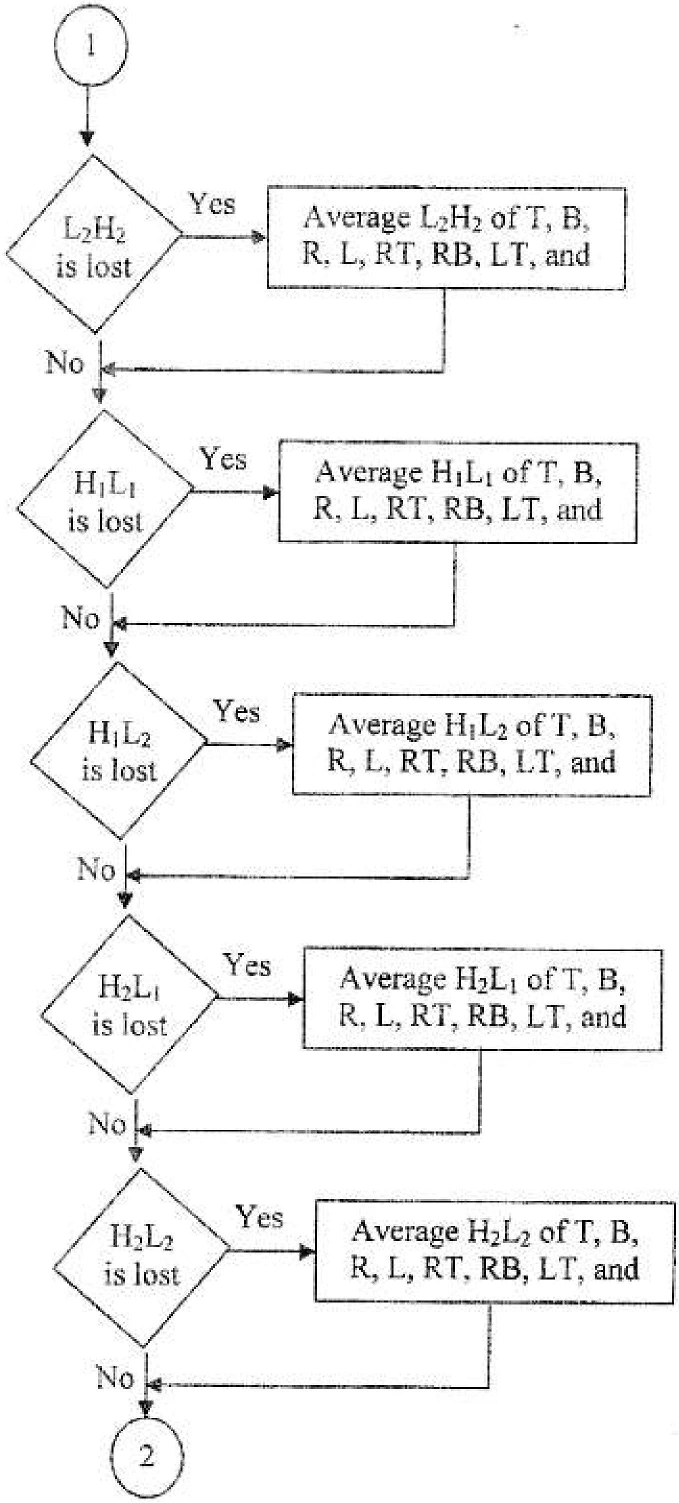
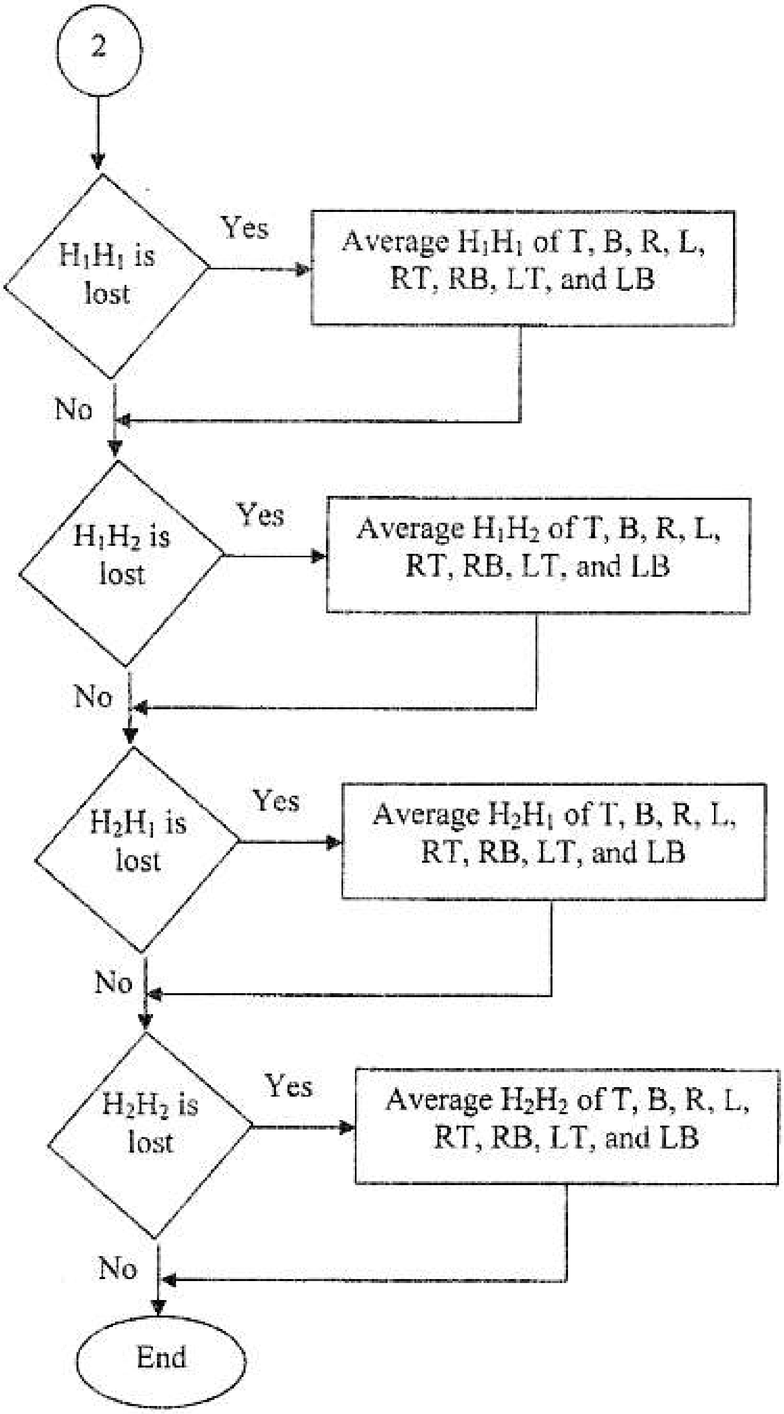


Fig.(1) The Flowchart of the Algorithm



Fig(1) Continued



Fig(1) Continued

(a) Position of The Lost Block

(b) Reconstruction when L_1H_1 is used

(c) Reconstruction when L_1H_2 is used

(d) Reconstruction when L_2H_1 is used

(e) Reconstruction when L_2H_2 is used

(f) Reconstruction when H_1L_1 is used

Fig.(2) Reconstruction of Lost Block Using RRP

(g) Reconstruction when H_1L_2 is used

(h) Reconstruction when H_2L_1 is used

(i) Reconstruction when H_2L_2 is used

(j) Reconstruction when H_1H_1 is used

(k) Reconstruction when H_1H_2 is used

(l) Reconstruction when H_2H_1 is used

Fig.(2) Continued

(m) Reconstruction when H_2H_2 is used

Fig.(2) Continued

(a) Position of The Lost Block

(b) Reconstruction when L_1H_1 is used

(c) Reconstruction when L_1H_2 is used

(d) Reconstruction when L_2H_1 is used

(e) Reconstruction when L_2H_2 is used

(f) Reconstruction when H_1L_1 is used

Fig.(3) Reconstruction of Lost Block Using CS

(g) Reconstruction when H_1L_2 is used

(h) Reconstruction when H_2L_1 is used

(i) Reconstruction when H_2L_2 is used

(j) Reconstruction when H_2L_1 is used

(k) Reconstruction when H_1H_2 is used

(l) Reconstruction when H_2H_1 is used

Fig.(3) Continued

(m) Reconstruction when H_2H_2 is used

Fig.(3) Continued