

Image Reconstruction Using Lapped Biorthogonal Transformation and Multiple Description Coding

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ABSTRACT

Multiple Description Coding (MDC) is one of the source coding methods in order to provide several independent and quantized streams of input data. Also, MDC is a useful source coding method for concealing error in lossy networks. In this paper, coded and quantized image streams are transmitted to the communication channel and any loss happens in the channel can be restored by averaging method. By using averaging method the average of received descriptions are taken and substituted with the lost descriptions. Input image is downsampled to 4 subimages. These 4 descriptions are mapped to transform domain by Lapped Biorthogonal Transform (LBT) besides are quantized and coded. Later, these descriptions are transmitted over the channel and once any link is lost at the receiver, by using averaging method, missing data is reconstructed. In the proposed method retransmission of the descriptions is not needed, which causes to have simplified method. The PSNR values are better and subjective evaluation element is clearer than the previous work, which causes to have higher throughput and less blur images. Furthermore, facial details of images are clearer and edges of the image details are sharper than the compared research.

KEYWORDS: Multiple Description Coding, Lapped Biorthogonal, Transform, Image Coding, Transform Codings

INTRODUCTION

Multiple Description Coding (MDC) is a source coding method, which produces various data streams of the source in the coder. The produced image streams are transmitted over different links in unstable networks [1-3]. At the decoder side data can be reconstructed by using any number of received descriptions. In real-time applications because of constraints of data retransmission, latency, so retransmission is not a efficient method (no feedback link). Therefore, the receiver must be relied on the number of obtained descriptions to recover the lost transmitted signal [1].

The Higher quality of recovered image is obtained from the more number of the received descriptions at the receiver. Obtaining fair quality, even though some of the coded data streams have been corrupted or lost is the advantage of MDC. However, the distortion is the lowest when the decoder receives all descriptions error less [4].

MDC prepares a method to reconstruct signals with acceptable quality, while some of the data streams have been lost. This method is different from the scalable coding [4]. This capability has made MDC potential for multimedia streams over multi-path channels which leads to have higher quality of transmitted signal. Several correlated streams of the image are prepared and transmitted on various channels. Also, in order to improve the quality of reconstructed image, the Lapped Biorthogonal Transform (LBT) is employed to MDC. The LBT and LOT (lapped orthogonal transform) has the same computational complexity, but LBT has less blocking effects.

The LBT and LOT was introduced for block signal processing applications and proved to be useful in various areas of signal processing [5-6]. Generally, block transform coding of images produces a blocking effect which can be reduced only by additional processing, increasing the coding bit rate or using complex adaptive schemes. The LOT and LBT reduces the blocking effect to very low levels.

The LBT and LOT is an orthogonal set of basis functions which extend beyond the transform block to overlap a part of adjacent blocks. The basis functions decay slowly beyond the block boundary. Therefore, the transition at the boundaries is smooth and discontinuities do not result [7-8].

The Block diagram of direct LBT is shown in Figure 1. The difference of the LBT with LOT is that in LBT the odd DCT coefficients of direct transform is multiplied to $\sqrt{\frac{1}{2}}$ and multiplied to $\sqrt{2}$ in the inverse transform [9]. The direct transform is defined by

$$V = \text{diag} \left\{ \sqrt{2}, 1, 1, \dots, 1 \right\} \quad (1)$$

and inverse transform is defined by

$$V^{-1} = \text{diag} \left\{ \sqrt{\frac{1}{2}}, 1, 1, \dots, 1 \right\} \quad (2)$$

Furthermore, the \tilde{Z} can be approximated by a series of $\frac{N}{2} - 1$ plane rotations, in the form

$$\tilde{Z} = T_1 T_2 \dots T_{\frac{N}{2}-1} \quad (3)$$

where each plane rotation is defined as

$$T_i = \begin{bmatrix} I & 0 & 0 \\ 0 & Y(\theta_i) & 0 \\ 0 & 0 & I \end{bmatrix} \quad (4)$$

The matrix $Y(\theta_i)$ is as a 2×2 butterfly is defined [9] as

$$Y(\theta_i) = \begin{bmatrix} \cos(\theta_i) & \sin(\theta_i) \\ -\sin(\theta_i) & \cos(\theta_i) \end{bmatrix}. \quad (5)$$

Unlike the LOT, where the basis functions decay to a value near zero at the boundaries [7], the LBT synthesis basis functions decay to zero at the boundaries. That is why the LBT has less blocking artefacts than the LOT. The more details of LOT and LBT can be studied in [5-6,10].

In this research, the LBT is joint with MDC in order to remove the redundant information of the image, quantize and code the LBT coefficients [9]. It leads to have higher throughput and better performance in terms of subjective observation and PSNR values.

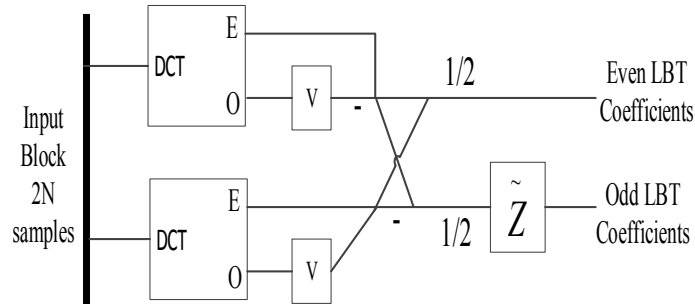


Figure 1: Lapped biorthogonal transform block

The rest of this paper is structured as follows. Section 2 describes proposed method of LBT based MDC. Simulation results are illustrated in section 3. Section 4 concludes the paper.

PROPOSED JOINT LBT-MDC

In this method input grey scale with size of 512×512 are downsampled to 4 subimages each size of 256×256 . Downsampling method is explained in [3]. Later, LBT is applied to all 4 subimages. LBT is one of the block transform codings technique that is similar to DCT. One of the advantageous of LBT over DCT is that in LBT during transformation from the spatial domain to transform domain, the blocks are overlapped to each other which leads no blocking effect.

In the next step, all 4 LBT subimages are scalar quantized with different quantization steps according to various bit per pixel (bpp). Later, these data links are transmitted along the channel and in the network if any loss happens, averaging method is employed to the received descriptions in order to recover the mislead links.

Finally, inverse LBT is taken to all descriptions and by upsampling of data links, reconstructed image is created. The block diagram of the proposed algorithms illustrated in Figure 2.

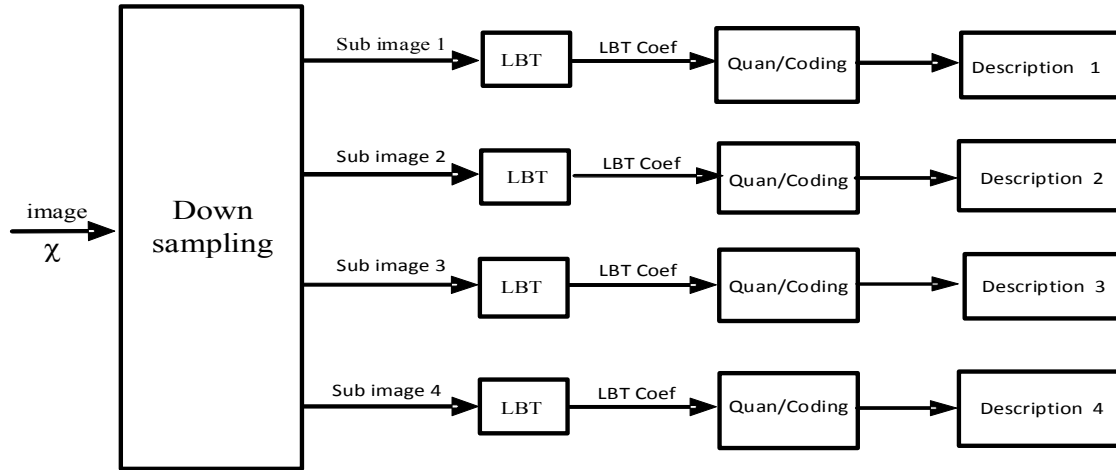


Figure 2: Proposed method using LBT based MDC

SIMULATION RESULTS

The input image is divided to four subimages by using down sampling method [3]. The LBT transform coding is employed to the four downsampled data and subsequently quantization is applied to sequences as well. Finally, coded data are sent through the channel. The inverse of the process is employed to received descriptions at the receiver side. In the circumstances that loss happens to a description in any channels, by substituting average of received streams in place lost data, absent descriptions can be reconstructed with higher throughput.

Having no blocking effect is the most advantage of LBT, so it makes LBT useful transform coding method to produce high quality reconstructed image even at low bpp such as 0.1 which shown in Table 1. Therefore, LBT performs better than the other transform codings in low capacity channel (since in low bit rate has acceptable PSNR value and clear subjective evaluation quality).

In Table 1 average PSNR for Lena image in LBT method is presented. Results show that by using LBT and MDC, in the low bpp good quality of image in terms of subjective evaluation and PSNR value are obtained. It can also concluded from the table, in low bit rate (less than 1 bpp), the PSNR factor is high (more than 26)and minor deviation is achieved even though most of the descriptions are lost.

Table 1: PSNR (dB) values for Lena image from LBT-MDC proposed method

Number of Lost Descriptions	Bitrate					
	0.11 bpp	0.28 bpp	0.51 bpp	1 bpp	2.6 bpp	4.8 bpp
0	25.38	28.13	29.80	30.87	32.80	32.75
1	25.20	27.93	29.58	30.41	31.93	32.20
2	25.10	27.60	28.86	29.50	30.70	31.15
3	24.96	27.37	27.53	29.11	30.12	30.80

The quality of reconstructed image around high bpp (more than 2 bpp) is saturated and does not rise sharply. Nevertheless, in other transform codings such as DCT and wavelet when bit rate increases (more than 2 bpp) the quality also increases. Table 1 shows that while bit per pixel increases from 2.66 to 4.8 bpp, the PSNR factor do not vary sharply although PSNR factor is high at 2.66 bpp.

Figure 3 presents the obtained image with 3 lost descriptions in low bit rate of 0.11 bpp. The figure shows there is no blocking effect in the image and high PSNR values (more than 25 dB) are achieved at low bit rates. Furthermore, small features of image such as eyes and lips of image are visible but the edges are not clear (especially in the hairs) due to high compression ratio that causes to remove high frequency coefficients of the image which is used and necessary for edge detection.



Figure 3: Obtained image in 0.11 bpp with three lost data streams from proposed LBT-MDC method

In Table 2, results of the [3] is shown. Comparing to Table 1, it is obvious that the PSNR values are higher by proposed method in the respective fixed bpp.

The rate-distortion plot of the proposed method together with [3] is shown in Figure 4. It is concluded from the results that in the fixed bpp the Mean Square Error (MSE) of the proposed method is lower than the [3].

Table 2: The PSNR (dB) factor for Lena image from [3]

Number of Lost Descriptions	Bit Rate		
	2 bpp	1 bpp	0.50 bpp
0	29.91	28.05	26.39
1	29.77	27.99	26.36
2	29.19	27.66	26.23
3	29.10	27.64	26.21

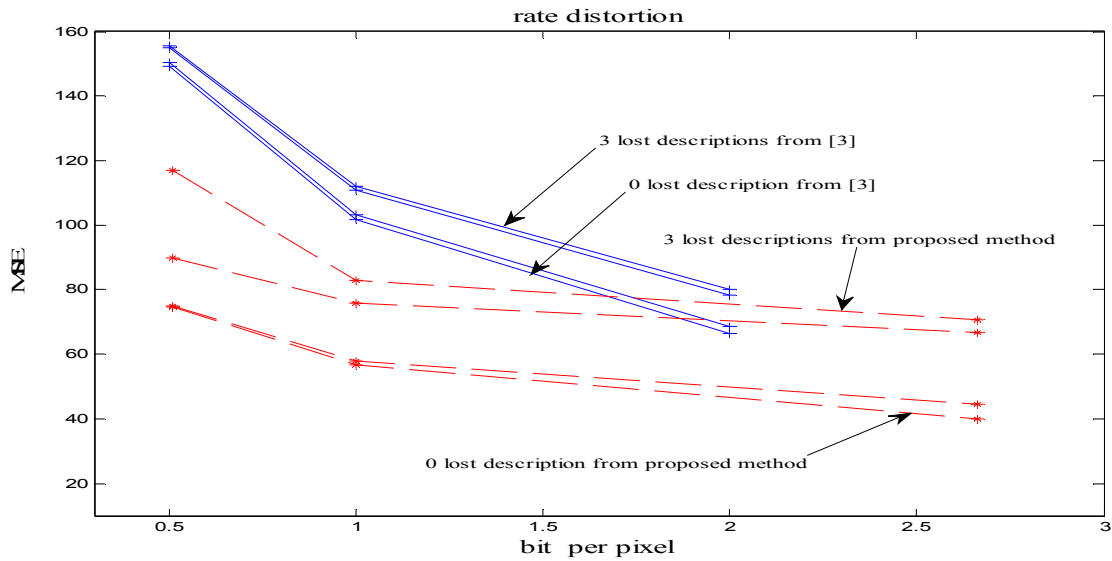


Figure 4: Rate-distortion performance for proposed LBT-MDC method (solid lines) and the method of [3] (dashed lines) for Lena. In each method the number of lost descriptions are rising from down to up

The facial details (face and hat) of Lena image in 0.5 bpp from proposed method and [3] are extracted and magnified into Figure 5. This figure shows that by applying LBT the blocking effect is removed from reconstructed data. Figure 5(a) and Figure 5(b) show that by applying the LBT-MDC method the eyes, eyebrows, nose and the edge of hat are clearer, sharper and have better subjective quality compared to Figure 5(c) and Figure 5(d) from [3].



Figure 5: Facial details of Lena image from proposed LBT-MDC and [3]. (a) Face image in 0.50 bpp with 1 received description from LBT-MDC method. (b) Hat image in 0.50 bpp with 1 received description from LBT-MDC method. (c) Face image in 0.50 bpp with 1 received description from [3]. (d) Hat image in 0.50 bpp with 1 received description from [3]

The obtained image with three lost descriptions in low bit rate of 1 bpp is shown in Figure 6. It is clear that in this bit rate, the quality of image is high and the edges of image features (especially hair edge) are clearer.

The proposed method is simulated for house grey level image with dimension of 512×512 pixel. This image is one of test images and it has many small horizontal, vertical and diagonal details. The clarity of these details are observable in reconstruction data. The original test image of house is presented in Figure 7.



Figure 6: Obtained image in 1 bpp from proposed LBT-MDC method with 3 lost descriptions.



Figure 7: Original image of house

Table 3 illustrates the PSNR factor for house image in various number of lost descriptions and bit rates. It is illustrated that in low bpp (0.1 bpp) the PSNR values are high (greater than 25 db). Also, decreasing of the PSNR values are small while lost number of descriptions increases.

In Figure 8, the house test image is obtained in low bit rates of 0.1 bpp with one received description. Figure 9 presents the rate distortion figure for house image and it is clear in this figure, by losing descriptions the MSE have minor increment.

In Figure 9 rate distortion analysis for house is presented with various number of lost descriptions. It shows that the MSE of the proposed method for low bpp is significantly small.

Table 3: PSNR (dB) values for house by proposed LBT-MDC method

Number of Lost descriptions	Bit Rate				
	0.10 bpp	0.20 bpp	0.57 bpp	1.65 bpp	3.40 bpp
1	26.90	30.88	34.20	35.98	36.10
2	26.65	30.56	33.78	35.59	35.76
3	26.48	29.93	32.82	33.72	33.86
4	26.20	29.57	32.44	32.94	33.15



Figure 8: Obtained house image in 0.1 bpp from proposed LBT-MDC while 3 descriptions lost

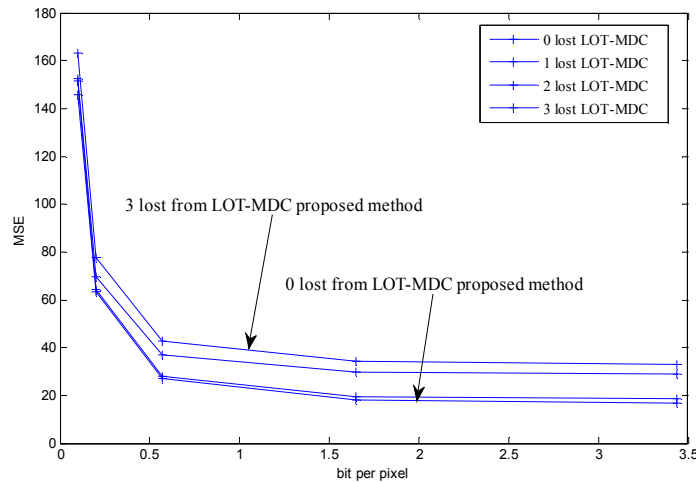


Figure 9: Rate-distortion performance plot for house from proposed LOT based MDC

CONCLUSION

In this paper, LBT based MDC is presented. The image is divided to four subimages by downsampling algorithm and subsequently LBT is applied to all sub images. Later, each description is scalar quantized based on the respective bit rates and all image descriptions are transmitted through the channel. If some of the descriptions are not received At the receiver side, then by taking the average of received descriptions and substituting in place of missing links, lost information is reconstructed. At the end by upsampling the subimages, recovered image is obtained. Simulation outcomes present that PSNR measuring factor and subjective evaluation are significantly better than the compared research. Also, facial details of the proposed method comparing to previous research is sharper and clearer which leads to have higher quality of reconstructed image.

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