Multiple Description Image Coding: A Low Complexity Approach for Lossy Networks

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***Abstract*–The development of an efficient and reliable multiple descriptions coding (MDC) scheme over lossy communication networks has been described. The advantage of MDC is that, if all the channels work, a high quality, possibly lossless, reconstruction can be achieved from all the received descriptions. On the other hand, a lower but still acceptable quality can be achieved if some of the channels are not received at all. In this article, a general framework of an efficient multiple description robust communication system with 2- and 4-channel cases is presented with a proposed block-based dc reallocation approach using intrinsic correlation. The peak signal-to-noise ratio (PSNR), mean squared error (MSE), bit rate, and entropy are calculated with the proposed method to analyze the reconstruction quality and the calculated results are compared with those of the other MDC methods. It is found that the proposed method, which uses an intrinsic correlation, gives comprehensive improvements over the other recently developed methods.**

KEY WORDS: *Multiple description coding, nonhierarchical decomposition, block-based transform coding, discrete cosine transform.*

I. INTRODUCTION

Multiple description coding (MDC) [1-5] and reconstruction of images have received considerable attention in the signal processing community for the last few years because of its interesting and excellent properties over lossy communication networks such as internet, ATM networks, packet-switched networks, wireless communication networks over fading multipath channel and so on. With MDC, multiple descriptions (called bitstreams) are generated by splitting the input signal into multiple subsignals. The subsignals are then quantized and transmitted over the separate communication channels to the receiver. It is useful to apply the quantizer on the subsignal in transform domain rather than spatial domain. The decoder reconstructs the original signal from the received descriptions allowing lost bitstream(s) to be estimated from the received ones. The advantage of this system is that, if all the channels work, a high quality, possibly lossless, reconstruction is achievable from all the received descriptions. On the other hand, a lower but still acceptable quality can be achieved if some of the channels are lost at the decoder.

In this article, the multiple description coding [3-5] for image transmission over unreliable communication networks (which cannot always guarantee the lossless data transmission) has been considered. A general framework of such a diversity system with an efficient and reliable MDC scheme with a simple approach (low complexity) is developed in this constraint. Here our special interest is the transmission of still images.

Transmission of compressed visual information over unreliable networks that cannot guarantee timely and lossless data delivery presents new challenges for research in image coding and reconstruction. This article is aimed at the development of a simple, efficient and reliable multiple description coding scheme for visual information delivery over unreliable communication networks. When discrete cosine transform (DCT), and JPEG quantizer is used, 8-by-8 pixel block is taken into account. In DCT, the dc component preserves most of the energy of the block. In a typical MDC scheme, data recovery is not a smooth process. Since in a typical MDC scheme with block-based approach, there is no mechanism to preserve the dc component, which is the most vital component of the 8-by-8 block, in this article we proposed a new approach in which the presence of dc component is assured by reallocating the dc component of the previous block in the (8, 8) position of the current block. With the proposed method, at the encoder, each 8-by-8 pixel blocks are transformed using type-2 DCT, and the resulting DCT coefficients of each block are split into 2 or 4 descriptions using the interleaved splitting pattern [1], shown in Fig. 1 and Fig. 2 and Table I and Table II, to produce the subsignals. Each subsignal is quantized and run-length encoded. The coded bitstreams resulting from different subsignals are then transmitted through the separate channels to the receiver. At the decoder, the received subsignals are decoded first and then the images are reconstructed from the descriptions received at the decoder. A straight forward method is used to recover the lost dc coefficients while interpolation reconstruction method is used to recover the lost ac components when some of the channels are lost.

In section II, the proposed MDC scheme is described after a brief review of the generation of multiple descriptions (bitstreams). In section III, simulation results are presented. Section IV concentrates on the summary of the work followed by the future research direction discussed in section V.

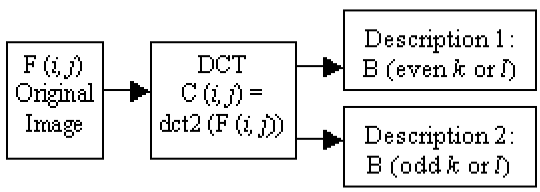

Fig. 1 Production of 2 descriptions using block-based dc reallocation method (*i, j* represents coefficient index, and *k, l* represents block index)

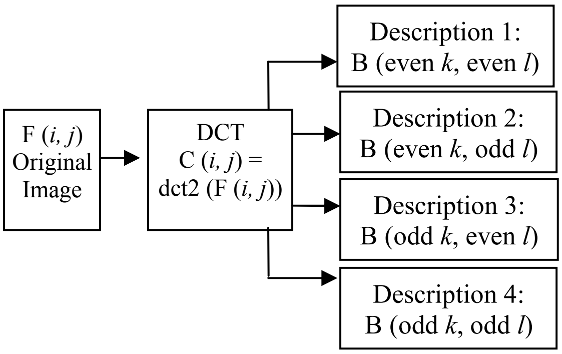

Fig. 2 Production of 4 descriptions using block-based dc reallocation method (*i, j* represents coefficient index, and *k, l* represents block index)

II. DESIGN OF PROPOSED MDC SCHEME

A. Producing Multiple Descriptions

In this article, a new method is proposed for producing multiple descriptions, which uses block based dc reallocation. Unlike transmitting the random coefficient blocks through the channel [1], here we present a new approach, where the signal is decomposed into 8-by-8 blocks and then transformed using DCT to produce different subsignals with unequal importance. Each subsignal consists of distributed coefficient blocks where the coefficients of each 8-by-8 blocks are divided using interleaved splitting pattern shown in Fig. 1 and 2. For two descriptions, as shown in Fig. 1, the first subsignal is comprised with even 8-by-8 blocks where the dc component of the previous block is placed at the (8, 8) position of the current block since DCT preserves most of the energy in the dc component, and the second subsignal is comprised with odd 8-by-8 blocks where the dc component of the previous block is placed at the (8, 8) position of the current block. On the other hand, for 4 descriptions, shown in Fig. 2, the first subsignal is comprised with even rows- even columns of the 64-by-64 subblocks, the second is comprised with even rows-odd columns, the third is comprised with odd rows-even columns and the fourth subsignal is comprised with odd rows-odd columns of the 64-by-64 blocks where the dc component of the previous blocks is placed in each 8-by-8 subblocks at the (8, 8) position.

TABLE I Distribution of transformed coefficient blocks for different channels for 2 descriptions (The numbers in boxes indicate the coefficient block belongs to that channel)

	1	2	..	..	..	..	..	..	64
1	1	1	1	1	1	1	1	..	..
2	2	2	2	2	2	2	2	..	..
:	1	1	1	1	1	1	1	..	..
:	2	2	2	2	2	2	2	..	..
:	1	1	1	1	1	1	1	..	..
:	..	..	..	..	..	..	..	..	..
64	..	..	..	..	..	..	..	..	..

At the decoder, the received coefficient blocks are decoded (run-length decoding) and dequantized first, and then reconstructed the images from the descriptions received at the decoder by using interpolation reconstruction method allowing lost bitstream(s) to be estimated from the received ones. For simplicity, we assume that the descriptions received at the decoder are equiprobable. Side decoder 1 or 2 is used to decode the signal when the signal of channel 1 or 2 is received at the decoder for 2-channel case. On the other hand, central decoder is used to decode the signal when the signals from both channels are received (Fig. 3).

TABLE II Distribution of transformed coefficient blocks for different channels for 4 descriptions (The numbers in boxes indicate the coefficient block belongs to that channel)

	1	2	..	..	..	..	..	..	64
1	1	2	1	2	1	2	1	..	..
2	3	4	3	4	3	4	3	..	..
:	1	2	1	2	1	2	1	..	..
:	3	4	3	4	3	4	3	..	..
:	1	2	1	2	1	2	1	..	..
:	..	..	..	..	..	..	..	..	..
64	..	..	..	..	..	..	..	..	..

B. Algorithm for Proposed MDC Scheme

Producing Multiple Description

- Compute 8-by-8 blocks DCT of the images,
- Separate dc component of each 8-by-8 block from the ac components,
- Produce multiple descriptions as follows:
  - For 2 descriptions: One channel carries even rows or columns of the 8-by-8 blocks and the other channel carries odd rows or columns of the 8-by-8 blocks.
  - For 4 descriptions: odd rows-odd columns, odd rows-even columns, even rows-odd columns and even rows-even columns of the 8 by 8 block for the first, second, third and fourth subsignal, respectively,
- The dc component of the previous block is placed at the (8, 8) position of the current block for 2 or 4 descriptions, respectively.

Encoding

- Generate multiple descriptions of the images by the procedure mentioned above,
- Quantize each description separately by using a uniform quantizer with unequal step size depending on the frequency of the signal,
- Apply entropy-coding scheme on each subsignal separately by using JPEG coder.

Decoding

- Decode the received subsignals separately,
- Reconstruct the images depending on the descriptions received at the decoder.

C. Image Reconstruction

Image can be reconstructed either without recovery of lost data or with recovery of lost data. An excellent quality reconstruction can be obtained when all descriptions are available. But when some descriptions are lost, the matrix inversion can be done by replacing the lost coefficients to zeros. In this case, of course, the reconstruction quality will not be good. On the other hand, the lost coefficients can be recovered by the interpolation method (which is used in this proposed Multiple Description Coding scheme).

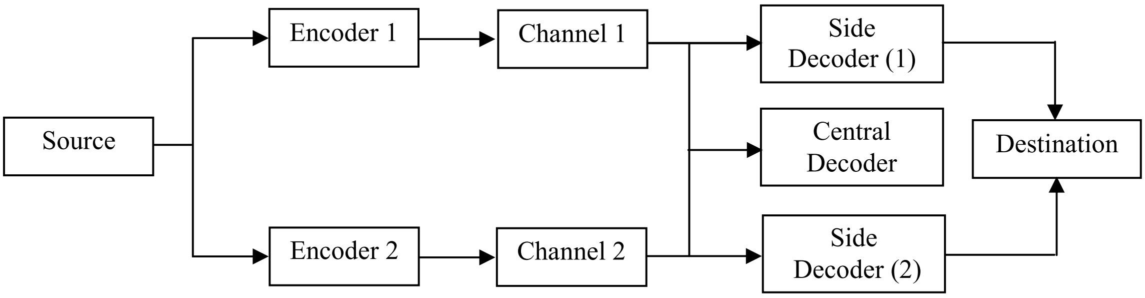

Fig. 3 Block-diagram of proposed MDC scheme for 2 descriptions

Interpolation equations that have been used are as follows:

For 2 channels

$$C(i,j)=\frac{1}{2}\{C(i-1,j)+C(i+1,j)\} \tag{1}$$

For 4 channels

$$C(i+1,j+1)=\frac{1}{2}\{C(i,j)+C(i+2,j+1)\}$$
$$C(i,j)=\frac{1}{2}\{C(i,j-1)+C(i,j+1)\} \tag{2}$$

where i, j represents coefficient index of the block.

III.SIMULATION RESULTS & DISCUSSIONS

We have simulated a communication system using the proposed block-based dc reallocation method for 2 and 4 descriptions (2 and 4 connection paths between the source and destination) systems. At first we evaluate the reconstruction performance of the DCT-based nonhierarchical signal decomposition with different reconstruction methods. We evaluate the reconstruction performance of the proposed block-based dc reallocation method and compare the simulation result with other similar MDC approaches.

TABLE III Performance measurement for 2-channel case (proposed block-based dc reallocation method)

Performance parameter	Received description(s)		
	One	Two	All (two)
PSNR (dB)	27.62	27.56	36.59
MSE (gray level)	112.45	113.92	14.23
Bit Rate (bpp)	0.28	0.29	0.45
Entropy (bpp)	0.87	0.87	0.90

Table III and Table IV show the performance (numerical result) of the proposed method for 4 descriptions. From Table III and Table IV, it is observed that the reconstruction quality (PSNR, MSE, bit rate and entropy) increases while MSE decreases with the increasing number of descriptions received at the decoder as expected. The complexity of the proposed block-based dc reallocation method has been also investigated, where execution time is taken as the complexity measurement parameter. MATLAB has been used as a simulation tool to simulate the proposed MDC scheme and it is found that the simulation time is very small of about 3.6 sec for 2-channel system, which clearly indicates the low hardware complexity of the system.

By keeping the same simulation environment, it is found that the execution time (about 4.7 sec) of the dc separation method [6] is somewhat larger, which also indicates that the proposed block-based dc reallocation method is less complex than the dc separation method. Since the proposed method does not use any extra redundancy, it is less complex than other recently developed methods [1, 3–5].

TABLE IV Performance measurement for 4-channel case (proposed block-based dc reallocation method)

Performance parameter	Received description(s)			
	One	Two	Three	All (Four)
PSNR (dB)	26.10	27.66	30.06	36.59
MSE (gray level)	159.58	111.24	64.12	14.24
Bit Rate (bpp)	0.20	0.41	0.61	0.82
Entropy (bpp)	0.83	0.87	0.89	0.90

TABLE V PSNR for different MDC schemes

MDC Scheme	Received description(s)			
	One	Two	Three	All (Four)
Without recovery of lost data	6.42	8.17	11.18	36.60
Mean Reconstruction Method	18.62	20.82	24.49	36.60
Maximally Smooth Recovery Method [1]	18.72	22.67	25.72	34.99
Proposed method	26.10	27.66	30.06	36.59

(a) (b) (c) (d)

Fig 4 Reconstructed images for 4-channel case: (a) original image, (b) nonhierarchical decomposition without recovery of lost data, (c) nonhierarchical decomposition with mean reconstruction method, and (d) proposed block-based dc coefficient reallocation method. first row - reconstructed images when all (4) channels are available, second row - reconstructed images when 3 channels are available, 3rd row - reconstructed images when 2 channels are available, 4th row - reconstructed images when 1 channel is available.

(a) (b) (c)

Fig. 5 Reconstructed images for 2-channel case: (a) Original image, (b) Reconstructed image when 2 channels are available, (c) Reconstructed image when 1 channel is available.

The reconstruction quality, for the test image Lena [512 × 512, 8bpp], with the number of descriptions received at the receiving end for 4- channel and 2- channel are depicted in Fig. 4 and Fig. 5, which shows that the reconstruction quality increases as the number of descriptions received at the decoder increases. The visual reconstruction quality for 4-channel case using different methods is compared in Fig. 4. Finally, the quantitative simulation results of proposed block-based dc reallocation method are compared with different MDC approaches [1, 3–5] in Table V. It is seen that, when all descriptions are available, the performances of all methods are almost the same, i.e. the reconstruction quality for all methods yields almost the same performances. But when some descriptions are lost, the proposed block-based dc reallocation method gives better result than other methods.

IV.SUMMARY

In this article, we describe a new framework of MDC scheme for accomplishing multiple description image coding for 2-, and 4-channel cases. With this new approach, the encoder first decomposes the input signal using the proposed block-based dc reallocation method and then encodes each subsignal separately. The decoder first processes the received descriptions in each channel to yield decoded subsignal, and then reconstructs the original image from the descriptions available at the receiver. It is clear that the reconstructed image quality depends on the descriptions available at the receiving end. If all descriptions are received, it is possible to achieve the best quality images. On the other hand, if some of the descriptions are lost, the reconstruction quality will still be acceptable. It is worthwhile to mention that, when all descriptions are available, the performances of all recently developed methods are almost the same, i.e. the reconstruction quality for all methods yields almost the same performances (Table V). But when some descriptions are lost, the proposed method gives better result than other methods.

V.FUTURE WORK

The proposed MDC scheme can be extended to develop the algorithm for handling the video signals, which will be reported elsewhere.

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