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Multiple Description Coding and Reconstruction of Images Using Intrinsic Correlation

Nafees Mansoor, Shahin Akter Chowdhury , Fatou Ndiaye, M. Abdur Razzak
School of Engineering & Computer Science, Independent University, Bangladesh.
14/2A North Road, Baridhara, Dhaka-1212
e-mail: nafees69@hotmail.com, chuti_iubc@yahoo.com, fatou.n@gmail.com, razzak@secs.iub.edu.b

ABSTRACT
In this article, a general framework of an efficient and reliable multiple description robust communication system with 2- and 4-channel cases is presented with a proposed block-based decomposition approach using inherent correlation. The peak signal-to-noise ratio (PSNR), mean squared error (MSE), bit rate, and entropy are also calculated with the proposed method to analyze the reconstruction quality. It is found that the proposed method gives comprehensive improvements over the other recently developed methods.

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

1. INTRODUCTION

Multiple description coding (MDC) [1-5] and reconstruction of images have received considerable attention in the signal processing community for the last decades because of its interesting and excellent properties over unreliable 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, have been considered). A general framework of such a diversity system with an efficient and reliable MDC scheme is developed in this constraint. Here our special interest is the transmission of still images.

With the proposed method, at the encoder, each 8-by-8 pixel blocks are transformed using type-2 discrete cosine transform (DCT), and the resulting DCT coefficients of each block are split into 2 or 4 descriptions using the interleaved splitting pattern [1], shown in Figs. 1, 2 and Table I, 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 algebraic 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. The details of the production of subsignals are described in the following section.

2. DESIGN OF PROPOSED MDC SCHEME

2.1 Producing Multiple Descriptions

In this article, a new method is proposed for producing multiple descriptions, which uses block based distribution. 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 discrete cosine transform (DCT) to produce different subsignals with unequal importance. Each subsignal consists of distributed coefficient blocks, 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 with 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 with 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 subblock, 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 with the dc component of the previous blocks is placed in each in the 8, 8 position in each 8-by-8 subblock.

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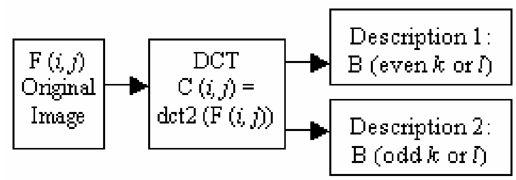

Fig: 1 Block-based producing 2 descriptions

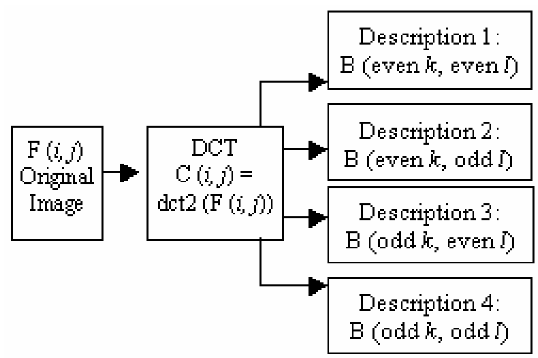

Fig: 2 Production of 4 descriptions (*i, j* represents coefficient index, and *k, l* represents block index)

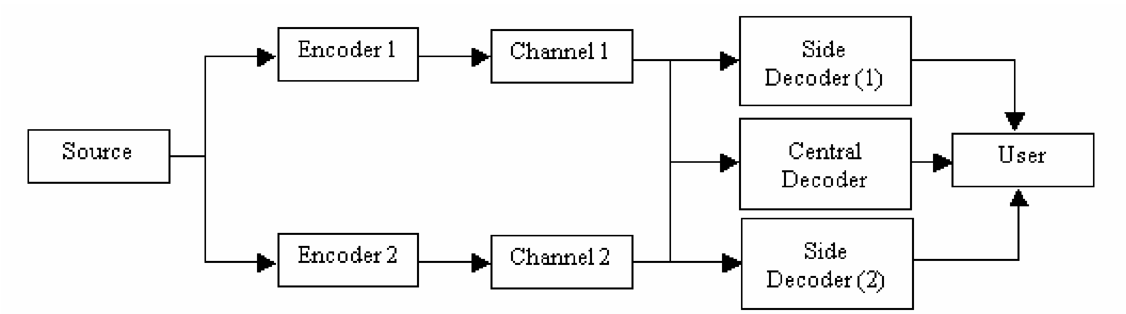

Fig: 3 Block-diagram of proposed MDC scheme for 2 descriptions

2.2 MDC Coder-Decoder Pair

Multiple bitstreams are generated by splitting the input signal into multiple coded descriptions (Figs.1 and 2), which are then transmitted over separate communication channels to the receiver. Each subsignal is then quantized and encoded separately by a DCT-based JPEG encoder. The subsignals are quantized in transform domain instead of spatial domain. In this article, 2 and 4 channels diversity systems are considered. For the quantization of transform coefficients, we use a uniform quantizer for each DCT coefficient, but with different step size for different coefficients. Zigzag ordering is used for the run-length coding step. The block diagram of proposed MDC scheme for 2 descriptions is shown in Fig. 3.

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 signal from both channels is received (see Fig.3).

2.3 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.

Table 1. Distribution of transforms coefficients 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	..	..	..	..	..	..	..	..	..

2.4 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 good. On the other hand, the lost coefficients can be recovered by the interpolation method (which is used in this work). Interpolation equations that have been used are as follows:

For 2 channels

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

For 4 channels

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

3. SIMULATION RESULTS & DISCUSSIONS

We have simulated a communication system using the proposed block-based distribution method. We have simulated the results 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 performance of this approach with and without the recovery of lost data at the receiving end. Then, we evaluate the reconstruction performance of the LOT-based nonhierarchical signal decomposition with maximally smooth recovery method [1]. Finally, we evaluate the reconstruction performance of the proposed block-based distribution method and compare the simulation result with different MDC approaches. Table 2 & 3 shows the performance (numerical result) of the proposed method for 4 descriptions. From Table 2 & 3, 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.

Table 2. Performance measurement for 2-channel case (proposed block-based 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 3. Performance measurement for 4-channel case (proposed 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

The reconstruction quality, for the test image Lena [512 × 512, 8bpp], with the number of descriptions received at the receiving end for 4 channels is depicted in Fig. 4, which shows that the reconstruction quality increases as the number of descriptions received at the decoder increases. The reconstruction quality for 4-channel case using different methods is compared in Fig. 4. 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 distribution method gives better result than other methods. Finally, the simulation results of proposed block-based dc distribution method are compared with different MDC approaches.

4. SUMMARY

In this article, we describe a new framework of MDC scheme for accomplishing multiple description image transmission for 2-, and 4-channel cases. With this new approach, the encoder first decomposes the input

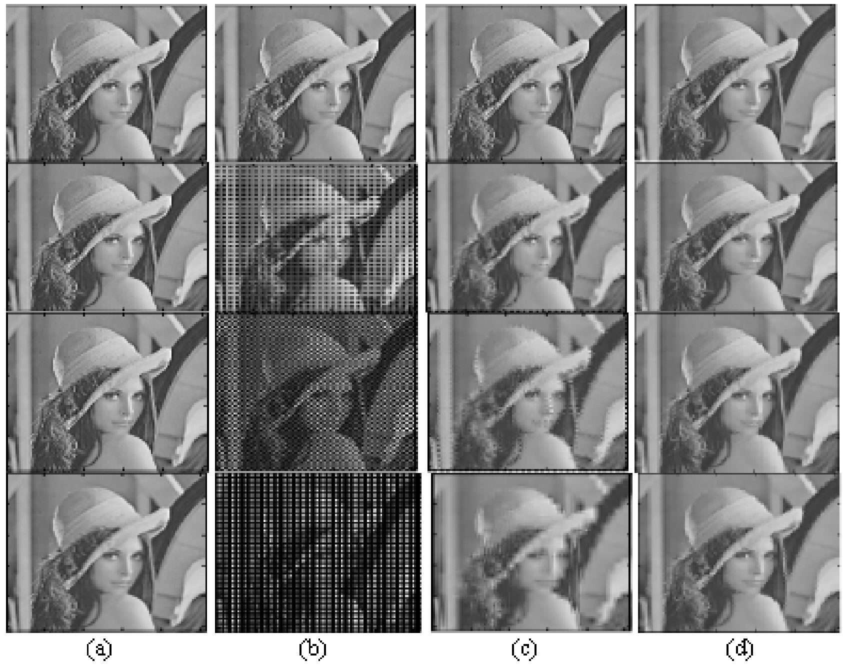

Fig 4: Reconstructed images for 4-channel case: (a) original image, (b) nonhierarchical decomposition without recovery of lost data, (c) nonhierarchical decomposition with mean reconstruction method, and (d) proposed block-based dc distribution method. first row - reconstructed images when all (4) channels 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.

signal using the proposed block-based distribution 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. Should all descriptions receive, 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. But when some descriptions are lost, the proposed method gives better result than other methods.

5. 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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