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Improved multiple description wavelet based image coding using Hadamard Transform

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ABSTRACT

A new Multiple Description Transform Coding (MDTC) was proposed by combining the Discrete Wavelet Transform (DWT) and Hadamard Transform (HT). To overcome the inherent drawbacks in the Pairwise Correlating Transform (PCT), which are the computational complexity and hardware implementation, HT was used to introduce an effective redundancy between the descriptions by improving their correlation coefficient. The new approach were analyzed and compared to the conventional scheme in the case of four descriptions by using multiple gray scale test images having different spectral characteristics. The findings show a better performance of the proposed method, especially in the case of two packets lost. In addition, the proposed method ensures a low degradation of the image reconstructed when one packet or two packets are lost. Therefore, the proposed coder provides a good redundancy performance and an easier practical implementation than the classical approach.

1. Introduction

The Multiple Descriptions Coding (MDC) was introduced to overcome different problems of transmission over error-prone networks. It is based on the encoding of an input information source into many correlated descriptions to be transmitted over different channels. At the reception, the original data is reconstructed by using the descriptions received. The quality of the reconstruction improves progressively with increasing the number of received descriptions [1].

Two main practical types of MDC were developed: the first was based on the quantization approach and the second was based on the transform approach. Vaishampayan proposed the first practical scheme using scalar quantizers (MDSQ) [2]. The second approach based on using of Pairwise Correlating Transforms (PCT) had been introduced by Wang et al. [3] and was generalized to the case of more than two descriptions by Goyal et al. [4].

In this study, the MDTC was considered in the case of four descriptions. The MDTC uses DCT and DWT to decorrelate the input source. Then, these uncorrelated transform coefficients were uniformly quantized and fragmented into four descriptions. Subsequently, a certain amount of redundancy was introduced between the uncorrelated descriptions by using PCT. Finally, the correlated descriptions are coded and transmitted through different channels. However, the PCT system has two main drawbacks [5]. The first disadvantage is that the PCT system does not exploit the high correlation between neighboring blocks and the second one is the difficulty of its practical implementation. To overcome these problems, we have proposed an improved scheme of MDTC based on DWT and Hadamard Transform referred as MDTC–DWT–HT. Hadamard Transform was chosen because of its low computational cost (only a small number of additions and subtractions are required to compute it) and its easiness of hardware implementation [6]. It offers several advantages: it is real symmetric and orthogonal, and the sorted Hadamard matrix can be calculated recursively. Moreover, its propriety of orthogonally ensures a simple encoding and decoding process. However, HT has a very poor performance to decorrelate the input data compared to DCT and DFT [7,8]. Therefore, it can be used as correlating transforms like PCT to introduce redundancy between descriptions.

In this paper, MDTC–DWT–PCT and MDTC–DWT–HT image coders are described. Mathematical models of HT, Cascade structure of the PCT and an approach of estimation of lost coefficients are reviewed. Theoretical analysis of two coders is considered. The analysis was based on the evaluation of the correlation coefficient between descriptions as a function of the bit rate. To compare and analyze the performance of both approaches, in the case of four descriptions, seven images having different spectral characteristics have been used as test images. The performances were evaluated

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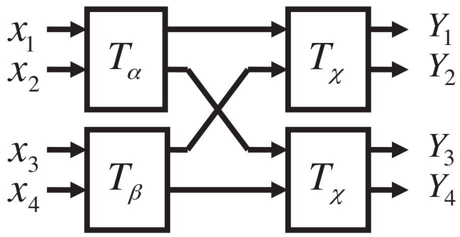

Fig. 1. Cascade structure of the correlating transform in case of 4 descriptions.

by using PSNR in the case of 2 bpp and PSNR according to bit rate for images reconstructions with different qualities. Results show that the proposed method provides correlation coefficient better than the one of conventional at all range of bit rate that leads to the superior performance, especially in the case of two packets lost.

2. Mathematical models of Hadamard Transform

The Hadamard transform was used to introduce redundancy among uncorrelated descriptions as the transform approach i.e. PCT. It is a special case of transforms based on Hadamard matrices. The Hadamard matrix of order 2 is defined by [6]:

$$H_2 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (1)$$

The Hadamard matrices of higher order can be generated recursively as follows:

$$H_n = H_{n-1} \otimes H_2 = \frac{1}{\sqrt{2}}\begin{bmatrix} H_{n-1} & H_{n-1} \\ H_{n-1} & -H_{n-1} \end{bmatrix}, \quad (2)$$

where $\otimes$ is Kronecker product and n is positive integer.

A Hadamard matrix of order N is a $N \times N$ matrix H with entries are either +1 or -1 which satisfies the orthogonal condition [6]. Similarly, H_n is symmetric and orthogonal. Hence,

$$H = H^* = H^t = H^{-1}, \quad (3)$$

3. Pairwise Correlating Transform (PCT)

The Pairwise Correlating Transform (PCT) is one among methods that introduce redundancy between input uncorrelated variables. To generate two correlated descriptions, the correlating transform is defined as [3]:

$$T_\alpha = \begin{bmatrix} \alpha & \frac{1}{2\alpha} \\ -\alpha & \frac{1}{2\alpha} \end{bmatrix} \quad (4)$$

where T_α is a pairing transforms that are applied on 2×2 input vectors independent and identically distributed (i.i.d.), zero-mean Gaussian random vectors with different variances. The 2×2 input

Fig. 2. Lena image reconstruction via MDTC–DWT–PCT image coder with (a) 4 received packets, (b) 3 received packets, (c) 2 received packets, (d) 1 received packet.

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