A Measurement Coding System for Block-based Compressive Sensing Images by Using Pixel-Level Features

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INTRODUCTION

Compressive sensing (CS) is data acquiring and innovative mathematical approach that accelerate and efficient sampling from large into small volumes of data. Moreover, it could be dramatically reduced amounts of sensor, power consumption, storage size, and bandwidth which results in lower hardware costs. In wireless cameras network for video surveillance, the large amount of data is produced. However, there is still a lot of redundant data in measurement domain. To solve this problem, coding techniques such as block-based CS (BCS), intra-prediction and quantization is applied to avoid higher rate-distortion than other CS frameworks. In this paper, we proposed a measurement coding system to further reduce the data redundancy and improve the efficiency of measurement process as shown in Fig.1. Firstly, we apply Hadamard instead of random measurement matrix to sense, compress, and generate predictive candidates since pseudo-random cannot guarantee the similarity between sender and receiver. Secondly, a new architecture of intra-prediction is proposed to reduce the spatial redundant in measurement domain by using the pixel domain features. Thirdly, we employ image quantization and Huffman coding to further compress the data. The reconstruction process is performed by using single iteration basis pursuit with inverse fast Walsh-Hadamard transform (IFWHT). The experimental results show that the proposed system can greatly improve the coding efficiency, which increases 1.94dB - 2.3dB in PSNR and reduces 42% - 65% bitrate in terms of bit-per-pixel.

COMPRESSIVE SENSING

CS asserts that only a few measurements are enough to recover the signals, if the signals are sparse enough. We consider measurement systems that acquire N linear dimensional given by $x \in \mathbb{R}^N$, which can represent in mathematically as

$$Y = \Phi x \qquad (1)$$

The M linear dimensional given by $Y \in \mathbb{R}^M$ that is x in spare and compressible form. The signals can be recovered by solving basis pursuit (L_1 −minimization) problem as follows:

$$\min \|x'\|_1, s.t.\ Y = \Phi\Psi x' \qquad (2)$$

In theory Φ can be random Gaussian, Bernoulli, and binary matrix. While transform matrix $\Psi \in \mathbb{R}^{N\times N}$ can be discrete cosine transform(DCT), discrete wavelet transform(DWT), walsh-hadamard transform(WHT), and so on. An inputs image is divided into $B \times B$ blocks $X \in [x_1, x_2, x_3, \dots, x_N]$, which is represented in term of underdetermined x signals are acquired. Thus, Y can be calculated though Eq. (1). Inspired by intra-prediction in H.264, We designed four directional prediction modes from neighboring block called left(Y_{le}), upper(Y_{up}), mean(Y_{dc}) and constant(Y_{cp}) modes as shown in Fig. 1.

In this paper, we used Hadamard as measurement matrix whose entries are complementary. The columns of this matrix are orthogonal. Given a matrix H of order N, H is said to be a hadamard matrix if the transpose of the matrix H is closely related to its inverse. This can be expressed by

$$HH^T = NI_n \qquad (3)$$

where I_n is the $N \times N$ identity matrix and H_T is the transpose of the matrix H. The random hadamard matrix consists of taking random rows from the hadamard matrix. This measurement matrix satisfies the RIP with probability at least 1 - 5/N - $e^{-\beta}$ provided M ≥ $C_0(1+\beta)$K log N with β and C_0 as positive constants, where K is the sparsity of the signal, N is its length, and M is the number of measurements. Moreover, we binarized hadamard to increases measurement processing time and decrease the hardware cost.

PROPOSED ARCHITECTURE

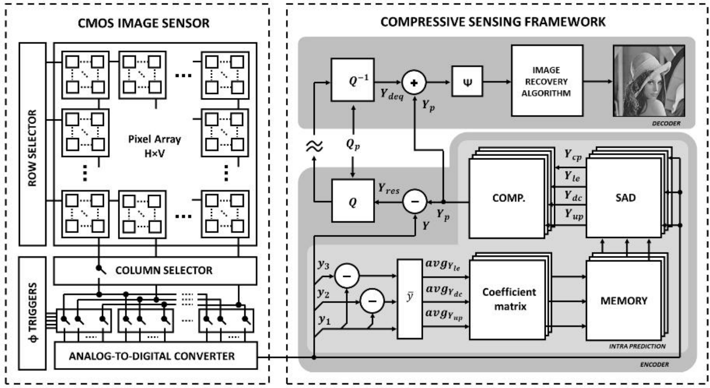

Figure 1. Proposed measurement coding system for block-based compressive sensing images.

SIMULATION RESULTS

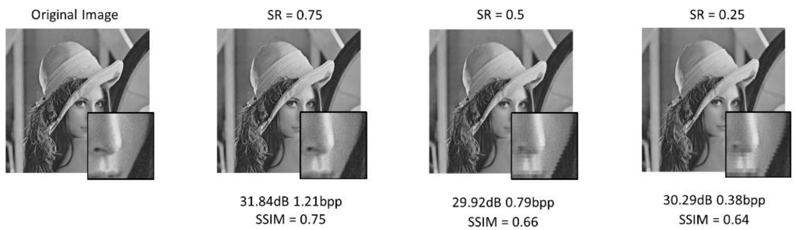

Figure 2. Comparison of visual qualities where N = 16, SR = 0.75, 0.5, and 0.25 with Q_{step} = 4.

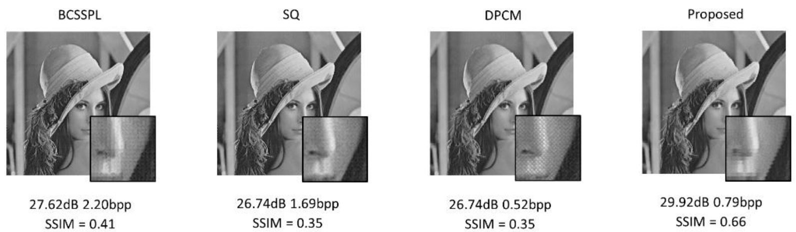

Figure 3. Comparison of visual qualities and compression artifacts among our proposed, BCSSPL, SQ, and DPCM where N = 16, SR = 0.5 with Q_{step} = 4.

INTRA PREDICTION

Left Mode Prediction:

$$Y_{le} = \left(\frac{y_1 - y_2}{N/2}\right) \times \Phi_{coefficient} \qquad (4)$$

Upper Mode Prediction:

$$Y_{up} = \left(\frac{y_1 - y_3}{N/2}\right) \times \Phi_{coefficient} \qquad (5)$$

Mean Mode Prediction:

$$Y_{dc} = \left(\frac{y_1}{N}\right) \times \Phi_{coefficient} \qquad (6)$$

To select a predictive candidate, sum of absolute differences (SAD) is required to compare between current Y with previous predictive candidate Y_{le}, Y_{up}, and Y_{dc}. Y_{cp} is constant prediction, which assigned to be zero. The minimum SAD is chosen as predicted y_p, which can be expressed by

$$Y_p = argmin\ SAD(Y, Y_{mode} \in [Y_{le}, Y_{up}, Y_{cp}, Y_{dc}]) \qquad (7)$$

In case there is no predictive candidate, Y_p will be zero for transmitting without prediction, which represent by Y_{cp}. Y_r is a residual information, where Y is information of current block. Thus, it can be expressed by

$$Y_r = Y - Y_p \qquad (8)$$

The simple quantization is needed for entropy coding before transferred to Huffman coding, which can be expressed by

$$Y_q = Y_p \gg Q_{step} \qquad (9)$$

Among three processes, intra-prediction, quantization and Huffman coding. Only quantization introduced lossy to image degradation, while intra-prediction and entropy coding are lossless.

CONCLUSION

Compressive sensing has been considered as innovative technology in signal sampling and compressing. In this paper, we present our architecture and simulation results of BCS framework using the measurement-domain to generate pixel-domain features, which can reduce the redundant information with low computational complexity and realize high compression ratio via hadamard matrix. The pixel-domain features is obtaining by subtracting with intra-prediction for upper, left and dc mode respectively and divided the summation by total active pixel. The simulation results shown that this framework can increase 1.94dB - 2.3dB in PSNR and reduced 42% - 65% bitrate in terms of bit-per-pixel when compared to previous works. The design of measurement matrix is greatly importance for image and video compression using compressed sensing.

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