

Distribution of Wavelet Coefficients and the Mid-Treat Quantizer of JPEG2000

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Abstract— The expectation of rate becomes ever more rapid in proportion to the growing image sizes, visually lossless coding is increasingly being considered as an alternative to numerically lossless coding, which has limited compression ratios and reduce the bit per pixels (bpp). This paper presents a method of encodes a colour image or video taking human perception in a visually of without loss manner using JPEG2000 and increase the Peak-Signal-to-Noise ratio (PSNR). In order to hide coding artifacts caused by quantization, visibility thresholds (VTs) are measured to the capacity of human eye to see fine detail and used for uniform quantization of subband signals are employed in JPEG2000 Part 1. The VTs are experimentally determined from statistically modelled uniform quantizer for rate distortion, which is based on the distribution of wavelet coefficients and the mid-treat quantizer of JPEG2000. The resulting VTs are adjusted of visibility of a signal due to presents of backgrounds through a visual masking model of image sharpening technique, and then used to determine the minimum number of coding passes to be included in the final codestream for visually lossless quality under the desired viewing conditions. Core Codestreams produced by this scheme are fully JPEG2000 Part-I compliant.

Keywords— Contrast sensitivity function (CSF), human visual system(HVS), JPEG2000, visibility threshold (VT), visually lossless coding.

I. INTRODUCTION

JPEG-2000 part 1 has recently been approved as a new international standard for still image compression. This standard, formally known as ISO/IEC15444-1[1], provides a rich feature set including support for both lossy lossless encoding. One of the core technologies employed by the JPEG-2000 codec is the discrete wavelet transform. Thus, in order to build a high-quality JPEG-2000 encoder or decoder, one must able to construct an effective of distribution wavelet transform in dead-zone quantizer. This observation motivated us to examine numerical lossless encoding for practical issues related to implementation of DWT's in the context of JPEG-2000.

The remainder of this paper is structured as follows. First, we begin with a brief introduction to JPEG-2000 part I. Then, we study various issues related the implementation of wavelet transforms. For example, normalized Cohen-Daubechies-Feauveau (CDF) 9/7 DWT [3] designed for efficient implementation. Finally, this proposes a visually lossless

JPEG2000 encoder for color images. In YCbCr color space, VT's are measured for a realistic quantization distortion model, which takes into account the statistical characteristics of wavelet coefficients as well as the dead-zone quantizer. The proposed [3] scheme is implemented without violating the JPEG2000 part I standard and automatically produces visually lossless imagery at lower bitrates than other visually lossless schemes in literature.

II. JPEG2000 FUNDAMENTALS

The fundamentals building blocks [4] of a JPEG2000 encoder are shown in the figure 1.

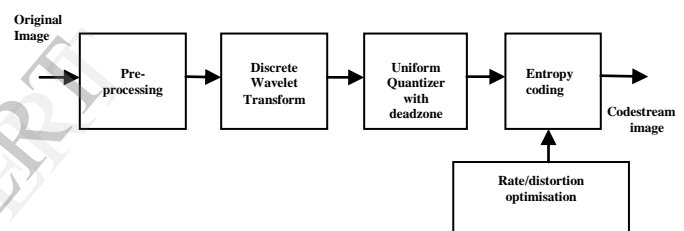


Figure1. JPEG2000 fundamentals building blocks.

These components include preprocessing, DWT, uniform quantization with dead zone quantizer and entropy encoder. The input image of JPEG2000 may contain one or more components. Although a typical color image would have three components, (e.g.RGB or YCbCr), upto $16384(2^{14})$ components can be specified for an input image to accommodate multispectral or other types of imagery [1,24]. Given a sample with a color-depth or bit-depth is the number of bits used in a single pixels of B bits, the unsigned representation would correspond to the range $[0, 2^{\text{bit-depth}} - 1]$, while the signed representation would correspond to the range $[-2^{\text{bit-depth}-1}, 2^{\text{bit-depth}-1} - 1]$. The bit-depth, resolution, and signed versus unsigned specification can vary for each components. If the components have different bit-depths, the most significant bits of the components should be aligned when estimating the distortion at the encoder.

A. Preprocessing:

The first step in preprocessing is to partition input image into rectangular and non-overlapping tiles of equal size. The

tile size is arbitrary and can be as [5] large as the original image itself (i.e. only one tile) or as small as a single pixel. Each tile is compressed independently using its own set of specified compression parameters. Tiling is particularly useful for application [6] where the amount of available memory is limited compared to the image size.

Next, unsigned sample values in each component are level shifted (DC offset) by subtracting a fixed value of 2^{B-1} from each sample to make its value symmetric around zero. Signed sample values are not level shifted. Finally, the level-shifted values can be subjected to a forward point-wise intercomponent transformation to decorrelate the color data. One restricted on apply the intercomponent must have identical bit-depths and dimensions. Two transformation choices are allowed in part-1, where both transforms operate on the first three components of an image tile with the implicit assumption that these components correspond to RGB. One transform is the irreversible color transform (ICT), which is identical to the traditional RGB to YCbCr color transformation and only be used for lossy coding. The forward ICT is identified as

$$\begin{pmatrix} Y \\ C_b \\ C_r \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.16875 & -0.33126 & 0.500 \\ 0.500 & -0.41869 & -0.08131 \end{pmatrix} \times \begin{pmatrix} R \\ G \\ B \end{pmatrix} \rightarrow (1)$$

This can alternatively be written as

$$Y = 0.299(R - G) + G + 0.114(B - G), \quad C_b = 0.564(B - Y), \quad C_r = 0.713(R - Y) \rightarrow (2)$$

While the inverse ICT is given by

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 1.0 & 0 & 1.402 \\ 1.0 & -0.34413 & -0.71414 \\ 1.0 & 1.772 & 0 \end{pmatrix} \times \begin{pmatrix} Y \\ C_b \\ C_r \end{pmatrix} \rightarrow (3)$$

The other transform is the reversible color transform (RCT), while integer-to-integer transform that approximates the ICT for color decorrelation and can be used for both lossless and lossy coding. The forward RCT is defined as

$$\tilde{Y} = \left\lfloor \frac{R + 2G + B}{4} \right\rfloor, \quad D_b = B - G, \quad D_r = R - G \rightarrow (4)$$

Where $\lfloor \omega \rfloor$ denotes the largest integer that is smaller than or equal to ω .

B. Discrete Wavelet Transform:

The block DCT transformation in baseline JPEG has been replaced with the efficient highly intuitive framework of DWT in JPEG2000. The DWT has several transformation that make it suitable for fulfilling some of the requirements set forth by the JPEG2000 committee. For example, a multiresolution image representation is inherent to the DWT. Furthermore, the

full-frame nature of the transform decorrelates the image across a large scale and eliminates blocking artifacts at high compression ratios. Finally, the use of integer DWT filters allows for both lossless and lossy compression within a single compressed bit stream. We consider a (1-D) DWT for simplicity, and then extended the concepts to two dimensions.

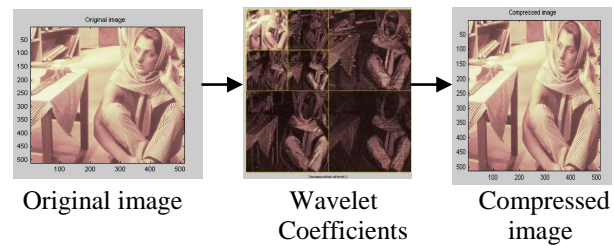


Figure2. Wavelet transform: effect of frequency filtering on a gray scale image [22].

For the forward DWT the standard uses a (1-D) subband decomposition of a 1-D set of samples into low-pass samples, representing reducing the sampling rate of low-resolution version of the original set, and high-pass samples, representing a reduce the size of data version of the original set, needed for the perfect reconstruction of the original set, needed for the perfect reconstruction of the original set from the wavelet operation. In general, any user supplied wavelet filter bank may be used Part II of the standard). The DWT can be irreversible or reversible.

TABLE I
Daubechies 9/7 analysis filter coefficients [8]

Analysis Filter coefficients		
i	Lowpass Filter $h_L(i)$	Lowpass Filter $h_H(i)$
0	0.6029490182363579	1.115087052456994
± 1	0.2668641184428723	-0.5912717631142470
± 2	-0.07822326652898785	-0.05754352622849957
± 3	-0.01686411844287495	0.09127176311424948
± 4	0.02674875741080976	

TABLE II
Daubechies 9/7 synthesis filter coefficients [8]

Synthesis Filter coefficients		
i	Lowpass Filter $g_L(i)$	Lowpass Filter $g_H(i)$
0	1.115087052456994	0.6029490182363579
± 1	-0.5912717631142470	0.2668641184428723
± 2	-0.05754352622849957	-0.07822326652898785
± 3	0.09127176311424948	-0.01686411844287495
± 4		0.02674875741080976

TABLE III
Daubechies 5/3 analysis filter coefficients [8]

Analysis Filter coefficients		
i	Lowpass Filter $h_L(i)$	Lowpass Filter $h_H(i)$
0	6/8	1
± 1	2/8	-1/2
± 2	-1/8	

TABLE IV
Daubechies 5/3 synthesis filter coefficients [8]

Synthesis Filter coefficients		
i	Lowpass Filter $g_L(i)$	Lowpass Filter $g_H(i)$
0	1	6/8
± 1	-1/2	2/8
± 2		-1/8

The default *irreversible transform* is implemented by means of the Daubechies 9-tap/7-tap filter [8]. The analysis and the corresponding synthesis filter coefficients are given in Table I and II. The default reversible transformation is implemented by means of the 5-tap/3-tap filter, the coefficients of which are given in Table III and Table IV [9]. Two filtering modes are supported by the standard: the convolution-based and the lifting-based [9, 10].

C. Uniform Quantizer with dead Zone:

The JPEG baseline system employs a uniform quantizer and an inverse quantization process that reconstructs the quantized coefficient to the mid-point of the quantization is called Mid-treat quantizer. A different step size is allowed for each DCT coefficient to take advantage of the sensitivity of the HVS, and these step sizes are conveyed to the decoder via an 8 x 8 quantization table. One difference is in the incorporation of a central dead zone in the quantizer. It was shown in [11] that the rate-distortion optimal quantizer for a continuous signal with Laplacian probability density is a uniform quantizer with a central dead zone. The size of the optimal dead zone as a fraction of the step size increases as the variance of the Laplacian distribution decreases.

In JPEG2000 part I, the dead zone can be parameterized to have a different value for each subband. Part-I adopted the dead zone with twice the step size as depicted in Figure.3, due optimal embedded structure [12]. This means that if an M_b -bit quantizer index significant bit (MSB) and proceeding to the LSB, the resulting index after decoding only N_b bits is identical to obtained by using a similar quantizer with a step size of $\Delta_b 2^{M_b - N_b}$. This property allows for Signal-to Noise Ratio *scalability*, which in its optimal sense means that the decoder can cease decoding at any truncation point in the code-stream and still produce exactly the same image would have been encoded at the bit-rate corresponding to the truncated code-stream. This allows an original image to be compressed with JPEG2000 to the higher quality required by a given set of clients and the disseminated to each client according to the specific image quality requirement without the need to decompress and recompress the existing code-stream.

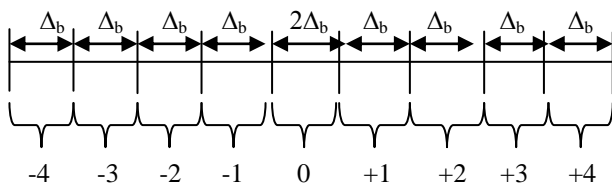


Figure3. Uniform quantizer with a central dead zone with step size Δ_b .

In JPEG baseline, a simple reconstruction strategy has been shown to improve the decoded image PSNR by approximately 0.25db [13]. Similar gains can be expected with the biased reconstruction of wavelet coefficients in JPEG2000.

Quantization at the encoder, for each subband b , a quantizer step size Δ_b can be driven by the perceptual importance of each subband on HVS data [14] or it can be driven by other

consideration such as rate control. The quantizer maps a wavelet coefficient $y_b(u, v)$ in subband b to a quantized index value $q_b(u, v)$ as shown in figure.3. The quantization operation is an encoder issue and can be implemented in any desired manner. However, it is most efficiently performed according to

$$q_b(u, v) = \text{sign}(y_b(u, v)) \left\lfloor \frac{|y_b(u, v)|}{\Delta_b} \right\rfloor \rightarrow (5)$$

The step size Δ_b is represented with a total of two bytes, an 11-bit mantissa μ_b and a 5-bit exponent ε_b , according to the relationship:

$$\Delta_b = 2^{R_b - \varepsilon_b} \left(1 + \frac{\mu_b}{2^{11}} \right) \rightarrow (6)$$

Where R_b is the number of bits representing the nominal dynamic range of the subband b . For the irreversible (9,7) wavelet transform, two modes of signalling the value of Δ_b to the decoder are possible. In one mode, which is similar to the q -table specification used in the current JPEG, the (ε_b, μ_b) value for every subband is explicitly transmitted. This is referred to as *expounded quantization*. The quantized values that must be chosen to take into account the HVS properties [15] and/or the L_2 -norm of each subband in order to align the bit-planes of the quantizer indices according to their true effort to the MSE. In another mode, referred to as *derived quantization*, a single (ε_0, μ_0) is sent for the LL subband and the (ε_b, μ_b) values for each subband are derived by scaling the Δ_0 value by some power of two, depending on the level of decomposition associate with that subband. In particular to the given equation,

$$(\varepsilon_b, \mu_b) = (\varepsilon_0 - N_L + n_b, \mu_0) \rightarrow (7)$$

where N_L is the total number of decomposition levels and n_b is the decomposition level corresponding to subband b . It is easy to show that the equation (7) scale the step sizes for each subband according to a power of two that best approximates the L_2 -norm of a subband relative to the LL subband fixed value for 0.67188 in (9,7) filter.

D. Entropy coding :

The coding models used by the JPEG 2000 entropy [16] coder employ 18 coding contexts, in addition to a uniform context, according to the following assignment. Contexts 0–8 are used for significance coding during the significance propagation and cleanup passes, contexts 9–13 are used for sign coding, contexts 14–16 are used during the refinement pass, and an additional context is used for run coding during the cleanup pass. Each code-block employs its own MQ-coder to generate an arithmetic code-stream for the entire code-block. In the default mode, the coding contexts for each code-block are initialized at the start of the coding process and are not reset at any time during the encoding process. Furthermore, the resulting codeword can only be truncated at the coding pass

boundaries to include a different number of coding passes from each code-block in the final code-stream. All contexts are initialized [17] to uniform probabilities except for the zero context (all insignificant neighbours) and the run context, where the initial less probable symbol (LPS) probabilities are set to 0.030053 and 0.063012, respectively.

E. Rate-Distortion optimization :

The embedded bit stream of a single codeblock [18] has several potential truncation points. i.e., each codeblock has a separate rate distortion (RD) function. The goal of an encoder is to arrange the bitstream data of all codeblocks in an RD optimal manner, i.e. to find the truncation points which minimize the distortion for a given rate. The most common algorithm for JPEG2000 is PCRD-Optimization (post-compression-rate-distortion). A truncation[4] point of the codeblock B_i is denoted by n_i , all truncation points by \vec{n} . The embedded bitstream of the codeblock B_i can be truncated to a rate $R_i^{n_i}$ (for a given truncation point n_i).

The rate constraint is then

$$|R(\vec{n}) = \sum_{i=1}^{\# \text{cbs of image}} R_i^{n_i} \leq R_{max} \rightarrow (8)$$

The distortion of each codeblock [19] R_i for a truncation points n_i is given by $D_i^{n_i}$. Given an additive distortion measure, the distortion D of the compressed image is derived by

$$D(\vec{n}) = \sum_{i=1}^{\# \text{cbs of image}} D_i^{n_i} \rightarrow (9)$$

An optimal solution (minimizing D) of truncation points for this constrained problem can be found by solving the corresponding unconstrained problem.

$$\vec{n}^* = \arg\min_{\vec{n}} [D(\vec{n}) + \lambda R(\vec{n})] \rightarrow (10)$$

III. PROPOSED METHOD AND CODING RESULT

The proposed encoder was implemented in Kakadu V7.2 demo [20]. In that software, we modified and change the value of encoder. And we cannot disturb the decoder in our operation. All reported results were generated with this Kakadu_expand, Kakadu_compress, Kakadu_transcode and unmodified decoder.

Images marked with an [20] asterisk in Table V were used during masking model calibration. For monochrome images, the numerically lossless coding method of JPEG2000 yields an average bitrate of 5 bpp visually lossless coding method achieves an average bit rate 3.127bpp and improvement in compression ratio of 1:1.6, without perceivable quality degradation.

Also the peak-signal-to-noise-ratios for the luminance component (Y PSNRs) vary widely depending on the image. In particular, the resulting bitrates range from 1 to

5bpp for monochrome images. The monochrome images have a minimum PSNR of 37.1db and a maximum of 49.3 db. These results demonstrate that bitrate and PSNR are effective criteria for determining visual lossless quality [21].

This table VI reports bitrates obtained by each method for encoding five 512 x 512 8-bit digitized radiographs used in [22]. The method proposed here provides significantly lower bitrates. These lower bitrates result in a lower average PSNR, but do not result in visual artifacts. The Kakadu implementation of JPEG2000 provides a CSF-based visual weighting option that can enhance the visual quality of compressed imagery.

TABLE V
BITRATES AND PSNRs FOR THE PROPOSED VISUALLY LOSSLESS JPEG2000 ENCODER FOR 8-BIT MONOCHROME IMAGE- BARBARA(512 x 512)

S. No	Bits per pixel	Lossless method (bpp)	Proposed method (bpp)	Comp ressed Ratio	MSE	Y PSNR (db)
1	1	1	0.126	1:8.0	12.7	37.1
2	2	2	0.51	1:4.0	3.2	43.0
3	3	3	1.111	1:2.7	1.1	47.9
4	4	4	2.13	1:2.0	0.8	47.9
5	5	5	3.127	1:1.6	0.8	49.3

TABLE VI
BITRATES AND PSNRs FOR THE PROPOSED VISUALLY LOSSLESS JPEG2000 ENCODER FOR 8-BIT 512 X 512 DIGITIZED RADIOGRAPHS[158208]

S. No	Bits per pixel	Lossless method (bpp)	Proposed method (bpp)	Comp ressed Ratio	MSE	Y PSNR (db)
1	1	1	0.125	1:8.0	1.8	45.7
2	2	2	0.465	1:4.3	0.9	48.4
3	3	3	1.074	1:2.8	0.9	48.4
4	4	4	2.014	1:2.0	0.9	48.4

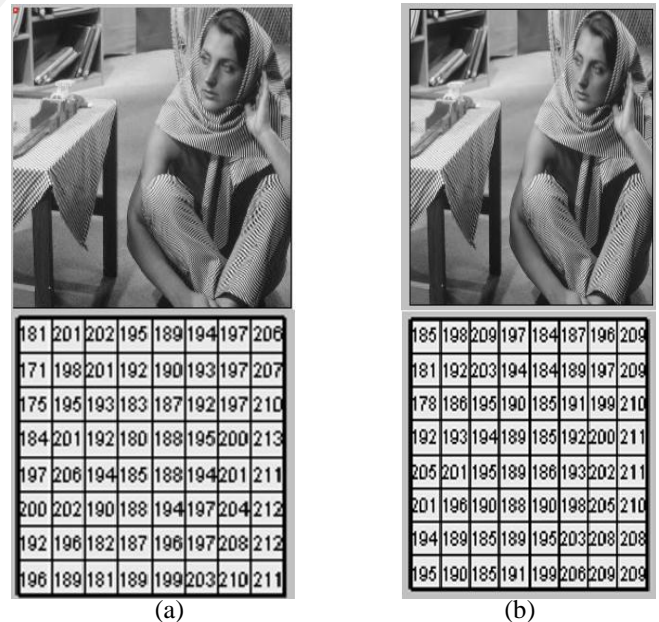


Fig. 1 (a) Original monochrome image [Barbara] and its pixels (512 x 512) value. (b) Visually lossless image encoded by the proposed method. After decompression to avoid rescaling during display. Reconstructed image of Barbara and its pixels (512 x 512) value.

IV. CONCLUSIONS

In this paper, an efficient visually lossless HVS image compression method is proposed that is compatible in JPEG2000 part I. this method employs YCbCr in Contrast sensitivity function based weighting in the discrete wavelet transform to reduce the imperceptible information. The proposed methods offer visually lossless encoding [23] of quality at a significantly reduced the bit per pixels value and increase the peak-to-signal-ratio (PSNR) value and limits the compression ratios numerically lossless coding.

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