

Pre-post quantisation and integer wavelet for image compression

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Quantisation prior to the integer wavelet transform (Pre-Qnt) is introduced. The best combination of the Pre-Qnt and the conventional post-quantisation (Post-Qnt) in multi-stage band splitting based on the integer wavelet transform is presented.

Introduction: Over the past few years a considerable number of studies have been made on the integer wavelet that contains rounding operations in the lifting structure [1, 2]. Since the integer wavelet expresses its output signals with integers, effective lossless coding becomes possible by applying an entropy coder to the output signals, and lossy coding is also implemented by inserting quantisation before the entropy coder. In addition, it is advantageous to have small scale of memory circuits due to expression of the signals with integers. However, in lossy coding mode, besides the quantisation errors, other errors caused by the rounding operation (rounding errors) are included in the decoded image signal [3]. For the purpose of reducing the rounding errors, in this Letter we propose a new multi-stage band splitting method based on the integer wavelet introducing a new quantisation 'Pre-Qnt' prior to the integer wavelet.

Integer wavelet: An analysis of the two band splitting integer wavelet 'WT', illustrated in the left half of Fig. 1, splits an input signal 'X' into two band signals 'Y₀' and 'Y₁' with down samplers '↓2' and FIR filters 'P₀(z)' and 'P₁(z)' [1, 2]. Outputs of the FIR filters are expressed in decimals, in general. However, the operations notated with 'S₀' and 'S₁' approximate their values into integers. As a result, the band signals 'Y₀' and 'Y₁' are expressed with a bit depth slightly longer than that of the input signal 'X' and therefore it becomes possible to compress the data volume of the input signal without any loss (lossless coding) by applying an entropy coder to the band signals. Lossy coding is also implemented by inserting the quantisation. However, in lossy coding mode, the rounding errors in the analysis part and those in the synthesis part do not cancel each other. It degrades the PSNR of the decoded signal, especially at high bit rates.

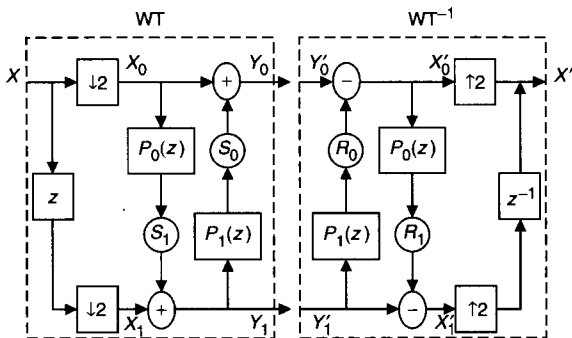


Fig. 1 Basic module of integer wavelet transform

Pre-post quantisation: To reduce the rounding errors in the decoded signals, in this Letter we introduce the quantisation prior to the wavelet (Pre-Qnt). It becomes possible to introduce the Pre-Qnt since the integer wavelet has outputs as integers. In the case of multi-stage decomposition (cascade of the two band splitting wavelets), some combinations of Pre-Qnt and the conventional post-quantisation (Post-Qnt) are feasible. For three-stage decomposition, Fig. 2 illustrates an example of the combinations. The input signal is split into ten band signals with integer wavelets. Notations 'WT(V)' and 'WT(H)' in the Figure indicate, respectively, the integer wavelet applied to the two-dimensional signal vertically and horizontally. A combination in the Figure is referred to as the '2V' method since the Pre-Qnt is put prior to the WT(V) in the 2nd stage. In this case, there are seven possible combinations such as '1V', '1H', '2V', '2H', '3V', '3H' and the conventional 'Cnv' method.

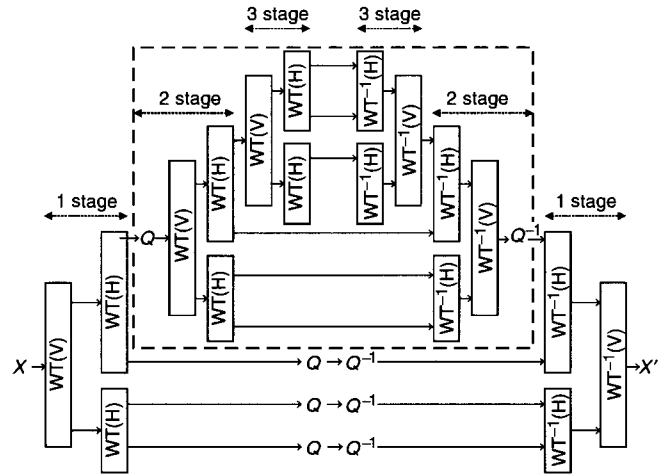


Fig. 2 '2V' method with Pre-Qnt and Post-Qnt

Results: Fig. 3 shows rate distortion curves for some of the above combinations. The standard image 'Lena' is used as an input signal for example. The entropy rate is calculated from the probability density function of the signal. The quantisation step size is optimised according to the energy gain for the quantisation error at each band [1]. According to our evaluation, the '1V' method and the '1H' method are the best at high bit rates, but the worst at low bit rates. The '2V' method and the '2H' method are almost the same at middle to low bit rates but better than the conventional 'Cnv' method at high bit rates. This is because of cancellation of the rounding errors inside the dotted square in Fig. 2.

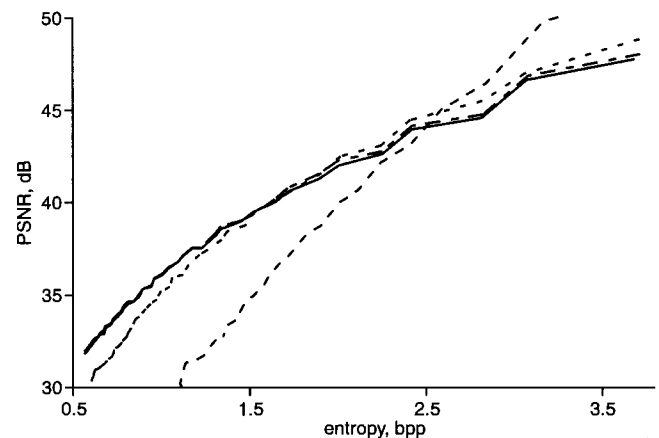


Fig. 3 PSNR against entropy rate

— conventional - - - - 3V method
 ····· 2V method - · - · 1V method

To evaluate comprehensively the superiority of each method over total bit rates, each rate distortion curve is recurred to $y_n = a_0 + a_1x + a_2x^2$ where 'x' is entropy rate, 'y_n' is PSNR and $n \in \{1V, 1H, 2V, 2H, 3V, 3H\}$. The integrated value 'I_n' defined by

$$I_n = \frac{1}{\max - \min} \int_{\min}^{\max} \{y_n - y_{Cnv}\} dx \quad [\text{dB}] \quad (1)$$

is summarised in Fig. 4. Parameters 'min' and 'max' are set to 0.5 and 3.7 bpp, respectively. It is indicated that the '1V' method and the '1H' method are always the worst for all the image data. The method which maximises the 'I' value is the '2H' method for 'Lena', 'Barbara', 'Boat' and the '2V' method for 'Aerial'. Strictly speaking, it depends on the input image signal and it requires experimental trials to determine the best one. However, this Letter proposes use of the hybrid method, which is a combination of the integer wavelet transforms 'Pre-Qnt' and 'Post-Qnt'. In the case of three-stage decomposition, according to the experiment the '2H' method is the best in general for standard images. It improves PSNR, especially at high bit rates. Overall

improvement, compared to the conventional method, is about 0.2 to 0.4 dB on average. Maximum improvement is approximately 0.8 dB.

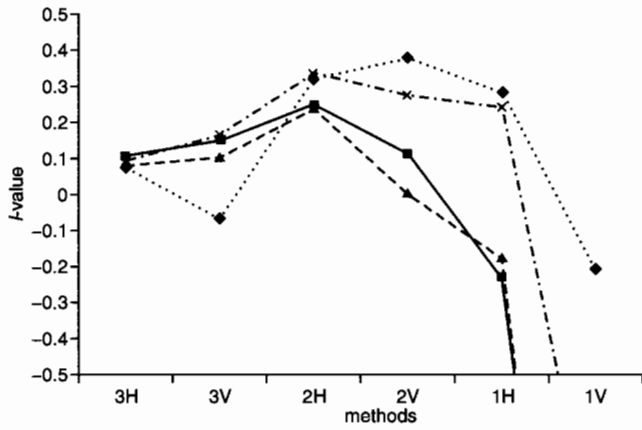


Fig. 4 Overall PSNR improvement for image data

—■— Lena - -▲- - Boat
 ...◆... Aerial - · x · - Barbara

The effectiveness of the combination of Pre-Qnt and Post-Qnt in the multi-stage decomposition base of the integer wavelet has been confirmed.

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