

# A Spatial Band Wavelet Video Coding

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**Abstract:** EZW, a wavelet transformation based compression algorithm, utilizes the correlations of the wavelet coefficients between subbands. Due to the reason that, it is based on Zero Tree's parent-descendant dependency of the subbands, subband coding is possible, but it is not efficient for applications, which require multi-resolution restorations.

In this paper we compare and analyze the performance between spatial band coding, which apply the correlation between adjusting pixels, and EZW. So as to prove that spatial band coding is superior to EZW in the sense that it exhibit higher PSNR values and that it is apt to multi-resolution restoration.

## 1. Introduction

The importance of image as a media for storing and distribution of information, in the multimedia era, has increasingly grown. Started in the 1980's digital image techniques initiated from still images and progressed to video and finally to multi-media services. But to elevate the efficiency of the multi-media services effective compression of audio and video is a necessity. Image has the ability to contain more data than the existing text format. But video, without the aid of a efficient compression algorithm, has little value. For this reason compression techniques are undergoing extreme researches.

JPEG, which is the existing standard for still image compression and MPEG for video compression is DCT (Discrete Cosine Transform) based. These systems are encoded by  $8 \times 8$  blocks, which can result in block artifacts for high compression ratios. Wavelet transform is applied to conquer these defects, which has recently taken its place as a key post in the image processing area. For the reason that it is not block based, the block artifacts is of no concern and at the same time because various resolution restorations is possible it can cope with varying scales. For these advantages wavelet was applied to the standards for JPEG2000.

EZW, a wavelet transform based encoding method, can be applied for video compression. The method progressively approximates the original signal. That is as the encoding process is proceeded the important information is transmitted first and the rest, gradually, resulting in a increasing improvement in the quality of the image [1]. Zerotree structure, which is utilized in EZW use the advantages of the wavelet transform to create a effective compression system.

## 2. Wavelet

### 2.1 Wavelet Transform

Wavelet transform was first proposed by Harr in the early 1900's. At the start the transform was studied in the areas of mathematics and physics but now has extended its territory to several areas such as image processing. Like the fourier transform it is a orthogonal transformation method and is expressed by scale and time, it also produces information of both spatial localization regions and frequency region information due to the hierarchical decomposition formula. By utilizing these characteristics it is efficient to analyze the two dimensional complexity issuing an outcome of numerous benefits in image processing [7].

Wavelet in the means of image processing, can be thought as a filter bank consisting of two filters, a low pass filter and a high pass filter. Because an image is a two dimensional signal, wavelet decomposition is executed horizontally and performed vertically again. The process of the wavelet decomposition is illustrated down below in Figure 1.

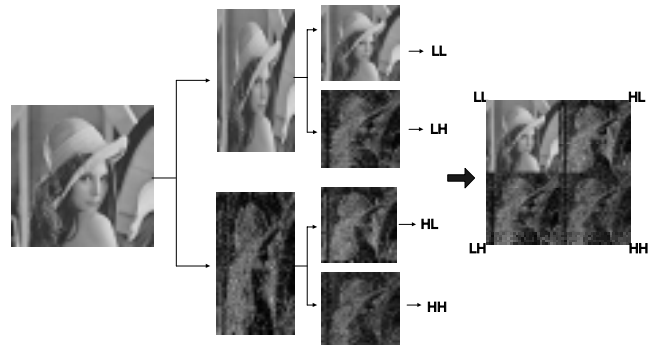


Figure 1. Wavelet Decomposition Process

By executing the wavelet decomposition once four different, LL, LH, HL, HH, subbands can be obtained. General most of the information will be included in the LL subband and for this reason an effective compression is possible. This is for the reason that the original image can be almost reconstructed by only encoding the LL subband by with merely a quarter of the data. Therefore in wavelet based image compression the efficiency is enhanced by repeating the octave decomposition of the LL band, which is denoted in Figure 3.

## 2.2 Wavelet Based Video Coding

EZW is a method of progressively approximating the original signal. That is as the encoding process is progressed more information is transmitted and so the quality of the restored video is improved. This progressive process may differ from various applications, but usually the transmission will be carried on until the receiver is satisfied with the quality. EZW coding, which can be seen in Figure 2, will undergo a dominant pass and a subordinate pass and at the end encoded by adaptive arithmetic coding. At this point if the target bit rate has not been reached the threshold is decreased and is repeated from the dominant pass.

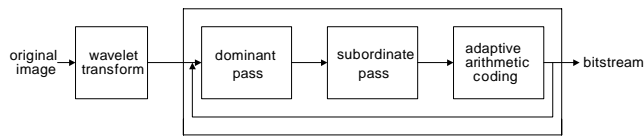


Figure 2. EZW Encoding Process

Parent-descendant dependency between the wavelet coefficients are used in the dominant pass. Figure 3 describes this relation.

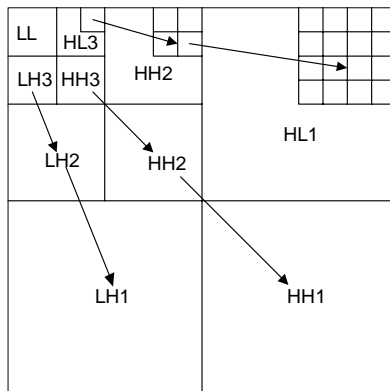


Figure 3. Parent-descendant relationship of the wavelet transform

Zerotree is a method that utilizes the character of the parent-descendant relation which states that if the absolute value of the parent is large, than its descendant's value has a relatively good change of being large as well. Accordingly the encoding is started from the low frequency band through to the high frequency band area. The encoding process is executed in a left to right order in the subband itself. At this point the absolute value of the wavelet coefficient is compared with the threshold. If the wavelet coefficient is larger than the threshold then it is confirmed as a significant coefficient. The significant coefficient is classified into two types POS when it is positive and NEG if it is negative. For the ones, which are not significant coefficients, are also classified into two types IZ (Isolate Zero), if it has even one significant descendant and ZTR (Zero Tree Root) if it has none.

Subordinate pass performed only on the coefficients, which has been declared as a significant coefficient. The significant coefficients are stored in the subordinate list, which is carrying its sign information because of the dominant pass. The subordinate pass utilizes the sign information to encode the difference between the original value and the quantized value. If the restored value is larger 1 and if not 0 is encoded.

After the first dominant and subordinate pass the adaptive arithmetic coding is initiated, if the target bit rate is reached the encoding process is terminated but if not the threshold is divided by half and the process is repeated from the beginning. For this reason a image can be reconstructed even if the transmission was incomplete.

EZW is a efficient method to encode the position of the significant wavelet coefficients and by using the energy concentration phenomenon of the wavelet transform, it generates a well organized method to encode precisely up to the target bit rate and at the same time enable progressive transmission.

## 3. Proposed Method

### 3.1 Spatial band coding

Natural images has a trend to have most of the energy concentrated in the low frequency band, in this case zerotree structure of EZW is very efficient, but this trend is not a rule. There are cases when the energy is concentrated in the high frequency zone and for this case the method above has little advantage over other techniques. For example, in Figure 3 even if there is no significant coefficient in HH2 band, but it exists in the HH1, because of the zerotree structure HH2 must be encoded in order to encode HH1. So to resolve this problem of wasting precious bit resources, we must give up the dependency between HH1 and HH2. In other words, by encoding HH1 and HH2 separately band HH1 can be coded without coding band HH2. Accordingly, each band can be seen as a independent space and coded effectively by spatial band coding.

The specific method of spatial coding is to encode '1' if there is a significant coefficient in an area, which is being encoded and to encode '0' if there aren't any. And after dividing the area possessing a significant coefficient into 4 sub-areas, the process is repeated.

An example of a  $4 \times 4$  area with two significant coefficients is shown in Figure 4. The first output is '1' because a significant coefficient exists in the area, and the entire area is divided into 4 as shown with the full lines. The output for the 4 areas encoded individually is '0110'. After the areas with a significant coefficient are divided into smaller areas using the dotted lines, they are coded and the results are '0100' and '0001'. So the bit stream for this area, with two significant coefficients, becomes '1011001000001'. This method can effectively make use of wavelet-transformed images distinctive quality, which was mentioned before. Like (b) of Figure 4, dismantling the areas nearby the area, possessing a significant coefficient, an efficient encoding is possible and this is because a wavelet transformed natural image's encoding process tend

to have a high probability of being concentrated around the area, which has a significant coefficient.

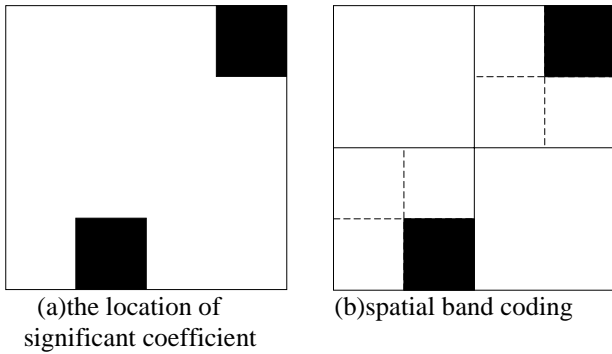


Figure 4. Example of a spatial band coding

This method make progressive encoding and encoding of high frequency band areas with the encoding of low frequency band areas.

### 3.2 Multi-Resolution

In the case of wavelet transformed images several subbands are created, EZW use the parent-descendant relationship between these subbands. So to speak, coding methods based on zerotree, begin coding from the MSB (Most Significant Bit) and that is what makes progressive encoding possible. But, because this relationship is the process of encoding a single bit plain all the other plains, which are associated with that single plain must be encoded and produced into a bit stream. That is as shown in Figure 4 all the subbands of the same spatial location will be processed together, but if spatial band coding is the occasion, the relation becomes terminated. So after LL band is encoded the spatial coding of resolution level 3, 2 and finally level 1, which enables effective multi-resolution restration.

In this paper we compare and analyze the performance between spatial band coding and EZW, which apply the correlation between adjusting pixels. So as to prove that spatial band coding is superior to EZW in the sense that it exhibit higher PSNR values and that it is apt to multi-resolution restoration.

## 4. Simulation Results

To compare EZW and spatial band coding the simulation was conducted under identical conditions. Daubechies 9/7 filter was used for the wavelet transform and the octave decomposition was carried out 7 times. The video used for the experiment was 40 frames of 256×256 size grey scale Claire (Figure 5) and salesman (Figure 6). The size of the GOP was 40 frames.



Figure 5. Claire image



Figure 6. Salesman image

PSNR, which is detailed in the algorithm below was selected to compare the results.

$$PSNR=10\log_{10}\left(\frac{255^2}{MSE}\right)[dB]$$

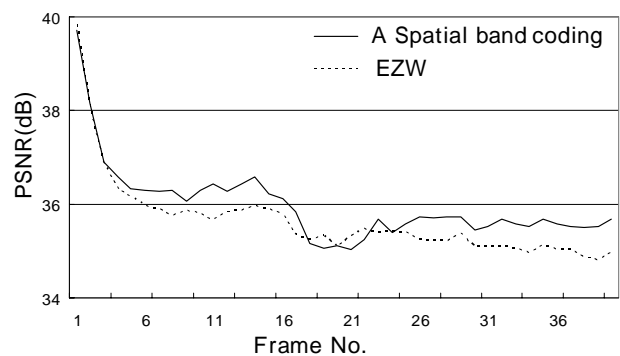


Figure 7. PSNR Graph for Claire (avg. bit rate 0.08bpp)

Figure 7 is the graph of the Claire's PSNR with the bit rate set to 0.08bpp. 0.3bpp was assigned for inter frame coding and 0.08bpp for predictive error coding. There was approximately 0.38dB improvement between EZW (avg. 35.6094dB) and the spatial band coding method (avg.

35.9821dB). Figure 8 is Claire for EZW and spatial band coding.



Figure 8. EZW vs. Spatial Band Coding for Claire

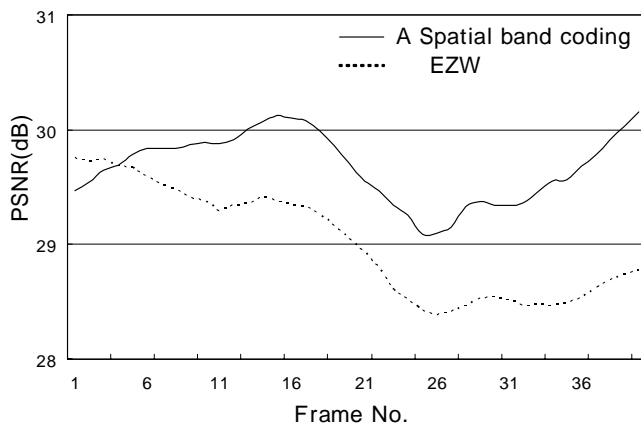


Figure 9. PSNR Graph for Salesman (avg. bit rate 0.08bpp)

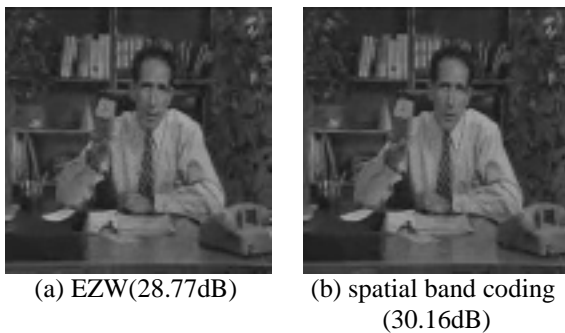


Figure 10. EZW vs. Spatial Band Coding for Salesman

Figure 9 is salesman at bit rate set to 0.08bpp. The average PSNR for EZW was 30.8714dB but 30.5365dB for spatial band coding equaling to about 0.34dB increase of PSNR results. In particular there is little difference between EZW and spatial band coding due to little movement, but as it progresses the movement becomes larger the difference in PSNR value increases rapidly, which states that spatial band coding is more superior to EZW. Figure 10 is Salesman for EZW and spatial band coding. Table 1 denotes the comparison between motion estimation (ME) and plain subtraction between sequences (SUB), expressed in average PSNR values. As it can be clearly seen in Table

1 spatial band coding was superior than EZW for both cases. In the case of SUB, spatial band coding was at an average 0.57dB better than EZW for all three images.

Method	EZW		Spatial Band Coding	
	ME	SUB	ME	SUB
Claire	35.6428	35.9460	35.9821	36.5257
Salesman	29.0066	30.5365	29.6739	30.8714
Walter	35.4232	33.3828	35.5820	33.6364

Table 1. PSNR Values for EZW and Spatial Band Coding Concerning Motion Estimation Existence

## 5. Conclusion

Though wavelet transform based EZW is capable of progressive encoding, it has a handicap toward encoding features with high energy concentration in the high frequency band and also it is inappropriate for multi-resolution restoration. After experimentation and comparison between EZW and spatial band coding, we found out that spatial band coding has an advantage of about 0.03dB to 0.77dB over EZW. And at the same time has nearly the same performance as EZW for inter frame coding. As a result, spatial band coding is an efficient method for encoding high frequency energy concentrated videos and has effective multi-resolution capabilities.

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