A Fast Context Modeling Using Tree-structure of Coefficients from Wavelet-domain

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***Abstract*—**In EBCOT, the context modeling process takes excessive calculation time and this paper proposed a method to reduce this calculation time. That is, if the finest resolution coefficient is less than a pre-defined transfer factor the coefficient and its descendents skip the context modeling process. There is a trade-off relationship between the calculation time and the image quality or the amount of output data such that as this threshold value increases, the calculation time and the amount of output data decreases, but the image degradation increases. The experimental results showed that in this range the resulting reduction rate in calculation time was from 3% to 64% in average, the reduction rate in output data was from 32% to 73% in average

***Index Terms*—**JPEG2000, EBCOT, context modeling, DWT.

I. INTRODUCTION

After JPEG2000 was adopted as an international standard for still image compression by ISO/IEC/ITU-T [1], it is rapidly replacing the JPEG market and it has been adopted as the basic technique for digital cinema, HDTV, etc. The architecture of JPEG2000 consists of discrete wavelet transform (DWT), scalar quantization, context-modeling, arithmetic coding, and post-compression rate allocation [1]. The most serious defect in JPEG2000 is that the context modeling process for entropy coding called as 'Tier 1 Encoding' takes too much calculation time, even if it is for still image [2].

Considerable research has been devoted to designing high throughput JPEG2000 encoders. Andra et al. proposed a system level architecture for all three tasks involved in JPEG2000 encoding [3]. Lian et. Al [2] introduced two methods: *Sample Skipping (SS)*, and *Group-Of-Column Skipping (GOCS)*. Cupta et al. corrected a minor error in Lian's architecture to properly account for significance propagation within a stripe column [4]. Chiang provide two new pass-parallel architectures by suggesting the use of two separate processing elements that run simultaneously [5]. Most of the previous work has focused their interest on hardware implementations to increase the computation speed.

This paper proposed a context modeling method to adjust the calculation speed and the resulting amount of data adaptively to network environments such as transmission capability, power requirements, etc.

The rest of the paper is organized as follows. The proposed algorithm is introduced in Section 2. Some experimental results and conclusions are presented in Section 3 and 4, respectively.

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II. THE PROPOSED ALGORITHM

The proposed algorithm is explained in the two following subsections.

A. Some properties in coefficients after DWT

Before explaining our algorithm, we point out some properties of wavelet coefficients (WCs) after DWT, which will be used to construct our scheme. It uses the tree-structure of the coefficients in subbands resulted from DWT (discrete wavelet transform). That is, each DWT subband has the same spatial information as the original image and a coefficient in a subband corresponds to four coefficients in the child subband, 16 coefficients in the grandchild subband, and so on, which is called as the coefficient-tree. This tree structure has a particular property that when a coefficient in a tree has a high value, its children seem to have high values, too, with very high probability. From this property, we can predict that if a coefficient has a very low value, its descendents also have very low values with high probability. Here, the coefficient at the coarse resolution is called the *parent*, and all coefficients corresponding to the same spatial location at the next finer resolution of similar orientation are

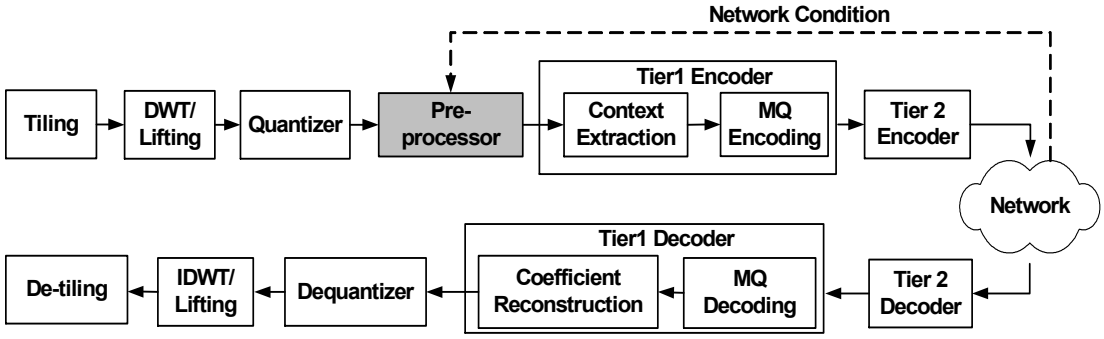


Fig. 1. Block diagram of JPEG2000 process including the proposed algorithm

called *children*. This property can be defined as follow;

[Property] If the energy value of a parent is high (or low), then the average energy value of the children in a lower level subband in also high (or low) with a very high probability.

[6] insisted that the probability is about 98%.

B. Pre-processing based on tree-structure for context modeling

The main idea of this paper is that if a coefficient has a lower value than a predefined value (significance threshold), the context modeling processes for all the descendents including that coefficient are discarded and only a predefined code is assigned to all of them. But if a coefficient has a higher value than a predefined one, the context modeling process is progressed by original context modeling algorithm. The significance threshold induces a trade-off property between the image quality and the calculation time (and output bit rate). That is, in a coefficient-tree, only the ancestors with higher values than a significance threshold are context-extracted and the descendents are assigned by a predefined context. Thus, our method preprocesses before Tier 1 encoding and the result affects the Tier 1 encoding. This method is depicted in Fig. 1, which includes the context modeling process. Before Tier 1 process, the quantized result is scanned to select the roots of the coefficient-trees (insignificant trees) whose values are less than a given transfer factor. In the context modeling process, all the coefficients in the insignificant trees are discarded from processing.

The flowchart of proposed a method and context extraction algorithm shown Fig. 2. The gray color box is the proposed method and white color box is the context extraction method. The generated significance map to the proposed method is to use context extraction (gray color box in the right side box of Fig. 2.).

The significance threshold is adaptively changed to the network condition according to the trade-off property mentioned above. That is, if a network condition is not good and requiring short latency time, low processing time, or low processing power, a higher transfer factor should be used to reduce the calculation time and output bit rate, which costs lowering the image quality. This relationship is shown in Fig. 3 in which three values, image quality (PSNR), calculation time (computation cycles), and bit rate (transmission data) are estimated with respect to the significance thresholds. As seen in Fig. 3 (a), the significance threshold larger than 5 cannot be used because image degradation could be too much. So, our method restricts its value from 0 to 4 to maintain the image quality better than 30dB.

III. EXPERIMENTAL RESULTS

The results tested on different images, have confirmed the superiority of the proposed method. This method has been applied to test images and a three of them are shown in Table 1, which includes a comparison to the work in [7] in calculation time. Table 1 shows the trade-off relationship between image quality and calculation time or amount of data according to the threshold, which as denoted as transfer factor (*TF*). Among the full scale of the transfer factor, we focused on the value lower than or equal to 4 to consider the image quality better than 30dB in PSNR. The performance in this range is compared to the one previous work in [7]. This table indicates that the proposed method can reduce the calculation time upto 70% in the image quality of better than about 30dB according to the transfer factor from 1 to 4.

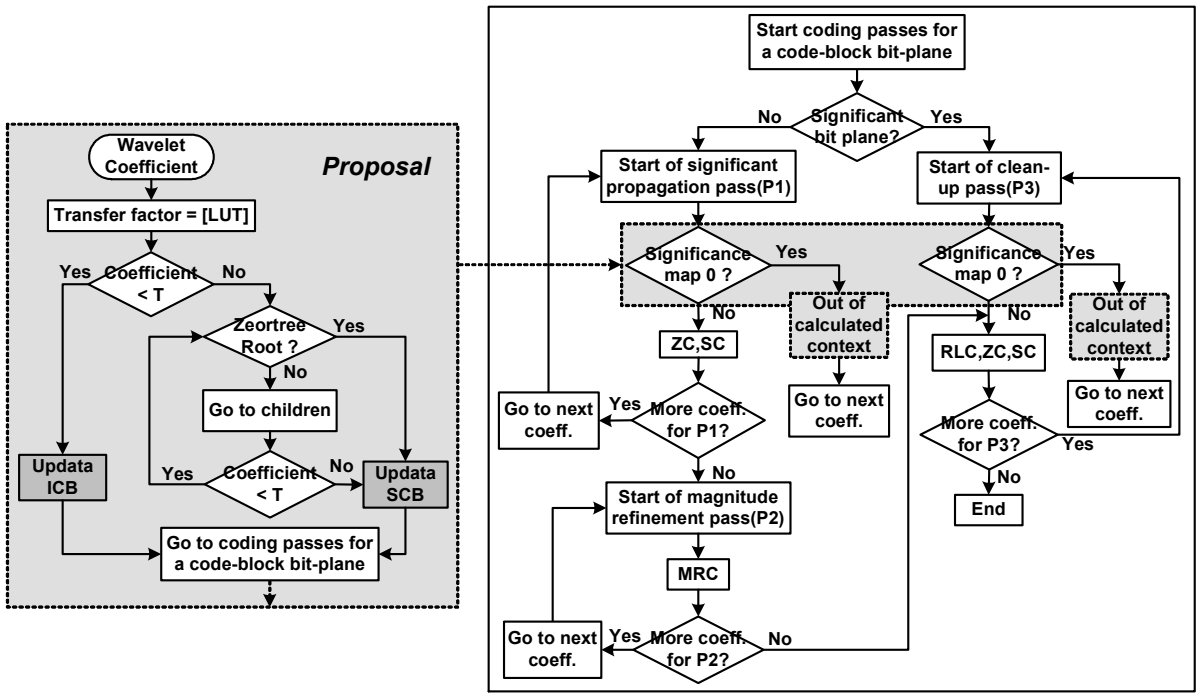
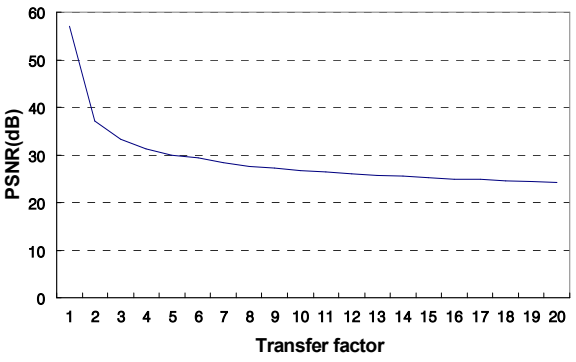
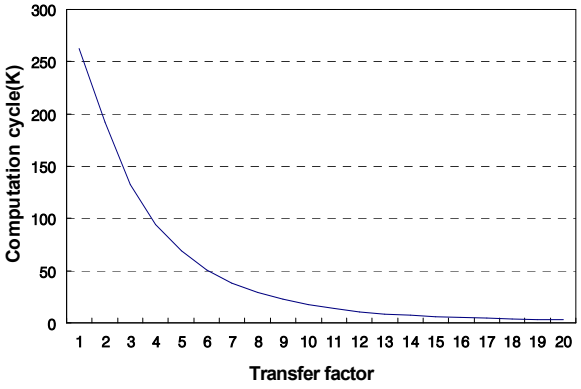


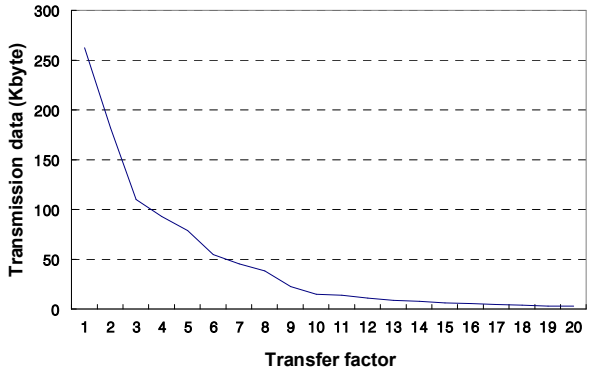
Fig. 2. Flow chart of proposed pre-processing and context modeling algorithm.



(a)



(b)



(c)

Fig. 3. The performance and its trade-off relationship to image quality for the range of transfer factor upto 20, (a) image quality in PSNR, (b) computation time (in cycle), (c) amount of data.

IV. CONCLUSIONS

In this paper, we proposed a method to reduce the context modeling time in JPEG2000. The methods to speed up calculation use the tree-structure of the coefficients in subbands resulted from DWT. It uses the tree-structure of the coefficients in subbands

Table I. Calculation time reduction compared to a previous work.

Images	[7]		Ours					
	CPU time (sec)	Data rate (byte)	TF	# of SCs	CPU time		Data rate	
					Value (sec)	Reduction ratio (%)	Value (byte)	Reduction ratio (%)
Lena	0.246	157,020	0	262144	0.246	0	157,020	0
			1	192249	0.236	4.07	115,455	26.47
			2	132212	0.164	33.30	79,303	49.49
			3	94001	0.115	53.25	56,279	64.16
			4	68581	0.084	65.85	40,997	73.90
Goldhill	0.241	155,551	0	262414	0.241	0	155,551	0
			1	191657	0.234	2.35	113,540	27.00
			2	138090	0.171	29.05	81,868	47.37
			3	104186	0.126	47.72	61,726	60.32
			4	78937	0.099	58.92	46,852	69.88
Woman	0.183	125,216	0	262144	0.183	0	125,216	0
			1	144121	0.179	2.19	68,800	45.05
			2	91680	0.113	38.25	43,781	34.97
			3	64625	0.080	56.28	30,841	75.37
			4	48059	0.061	66.67	22,602	80.95

resulted from DWT and its property that when a coefficient has high value, its children seem to have high values, too, with very high probability. That is, in a coefficient-tree, only the ancestors with higher values than a threshold are context-extracted and the descendents are assigned by a predefined context. The threshold value is adaptively changed to the network condition. Thus, we expect that the proposed method is very useful in the application area that the image compression process is dependent of network environments such that the captured image with portable device such as cellular phone, PDA, etc needs to be transmitted immediately.

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