行政院國家科學委員會專題研究計畫成果報告

利用最佳小波作有損耗及無損耗的影像壓縮(III)

Universal Lossy and Lossless Image Compression Using Optimal Wavelets (III)

計畫編號：NSC 90-2213-E-002-097
執行期限：90 年 8 月 1 日至 91 年 7 月 31 日
主持人：馮世邁　國立台灣大學電信工程研究所

一、中文摘要

這是三年期計畫的第三年。在第二年我們提出一種適用於有損耗及無損耗的影像壓縮最佳編碼器稱為預測式下三角轉換(PLT)。在本計畫中，我們利用 PLT 發展出階層式插入(HINT) 編碼器。實驗模擬證實在高品質影像壓縮中，HINT 編碼器有非常好的結果。

關鍵詞：影像壓縮, 小波, 編碼器

Abstract

This is the final year of a three-year project. In the second year, we have proposed an optimal transform coder called prediction based lower triangular transform(PLT) which can be used for lossless and lossy image compression. Using the PLT, we develop an lossy/lossless image coder, Hierarchical INTerpolation (HINT) coder, in this project. Simulations show that the HINT coder has an excellent performance when high-quality coded images are needed.

Keywords: Image compression, wavelet, coder

二、緣由與目的

Transform coding has found many applications in various areas of signal processing and communication [1]. It is well known that the optimal unitary transform that yields the maximum coding gain is the KLT. Due to its signal dependence and computational cost, the KLT is often only used as a benchmark for performance comparison. In the second year of this three-year project, we have derived a new optimal transform called prediction based lower triangular transform (PLT) which can be used for lossless and lossy image compression. PLT has the same coding performance as KLT but its complexity is much lower [2]. Moreover it was shown that PLT enjoys the following advantages that make it an attractive candidate for image coding:

(i) The design cost of PLT is much lower than that KLT. The implementational of PLT is less than one half of KLT.

(ii) Unlike KLT, PLT has a structurally PR implementation using simple building blocks.

(iii) PLT coders can implement both lossy and lossless compression while KLT in general cannot be used for lossless coding.

(iv) Unlike KLT, PLT has a simple closed form for AR(1) inputs. In this case, the M-dimensional PLT takes only M-1 multiplications and additions for each input block. Moreover it is almost signal independent.

In this report, using the PLT, we will derive an image coder called Hierarchical INTerpolation (HINT) coder. Simulations show that the HINT coder has an excellent performance when high-quality coded images are needed.

三、結果與討論

We will illustrate the 3-level HINT coder step by step. It's not difficult to extend it to n-level case. The HINT coder involves 2 steps:

Step 1: Partition

Partition the input pixels $x(n_1,n_2)$ into groups. For a 3-level partition, we use a tree structure to divide the pixels as shown in Fig. 1. Thus we obtain the ten groups:

For level 1,

$$\text{x} = \{x(n_1,n_2):\ n_1 = 2k+1,\ n_2 = 2k+1\}$$

$$\cdot = \{x(n_1,n_2):\ n_1 = 2k,\ n_2 = 2k+1\}$$

$$* = \{x(n_1,n_2):\ n_1 = 2k+1,\ n_2 = 2k\}$$

For level 2,

$$\Diamond = \{x(n_1,n_2):\ n_1 = 4k+2,\ n_2 = 4k+2\}$$

$$\triangle = \{x(n_1,n_2):\ n_1 = 4k,\ n_2 = 4k+2\}$$

$$\square = \{x(n_1,n_2):\ n_1 = 4k+2,\ n_2 = 4k\}$$

For level 3,

$$@ = \{x(n_1,n_2):\ n_1 = 8k,\ n_2 = 8k\}$$

$$◎ = \{x(n_1,n_2):\ n_1 = 8k+4,\ n_2 = 8k+4\}$$

$$\oplus = \{x(n_1,n_2):\ n_1 = 8k,\ n_2 = 8k+4\}$$

$$\odot = \{x(n_1,n_2):\ n_1 = 8k+4,\ n_2 = 8k\}$$

where k are integers in the above expressions.

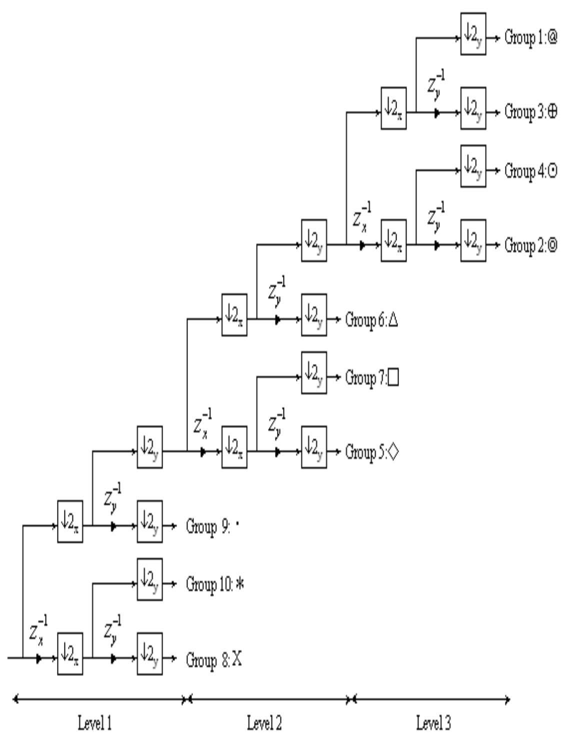

Fig. 1. A 3-level tree structure

For example, when the image block is 16 by 16, then the partition is as shown in Fig. 2.

Step 2: Prediction and Interpolation

After partition in step 1, we will use some nearest samples to predict some other samples and then interpolate them for further prediction. We first quantize group @ directly and then use four nearest quantized samples in group @ as "prediction seed" to predict group ◎ as shown in Fig. 3(a). The prediction error in group ◎ is then quantized and therefore we can reconstruct group ◎ by the quantized error and its estimation. Four nearest samples in group @ and ◎ are then used to predict group ⊕ as shown in Fig. 3(b). Similarly, the prediction error in group ⊕ is then quantized and we can reconstruct group ⊕. After that, the nearest eight samples in group @, ◎ and ⊕ are used as observations to predict ⊙ in Fig. 3(c). We can continue to proceed the similar prediction and interpolation procedure for other groups in level 1 and 2 until the whole two-dimensional data are quantized. Fig. 4 illustrates the interpolation procedure. Samples labeled "k+1" are estimated from the nearest 4 or 8 samples among those labeled "1" through "k", each sample is reconstructed from its estimation and quantized error of the estimation.

@	*	□	*	⊙	*	□	*	@	*	□	*	⊙	*	□	*
·	x	·	x	·	x	·	x	·	x	·	x	·	x	·	x
△	*	◇	*	△	*	◇	*	△	*	◇	*	△	*	◇	*
·	x	·	x	·	x	·	x	·	x	·	x	·	x	·	x
⊕	*	□	*	◎	*	□	*	⊕	*	□	*	◎	*	□	*
·	x	·	x	·	x	·	x	·	x	·	x	·	x	·	x
△	*	◇	*	△	*	◇	*	△	*	◇	*	△	*	◇	*
·	x	·	x	·	x	·	x	·	x	·	x	·	x	·	x
@	*	□	*	⊙	*	□	*	@	*	□	*	⊙	*	□	*
·	x	·	x	·	x	·	x	·	x	·	x	·	x	·	x
△	*	◇	*	△	*	◇	*	△	*	◇	*	△	*	◇	*
·	x	·	x	·	x	·	x	·	x	·	x	·	x	·	x
⊕	*	□	*	◎	*	□	*	⊕	*	□	*	◎	*	□	*
·	x	·	x	·	x	·	x	·	x	·	x	·	x	·	x
△	*	◇	*	△	*	◇	*	△	*	◇	*	△	*	◇	*
·	x	·	x	·	x	·	x	·	x	·	x	·	x	·	x

Fig. 2. Partition into 10 groups @, ◎, ⊕, ⊙, ◇, △, □, x, ·, *.

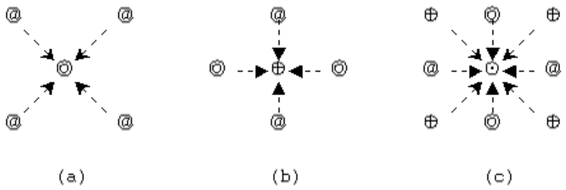

Fig. 3. Prediction pattern for level 1.

Notice that we use the quantized data instead of the unquanitized data as the input to the predictor at encoder. The reason is the same as the idea of MINLAB structure. By doing so, we can avoid the amplification of quantization noise. As for the predictors, we can obtain them by solving the normal equations described in previous chapter and thus these predictors will be input dependent. In order to reduce the computational complexity, we may properly set the predictors to some fixed numbers and thus they are input independent. For example, one set of fixed predictors is shown in Fig. 3.3.5. The coefficients of these predictors are 1/4, ± 1/8, 3/8. Therefore, the time-consuming multiplication operations are replaced by the fast shift operations.

1	10	7	10	4	10	7	10	1	10	7	10	4	10	7	10	1	10
9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8
6	10	5	10	6	10	5	10	6	10	5	10	6	10	5	10	6	10
9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8
3	10	7	10	2	10	7	10	3	10	7	10	2	10	7	10	3	10
9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8
6	10	5	10	6	10	5	10	6	10	5	10	6	10	5	10	6	10
9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8
1	10	7	10	4	10	7	10	1	10	7	10	4	10	7	10	1	10
9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8
6	10	5	10	6	10	5	10	6	10	5	10	6	10	5	10	6	10
9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8
3	10	7	10	2	10	7	10	3	10	7	10	2	10	7	10	3	10
9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8
6	10	5	10	6	10	5	10	6	10	5	10	6	10	5	10	6	10
9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8
1	10	7	10	4	10	7	10	1	10	7	10	4	10	7	10	1	10
9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8	9	8

Fig. 4. Order of Interpolation

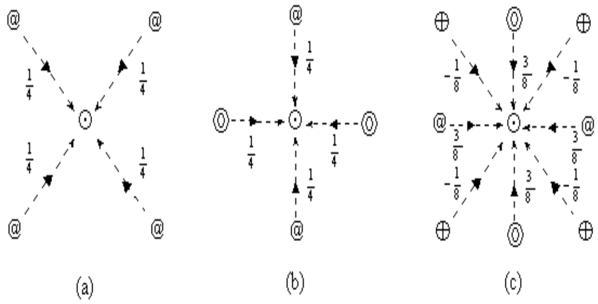

Fig. 5. One set of fixed predictor.

In the following example, we will compare the performances of the HINT-based, NLP-based (proposed in [3]) and the DCT-based JPEG coders by using the image "lenna", "baboon" and "pepper". We implement the NLP-based JPEG coder by replacing the prediction method in the HINT-based JPEG coder and keep other structures unchanged. Fig. 6, 7 and 8 show respectively the results of the performance comparison for the image "lenna", "baboon" and "pepper". We find the three coders have very close performance for bit rate less than 1 bits/pixel. When the bit rate is larger than 1 bits/pixel, the HINT-based and the NLP-based JPEG coders will outperform the DCT-based JPEG coder and have a gain about 2-4 dB.

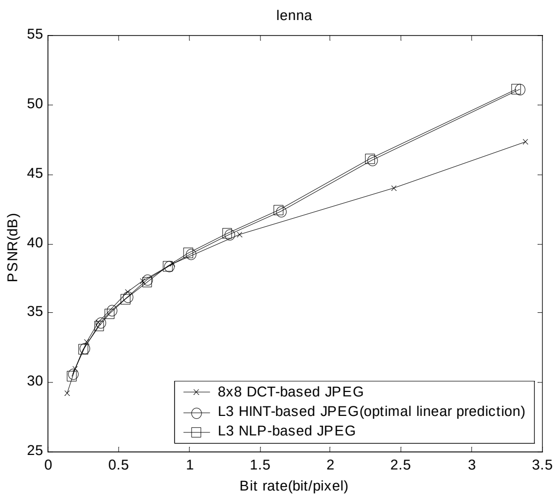

Fig. 6. Performance comparison for "lenna"

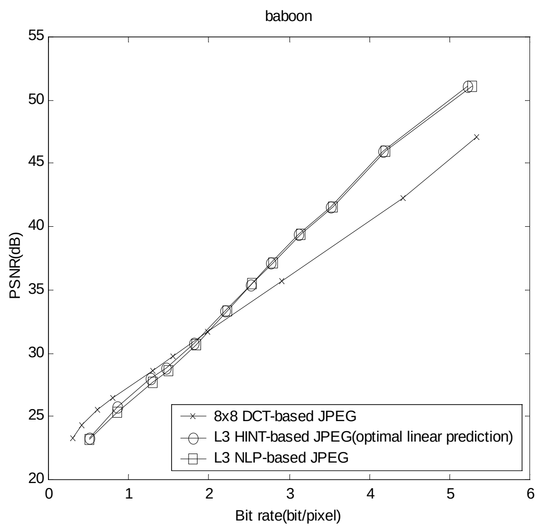

Fig. 7. Performance comparison for "baboon"

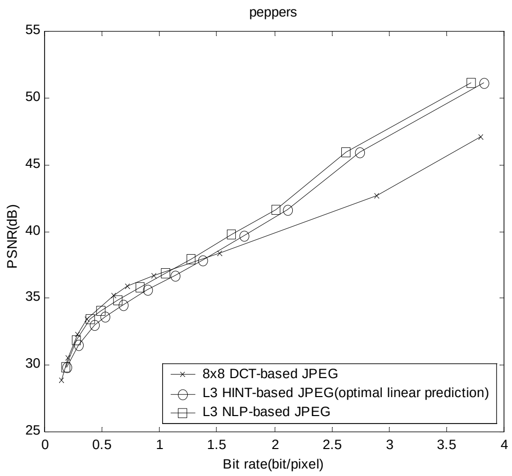

Fig. 8. Perfomance comparison for "pepper"

四、計畫成果自評

The result of this project is very satisfactory. We have applied the PLT proposed in the previous year to the HINT coder for image coding. The HINT coder can have both lossy and lossless compression in the same coder structure. The simulation results show that for high quality coded images, HINT coder has an excellent performance.

五、參考文獻

[1] N. S. Jayant, and P. Noll, *Digital coding of waveforms*, *Prentice Hall*, 1984.

[2] S.-M. Phoong, and Y. P. Lin, ``Prediction based lower triangular transform,'' *IEEE Trans. Signal Processing,* pp. 1947-1955, July 2000.

[3] Ricardo L. deQueiroz, Dinei A. F. Florencio, and Ronald W. Schafer, "Nonexpansive Pyramid for Image Coding Using a Nonlinear Filterbank," pp. 246-252, *IEEE Transactions on Image Processing,* vol. 7, No. 2, Feb. 1998.

附件：封面格式

行政院國家科學委員會補助專題研究計畫成果報告

※※※※※※※※※※※※※※※※※※※※※※※※※※
※　　　　　　　　　　　　　　　　　　　　　　　　※

多媒體信號處理（III)—子計畫四:
利用最佳小波作有損耗及無損耗的影像壓縮

※　　　　　　　　　　　　　　　　　　　　　　　　※
※※※※※※※※※※※※※※※※※※※※※※※※※※

計畫類別：□個別型計畫　　x 整合型計畫

計畫編號：NSC 90－2213－E－002－097－

執行期間：90 年　8 月　1 日至 91 年　7 月 31 日

計畫主持人：馮世邁

共同主持人：

計畫參與人員：

本成果報告包括以下應繳交之附件：

□赴國外出差或研習心得報告一份

□赴大陸地區出差或研習心得報告一份

□出席國際學術會議心得報告及發表之論文各一份

□國際合作研究計畫國外研究報告書一份

執行單位：國立台灣大學電信工程研究所

中　華　民　國　　91　年　　8 月　　1 日