

EZW

A Study on Improving the Performance of EZW based Image Compression

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Zerotree Wavelet) EZW (Embedded

EZW (POS, NEG) 가 (IZ, ZTR) PSNR 0.4 0.7dB

(ZTR) (IZ)

1. 가 4가

JPEG 가 JPEG DCT (Arithmetic coding)

가 JPEG2000

8x8 JPEG 가 가 DCT

가

PSNR JPEG EZW 2, 3, 4, 5

. EZW EZW 6

EZW 4가

1, 2. 2.1

0 가

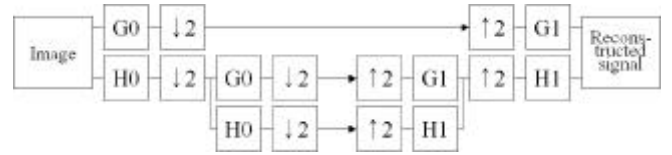
1

, 0 가

가

[3]

lowpass highpass



[3]

2.2

[1]

[4]

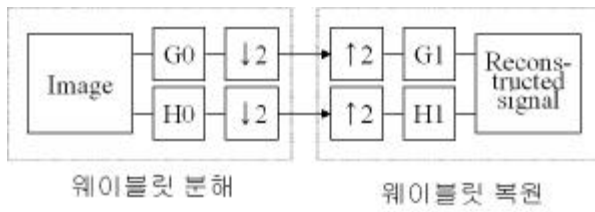
highpass H0 lowpass
lowpass highpass

G0

4

[2] HL HL1, LH LH1,
HH HH1 4
LL2, HL2, LH2, HH2

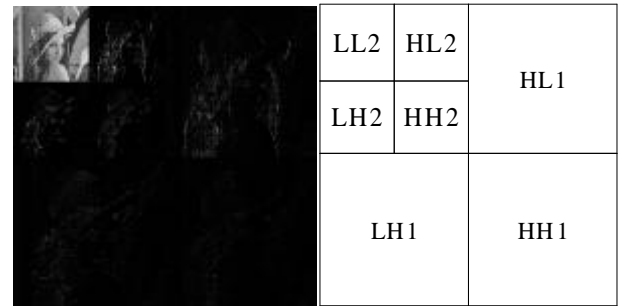
[2.3].



웨이블릿 분해

웨이블릿 복원

[1]



[4] Lena

가 [2]

lowpass

highpass

[2]
(LL band)

가
(LH band)

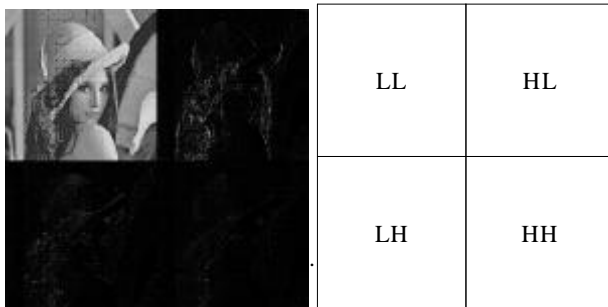
가
(HL band)

(HH band)

[5] 가 가 가

[2] [4]

가



[2] Lena

[2]

(LL band)

가 가

4

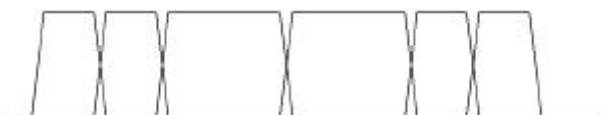
512×512
가 Shapiro EZW
512x512 6
[1]



0 /2 (a)

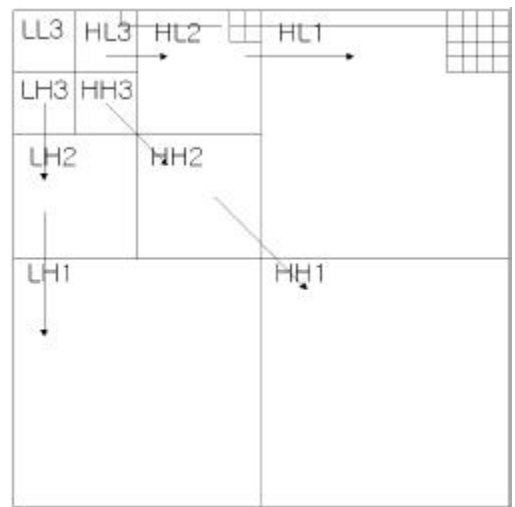


0 /2 (b)



0 /2 (c) [5]

HH1 16 가
 HH3 4 , HH2
 HH1 4 가 가
 가



[6]

3. Embedded Zerotree Wavelet

Sahapiro가 Embedded Zerotree Wavelet (EZW) (self-similarity) (Successive Approximation Quantization) [1]. EZW

3.2 Zerotree Root

[2] [4] 가 0 bit plan

0 bit plan

bit plan

Zerotree Root

EZW bit plan MSB bit plan 가

3.1 (Self-similarity)

3 HH3 가 4 가
 가 HH2 4 가
 가 HH2 가 HH1
 4 가 , HH3

· POS - [Positive Significant]

가

EZW

· NEG - [Negative Significant]

가

가

가

· IZ - [Isolated Zero]

Zerotree Root

· ZTR - [ZeroTree Root]

가 POS, NEG

, IZ

POS, NEG, IZ, ZTR

, ZTR

가

가

, ZTR

가

0

EOB(End Of Block)

3.4

(Arithmetic coding)

3.3 EZW

EZW

(dominant pass)

EZW coding)가

[5],

(Arithmetic

(subordinate pass)

가

가

가

, EZW

Zerotree root

가

EZW

[7]

가

가

가

가

가

가

4 (POS, NEG, IZ, ZTR)

Histogram

2 (1, 0)

Histogram

가

4가

EZW

Histogram

4

Histogram

4

Histogram

2

4.

EZW

EZW

4

가 POS, NEG

가

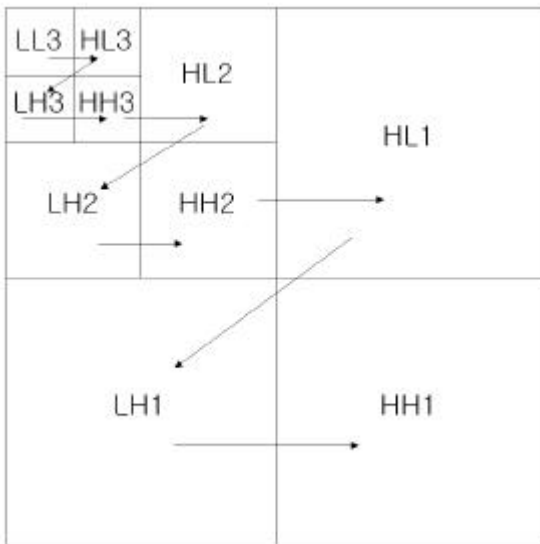
POS, NEG

ZTR, IZ

가

POS, NEG

ZTR, IZ



[7]

EZW
ZTR, IZ
4.1
ZTR, IZ
ZTR, IZ
IZ
ZTR
가 , IZ
IZ 가

[3] Goldhill

	POS	NEG	IZ	ZTR
0.125bpp	2526	2314	1991	21221
	9.0%	8.2%	7.1%	75.7%
0.25bpp	5005	4821	2909	49233
	8.1%	7.8%	4.7%	79.4%
0.5bpp	11134	10637	7199	81223
	10.1%	9.7%	6.5%	73.7%
1bpp	22482	21265	15841	140251
	11.3%	10.6%	7.9%	70.2%

[1] Lena
0.5bpp, 1bpp
POS, NEG, IZ, ZTR
[2] Barbara
Lena
[3] Goldhill
Lena
Lena , Barbara , Goldhill
가
POS NEG 8% 10%
IZ 5% 10%
ZTR 70% 78% 가

POS NEG IZ
ZTR IZ ZTR
10
ZTR , IZ
가
4.2 Z
EZW 4
(POS, NEG, IZ, ZTR)
, IZ IZ
4
, IZ 3 (POS, NEG,
ZTR)
IZ

[1] Lena

	POS	NEG	IZ	ZTR
0.125bpp	2393	2412	1364	23034
	8.2%	8.3%	4.7%	78.8%
0.25bpp	4713	4718	2571	46734
	8.0%	8.0%	4.4%	79.6%
0.5bpp	9316	9323	5492	87273
	8.4%	8.4%	4.9%	78.3%
1bpp	18939	19280	13909	148532
	9.4%	9.6%	6.9%	74.1%

[2] Barbara

	POS	NEG	IZ	ZTR
0.125bpp	2176	2244	3561	20402
	7.7%	7.9%	12.5%	71.9%
0.25bpp	4841	4829	6096	36992
	9.2%	9.2%	11.6%	70%
0.5bpp	10182	10102	9326	71471
	10.1%	10.0%	9.2%	70.7%
1bpp	20233	19999	16055	128978
	10.9%	10.8%	8.7%	69.6%

POS NEG
POS NEG
, 4
, 3
POS NEG가
POS, NEG
POS, NEG
IZ POS, NEG
ZTR
ZTR , IZ

IZ , 4 , IZ
 IZ , 3 , ZTR , A ,
 가 , ZTR ,
 , ZTR , IZ ,
 ZTR , 4 , 가 ,
 ZTR , 3 , ZTR , IZ , 2 , 가 ,
 , 1 , 가 , A ,
 , 2 , 가 , B , ZTR ,
 , 가 , 가 , ZTR ,
 , 가 , , 5 ,
 , 가 , ZTR , , 3 , 8 ,
 , 3 , ZTR , 가 ,
 , 가 , 4.4 , EZW ,
 가 , 가 , , EZW ,
 (가) , [NEW]가 , EZW ,
 , 가 ,
 4.3 IZ , IZ ,
 , IZ , IZ , A ,
 (redundancy) , IZ , [NEW] ,
 가 , ZTR , [NEW] ,
 IZ , POS, NEG, IZ , 가 2 ,
 IZ , A , POS, NEG, IZ , 가 1 ,
 IZ A , B ,
 A , B , 3 , (POS, NEG, ZTR) ,
 IZ , Arithmetic , [NEW] ,
 , 가 ,
 IZ , A , B ,
 IZ , 가 , [NEW] ,

IZ 가 2
 ZTR 가 1
 ZTR
 가 8 1
 , 2 2 가 1
 가 가
 IZ ZTR
 가

(Arithmetic coding)

B , A
 Histogram 3 POS, NEG, ZTR
 Histogram
 B A
 가 A
 가

4.5 Program Coding

A B EZW 가
 EZW 가
 5.

가 가
 Barbara 8bpp 512 x 512 Lena
 Goldhill
 6
 EZW PSNR
 EZW PSNR
 PSNR PSNR

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

MSE

[4] Lena

# bytes	R	Compression	EZW	EZW
32768	1.0	8:1	39.42dB	39.93dB
16384	0.5	16:1	36.30dB	36.94dB
8192	0.25	32:1	33.26dB	33.92dB
4096	0.125	64:1	30.35dB	30.95dB
2048	0.0625	128:1	27.75dB	28.14dB

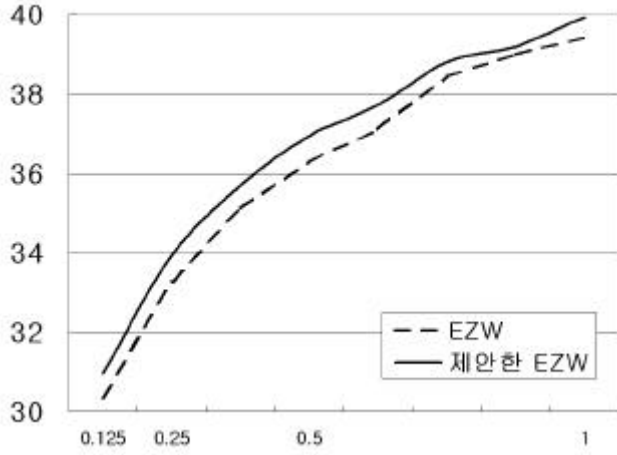
[5] Barbara

# bytes	R	Compression	EZW	EZW
32768	1.0	8:1	35.00dB	35.66dB
16384	0.5	16:1	30.43dB	30.72dB
8192	0.25	32:1	26.61dB	27.33dB
4096	0.125	64:1	24.07dB	24.21dB
2048	0.0625	128:1	23.08dB	23.19dB

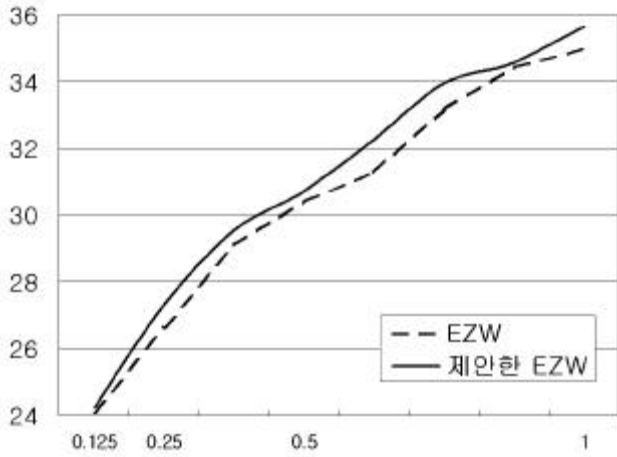
[6] Goldhill

# bytes	R	Compression	EZW	EZW
32768	1.0	8:1	35.50dB	36.13dB
16384	0.5	16:1	32.54dB	32.87dB
8192	0.25	32:1	30.26dB	30.29dB
4096	0.125	64:1	28.03dB	28.41dB
2048	0.0625	128:1	26.44dB	26.62dB

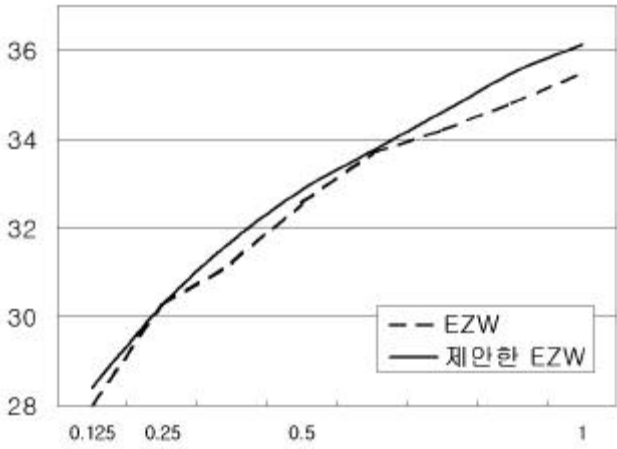
[4] Lena 0.0625bpp, 0.125bpp, 0.25bpp, 0.5bpp, 1bpp EZW PSNR EZW PSNR , [5] Barbara , [6] Goldhill , [8] Lena EZW PSNR EZW PSNR , [9] Barbara , [10] Goldhill



[8] Lena PSNR



[9] Barbara PSNR



[10] Goldhill PSNR

EZW PSNR , EZW 가
EZW PSNR , EZW 가

가
10
10
PSNR , 가
[7] Lena EZW EZW
10

[7] Lena 35.89dB EZW
EZW

	POS	NEG	IZ	ZTR	PSNR	#bytes
EZW	7930	7923	3210	81927	35.89dB	14186
EZW	7930	7923	829	123247	35.89dB	13496

PSNR 35.89dB ,
10 POS
NEG , IZ 3210
829 0.26 , ZTR 81927
123247 1.5 가
[8] Barbara EZW EZW
10

[8] Barbara 34.64dB EZW
EZW

	POS	NEG	IZ	ZTR	PSNR	#bytes
EZW	18570	18349	13378	125226	34.64dB	30530
EZW	18570	18349	4462	184439	34.64dB	29294

PSNR 34.64dB , 가 POS
NEG , IZ 13378
4462 0.33 , ZTR 125226
184439 1.47 가
[9] Goldhill EZW EZW
10

[9] Goldhill 33.80dB EZW
EZW

	POS	NEG	IZ	ZTR	PSNR	#bytes
EZW	13203	12533	7199	108348	33.80dB	21600
EZW	13203	12533	2270	159423	33.80dB	20991

PSNR 33.80dB , 가 POS
NEG , IZ 7199
2270 0.32 , ZTR 108348
159423 1.47 가
가 PSNR IZ
, ZTR 가 ,

bytes가 , Lena
 690bytes가 , Barbara 1236bytes
 가 , Goldhill 609bytes가

EZW EZW
 Lena Barbara
 Goldhill [11] 512 ×
 512 Lena , [12] (a) EZW
 0.125bpp , (b) EZW 0.125bpp



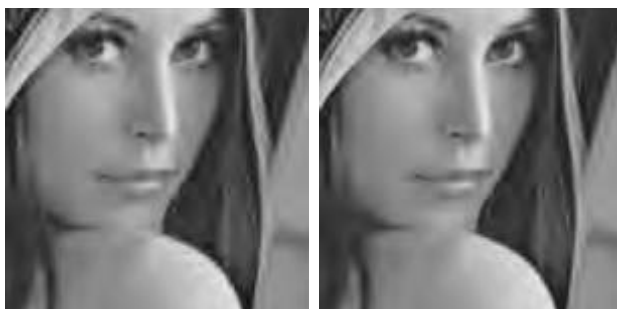
[13] Barbara



[11] Lena



(a) EZW (b) EZW
 [14] Barbara PSNR 0.25 EZW
 EZW



(a) EZW (b) EZW
 [12] Lena PSNR 0.125 EZW
 EZW

[12]
 (ringing) 가 (a) EZW (b)
 EZW
 [13] 512 × 512 Barbara , [14]
 (a) EZW 0.25bpp , (b)
 EZW 0.25bpp

[14]
 (ringing) 가 (a) EZW (b)
 EZW
 [15] 512 × 512 Goldhill , [16]
 (a) EZW 0.125bpp , (b)
 EZW 0.125bpp



[15] Goldhill



(a) EZW (b) EZW
[16] Goldhill PSNR 0.125 EZW
EZW

[16] (ringing) 가 (a) EZW (b)
EZW

6.

EZW
IZ , IZ 가
ZTR
0.2 0.1 ,
ZTR 1.3 가
ZTR PSNR
가 ,
Lena PSNR 0.6dB
가 , Barbara PSNR

0.4dB, Goldhill PSNR 0.3dB 가
EZW IZ
PSNR 0.1dB 가 ,
POS, NEG, IZ 가 2
ZTR PSNR
0.1dB 가 , POS, NEG, IZ
가 1 ZTR
PSNR 0.3dB 가 .

- [1] J. M. Shapiro, "Embedded image coding using zerotrees of wavelets coefficients," *IEEE Trans. Signal Processing*, vol. 41, pp. 3445-3462, Dec. 1993.
- [2] J. W. Woods and S. O'Neil, "Subband coding of images," *IEEE Trans. Acoustics, Speech, and Signal Processing*, vol. 34, pp. 1278-1288, October 1986.
- [3] G. Strang and T. Nguyen, "Wavelets and filter banks," *Wellesley-Cambridge Press*.
- [4] A. Said and W. A. Pearlman, "A new fast and efficient image codec based on set partitioning in hierarchical trees," *IEEE Trans. Circuits and Systems for Video Technology*, vol. 6, pp. 243-250, June 1996.
- [5] I. H. Witten, R. Neal, and J. G. Cleary, "Arithmetic coding for data compression," *Comm. ACM*, vol. 30, pp. 520-540, June 1987.