[00391] Recent Advances in Multiscale Transforms for Image Analysis

Improvement of Coding Procedures for Haar Transform-based Lossy Image Compression

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Session Time & Room: 4Đ (Aug.24, 15:30-17:10) @A502

Outline

- Motivations
- Problem Formulation
  Multi-neighbor predictors and residual orthogonal transforms
- Numerical Examples
- Improved MPROT with frequency space filter
- Proposal for the Slice Run-Length Encoding
- Summary & Future plan
- Acknowledgment & References

Lossy image compression

JPEG Standard ([1]1992)

- ĐCT in 8x8 pixel units
- Block Artifacts
- Mosquito Noise

Based on the Haar Wavelet Transform [2]

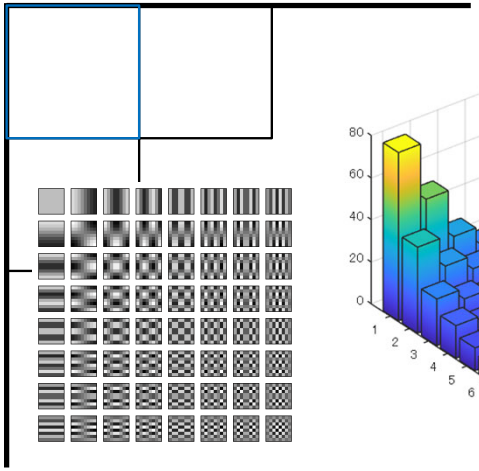
- Localized rectangular wave basis
- Consists of a recursive process of addition and subtraction
- Lose smoothness

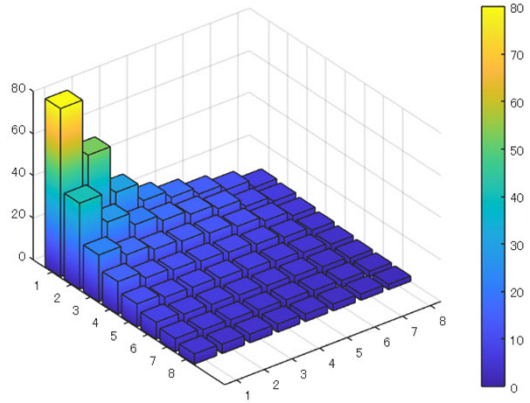
Multi-neighbor Predictors and Residual Orthogonal Transform ([3] K.Ashizawa, K.Yamatani, N.Saito,2007)

		JPEG (DCT)	Haar Wavelet	MPROT (Hierarchical HT + Gradient Prediction)
Image Quality	Block Artifacts			
	Mosquito Noise		non-generated	non-generated
	Smoothness			
	Noticeable basis pattern (isolated island noise)	non-generated	non-generated	
Computational Cost				

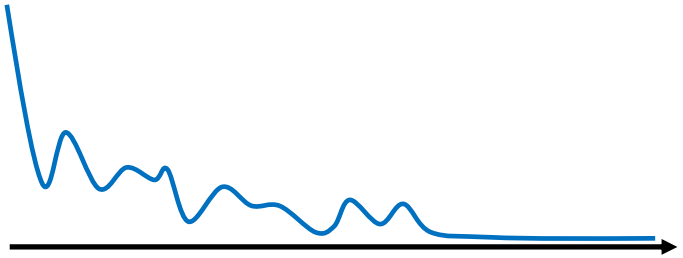
Considering the reduced computational cost,
we chose a method based on the Haar transformation.

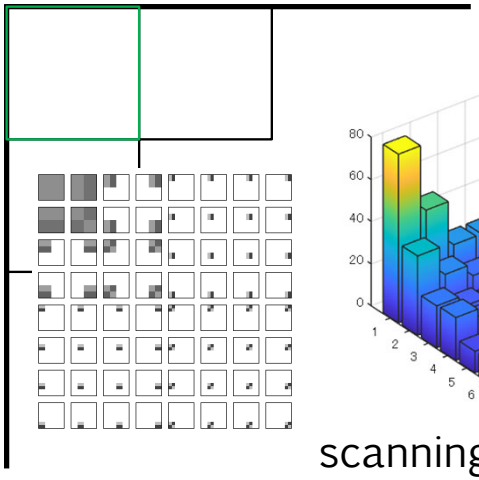
Target: Coefficients sorted into 1Đ signals for coding

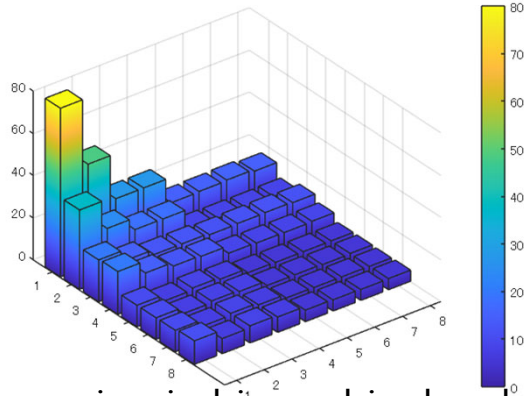




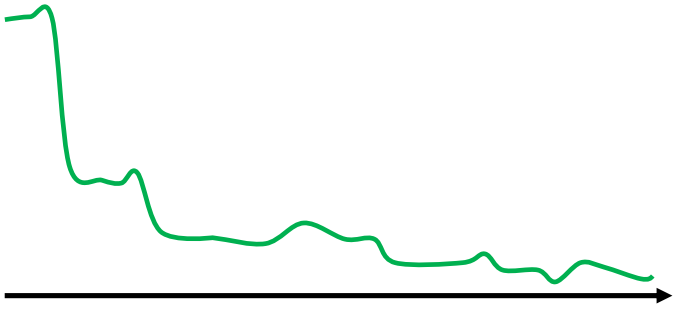
DCT coefficients oscillate and decay



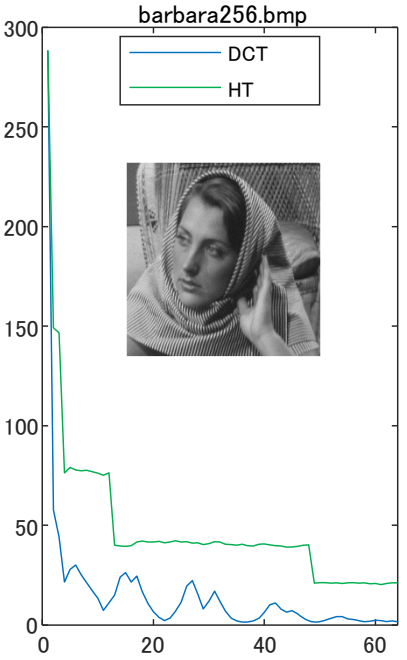




HT coefficients are stepped and damped



scanning in hierarchical order



Example of 1Đ signal in 8x8 pixel block

Entropy encoding after quantization

Haar Transform-based Residual Orthogonal Transformation (ROT)

The Haar transform decomposes the data into an average component (ĐC) and a difference (AC).

$$\begin{pmatrix} DC \\ AC \end{pmatrix} = \frac{1}{\sqrt{2}} \begin{pmatrix} f_0 + f_1 \\ f_0 - f_1 \end{pmatrix}$$

Quantization causes a loss of gradient information (smoothness) in the reconstructed image.

The ROT predicts AC components from multi-neighbor components.

- Encoding:
  The residual: the predictive AC component subtracts from the AC component.
- Đecoding:
  Predicts gradient information from residuals.

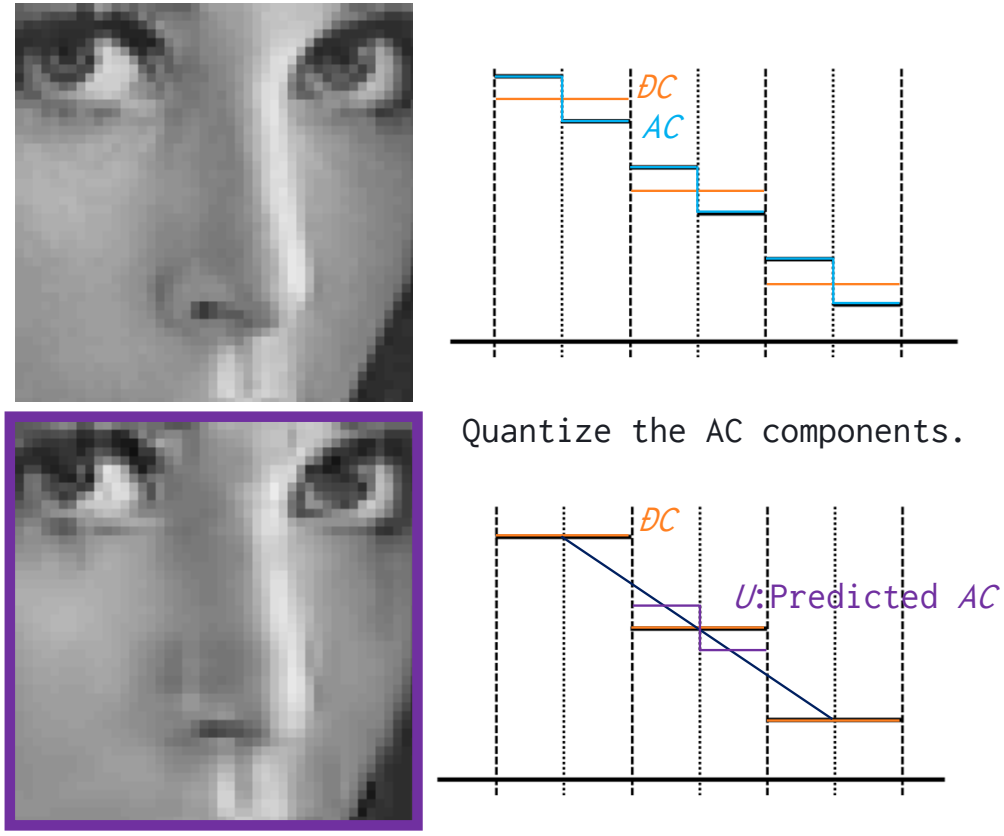
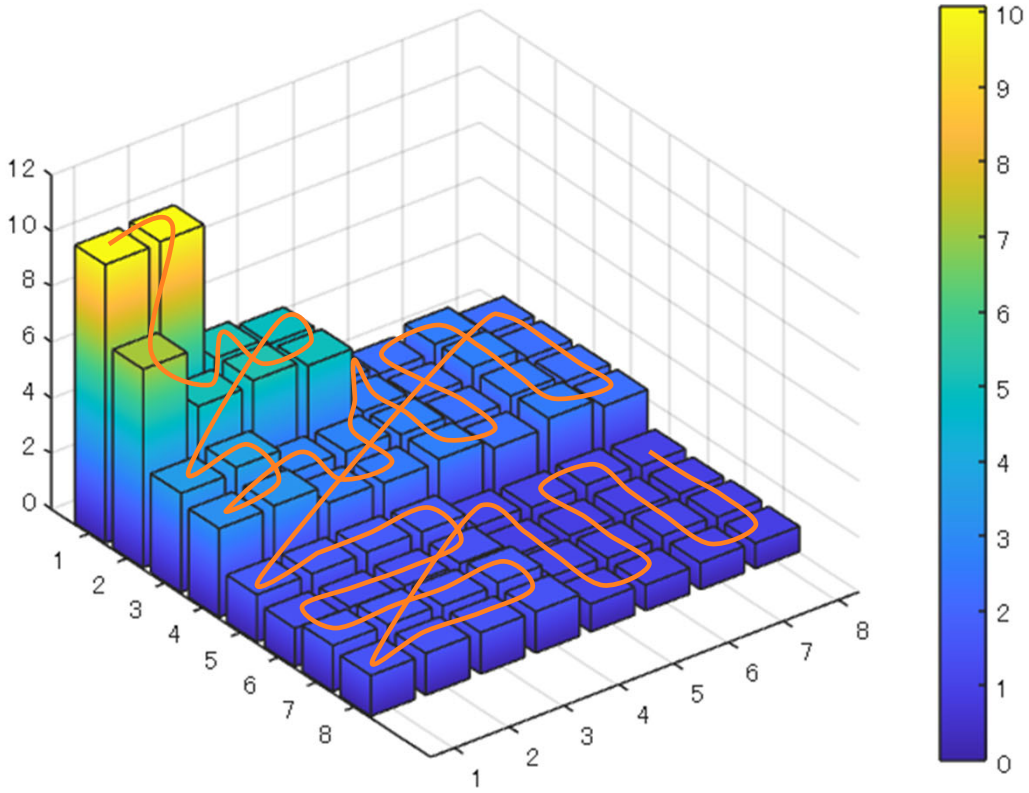


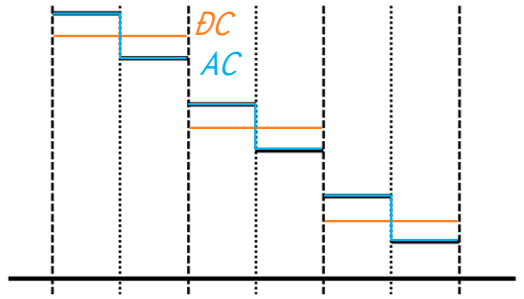
Fig.1 Schematic of Haar transform-based residual orthogonal transformation

Haar Transform-based Residual Orthogonal Transformation (ROT)

The residual value is smaller than the AC component value.



The distribution of the 1Đ signal is similar to the Haar transformation coefficients.



Quantize the AC components.

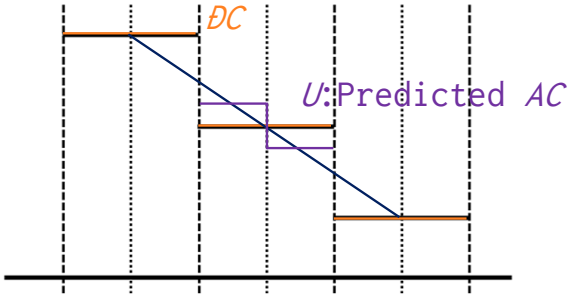


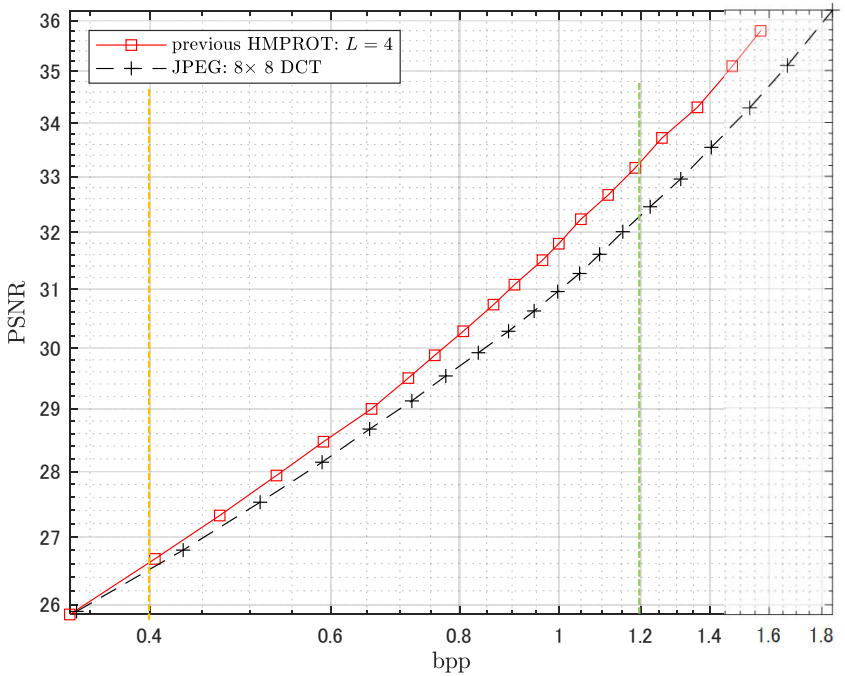
Fig.1 Schematic of Haar transform-based residual orthogonal transformation

The Multi-neighbor Predictors and Residual Orthogonal Transformations (HMPROT)

Test image (512x512, 8 bit/pixel, grayscale)

0.40 bpp

The Multi-neighbor Predictors and Residual Orthogonal Transformations (HMPROT)



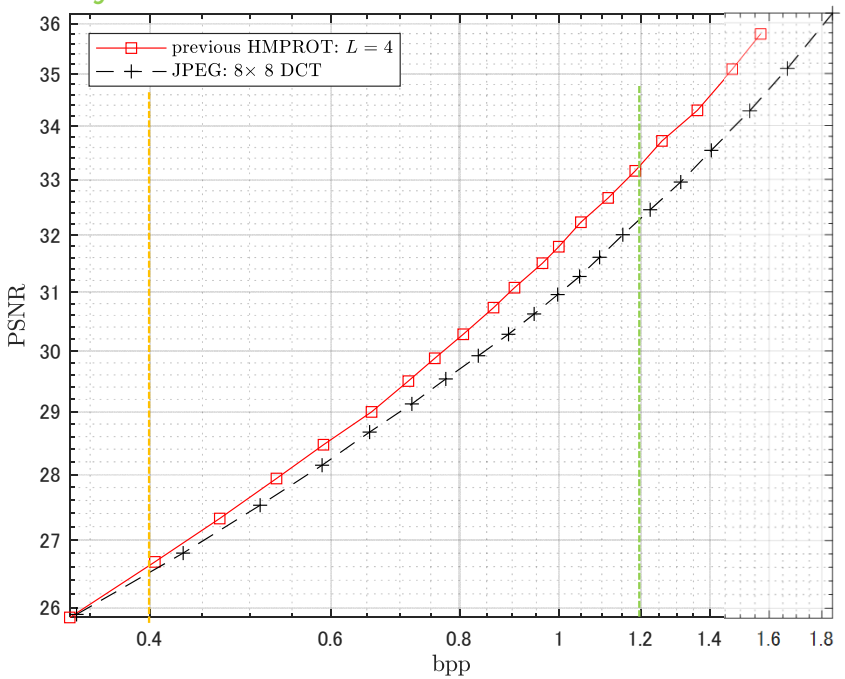
Objective evaluation (PSNR value) improved

Noticeable basis pattern (isolated island noise)

0.40 bpp

The Multi-neighbor Predictors and Residual Orthogonal Transformations (HMPROT)

Noise actually occurs even with low compression:
not visually noticeable



Objective evaluation (PSNR value) improved

Noticeable basis pattern (isolated island noise)

Considered to be a pattern present in the original image.

1.20 bpp

Problem to be solved

MPROT's Causes of Degradation: Comparison with the original image
Evaluation of PSNR value

-> Attempts to faithfully reproduce the original image resulted in new visually fatal noise.

Challenge 1 : Cutting isolated AC components to improve subjectivity
(Even if the objective evaluation is reduced.)

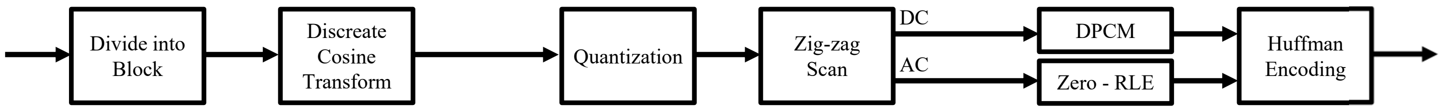
Coding of Haar transform coefficients turned into 1D signals by scanning

Challenge 2 : Develop bit rate reduction methods other than zero run-length encoding

Suggest two ideas

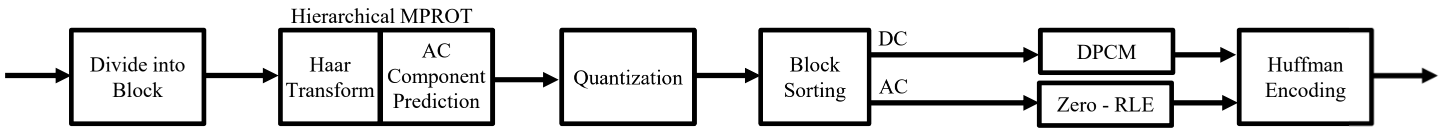
- ☑ Filters to remove isolated AC components
- ☑ Slice Run-Length Encoding

Numerical Examples



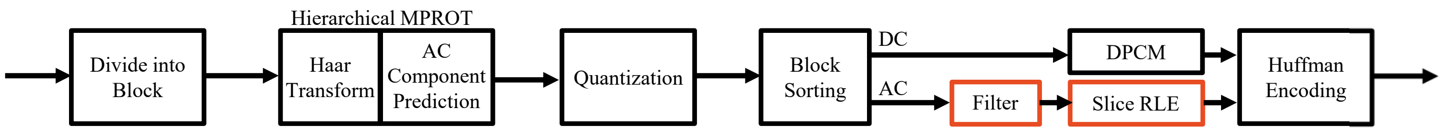
8×8, 16×16

a) JPEG Baseline



16×16, L=4

b) Previous MPROT



16×16, L=4

c) Proposed Method

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

8×8

16	16	11	11	10	10	16	16	24	24	40	40	51	51	61	61
16	16	11	11	10	10	16	16	24	24	40	40	51	51	61	61
12	12	12	12	14	14	19	19	26	26	58	58	60	60	55	55
12	12	12	12	14	14	19	19	26	26	58	58	60	60	55	55
14	14	13	13	16	16	24	24	40	40	57	57	69	69	56	56
14	14	13	13	16	16	24	24	40	40	57	57	69	69	56	56
14	14	17	17	22	22	29	29	51	51	87	87	80	80	62	62
14	14	17	17	22	22	29	29	51	51	87	87	80	80	62	62
18	18	22	22	37	37	56	56	68	68	109	109	103	103	77	77
18	18	22	22	37	37	56	56	68	68	109	109	103	103	77	77
24	24	35	35	55	55	64	64	81	81	104	104	113	113	92	92
24	24	35	35	55	55	64	64	81	81	104	104	113	113	92	92
49	49	64	64	78	78	87	87	103	103	121	121	120	120	101	101
49	49	64	64	78	78	87	87	103	103	121	121	120	120	101	101
72	72	92	92	95	95	98	98	112	112	100	100	103	103	99	99
72	72	92	92	95	95	98	98	112	112	100	100	103	103	99	99

16×16

20	20	20	20	20	20	20	20	40	40	40	40	40	40	40	40
20	20	20	20	20	20	20	20	40	40	40	40	40	40	40	40
20	20	20	20	20	20	20	20	40	40	40	40	40	40	40	40
20	20	20	20	20	20	20	20	40	40	40	40	40	40	40	40
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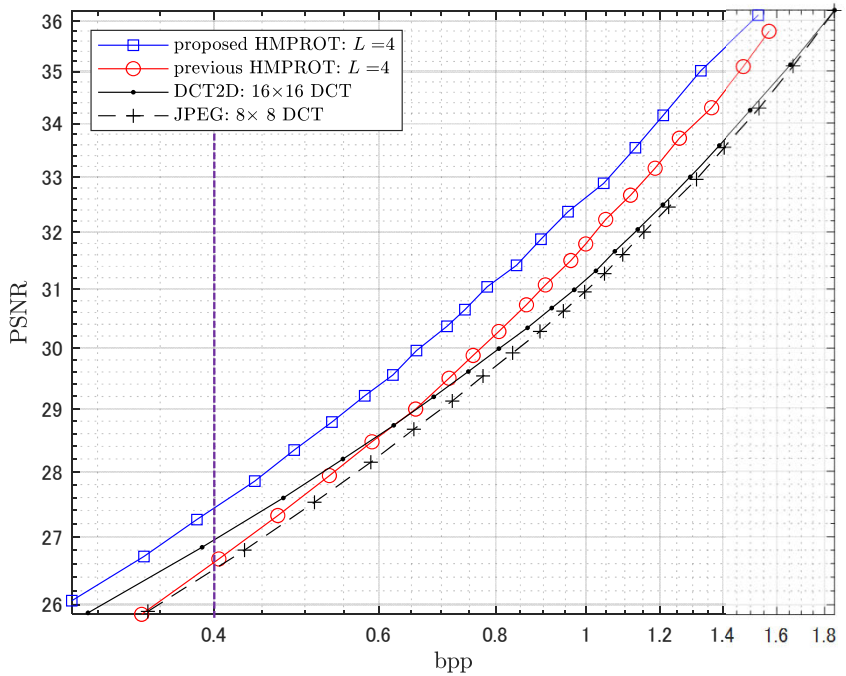
40	40	40	40	40	40	40	40	80	80	80	80	80	80	80	80
40	40	40	40	40	40	40	40	80	80	80	80	80	80	80	80
40	40	40	40	40	40	40	40	80	80	80	80	80	80	80	80
40	40	40	40	40	40	40	40	80	80	80	80	80	80	80	80
40	40	40	40	40	40	40	40	80	80	80	80	80	80	80	80

Quantization Tables

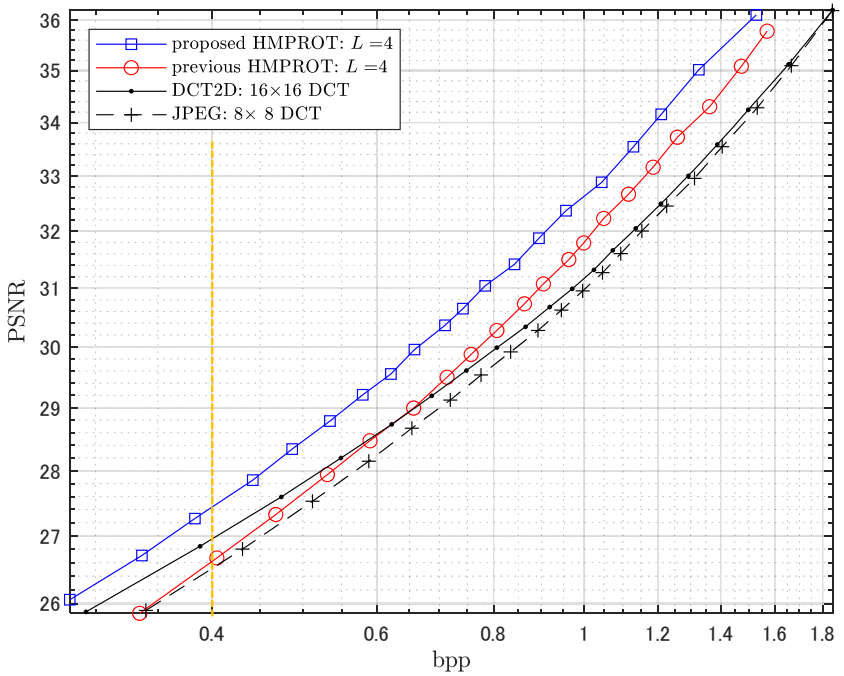
Evaluation by PSNR value



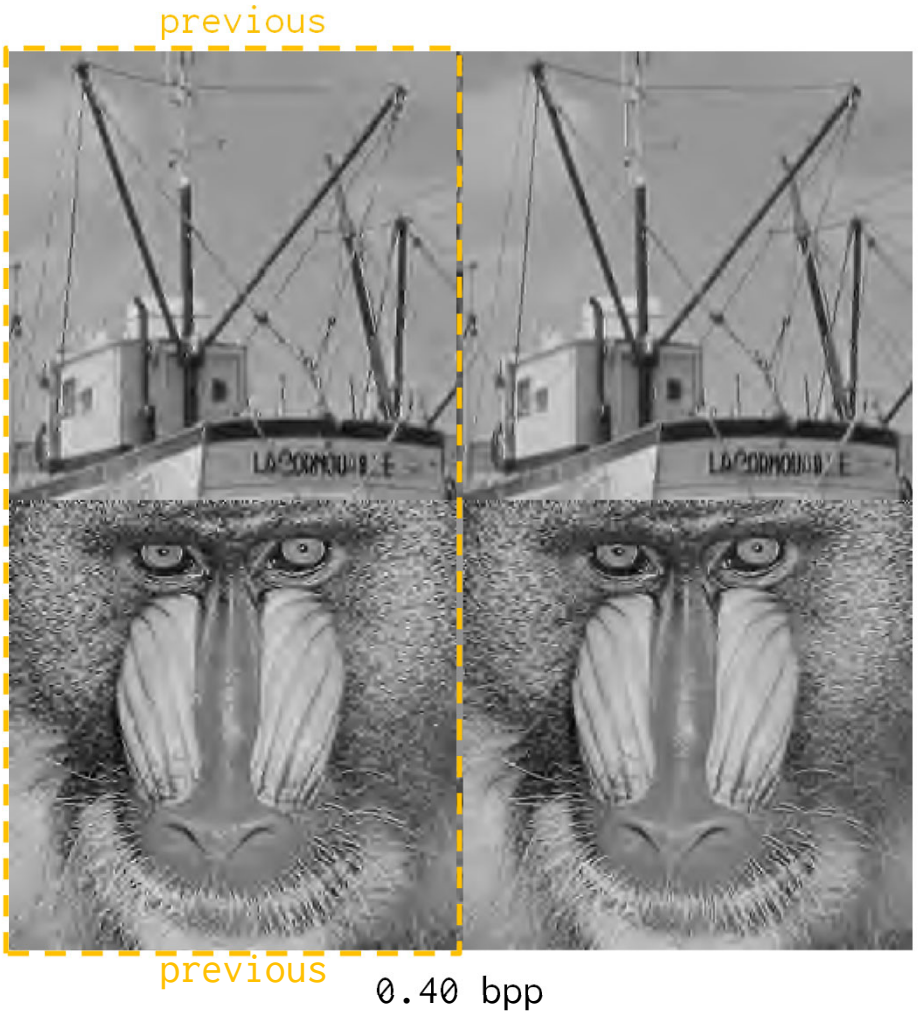
PSNR value improvement over the preceding method can be confirmed for all compression bands.

0.40 bpp

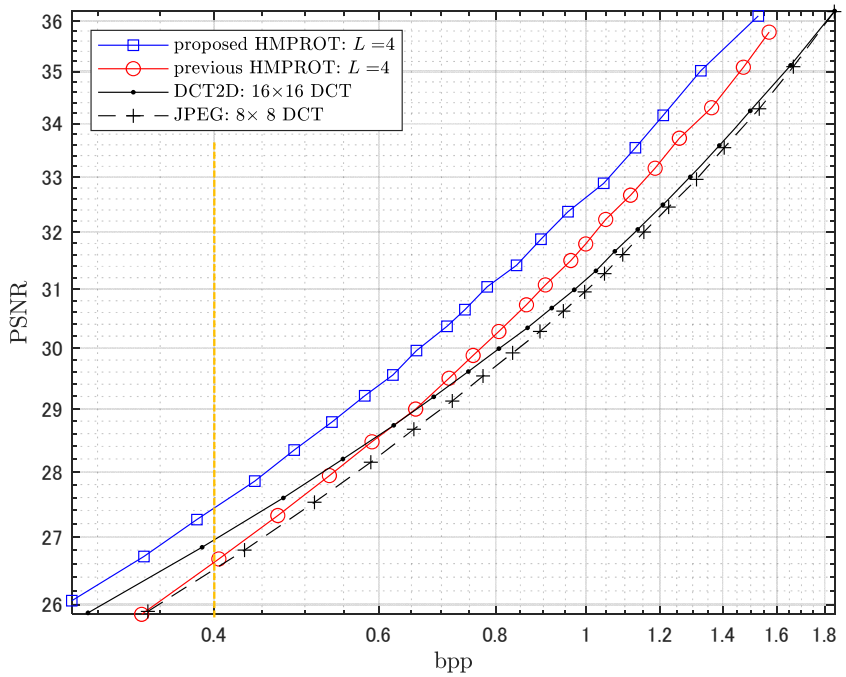
Subjective evaluation (at 0.4 bpp)



A reduction in the basis pattern (isolated island noise) was observed.

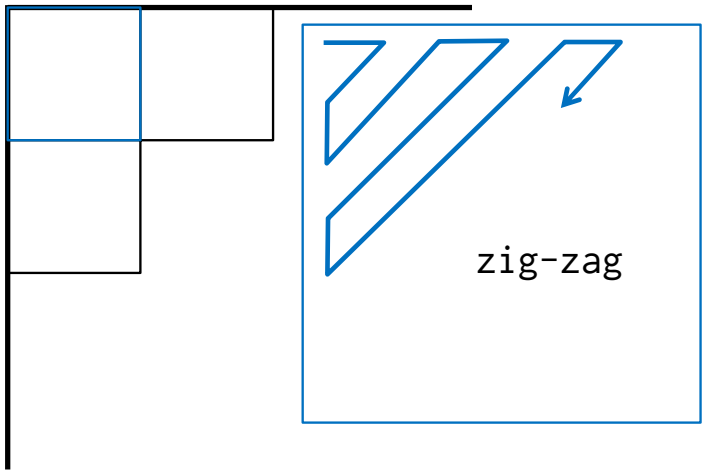


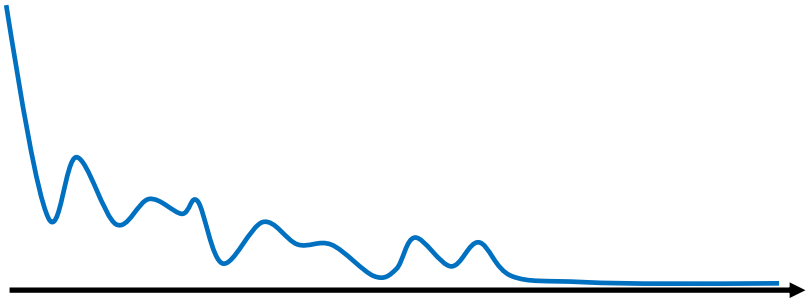
Subjective evaluation (at 0.4 bpp)

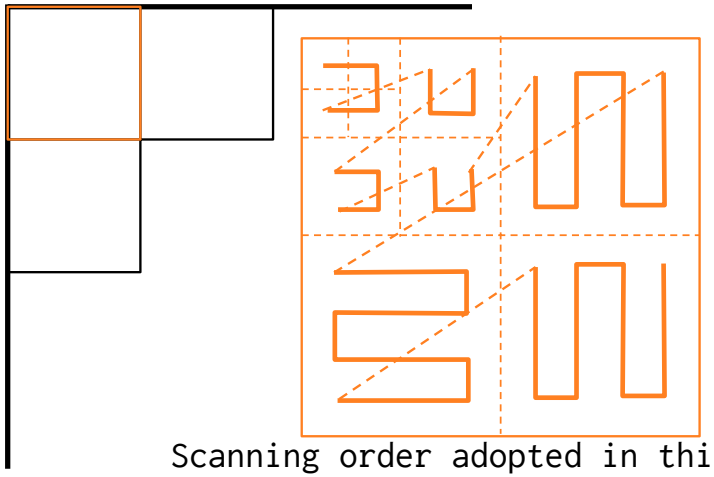


A reduction in the basis pattern (isolated island noise) was observed.

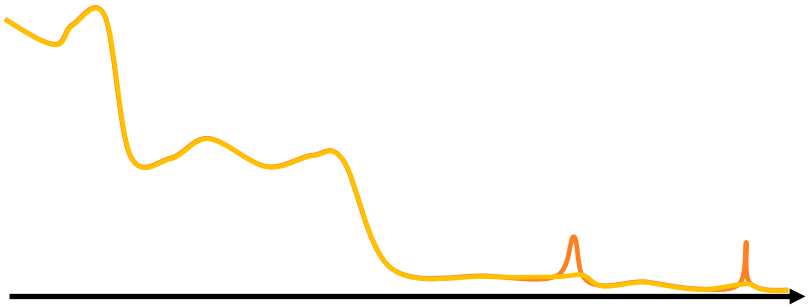
Filters concept to remove isolated AC components



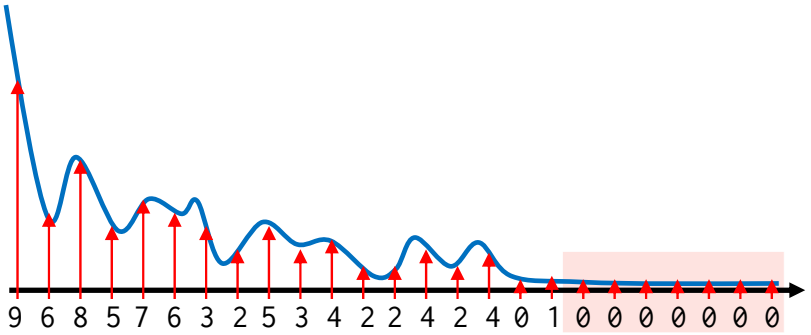




Scanning order adopted in this study



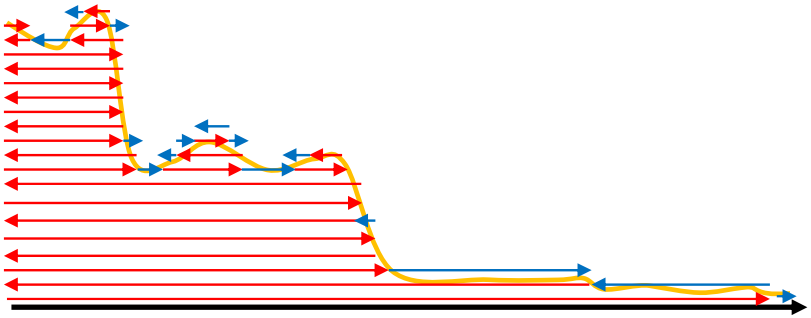
Slice Run-Length Encoding



Zero Run-Length Encoding

Previous method:

Reduce the amount of information by using
zero-sequence length codes
in the high-frequency band.



Proposed **Slice Run-Length Encoding**

The sequence consists of only 0s and 1s

… Slice Run-Length Encoding works amazingly well.

1 1 ⋯ 1

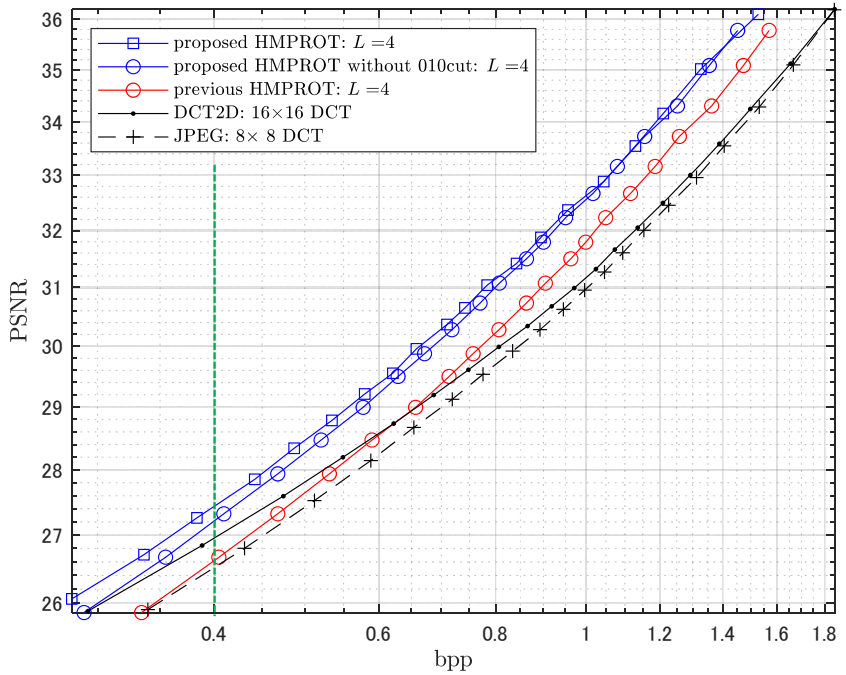
1 1 ⋯ 1 0 0 0

1 1 ⋯ ⋯ ⋯ 1 0 0 0

1 1 ⋯ ⋯ ⋯ 1 1 1 1 0

1 1 ⋯ ⋯ ⋯ 1 1 1 1 0 0 0 0 1 ⋯ ⋯ ⋯ 1 1 1 1 ⋯ 1 0 0 0 1 ⋯ 1 1 ⋯

Effects of Slice Run-Length Encoding



PSNR values improve in all compression bands.

Slice Run-Length Encoding is effective.

PSNR value improves with only slice coding at low compression.

0.40 bpp

Summary & Future plan

We discussed an improved version of
our Multi－neighbor Predictors and Residual Orthogonal Transformations,
MPROT, which was a Haar transform-based lossy image compression method
without generating mosquito noise and block artifacts.

Challenge 1：Cutting isolated AC components to improve subjectivity

Challenge 2：Đevelop bit rate reduction methods other than zero run-length encoding

☑ Filters to remove isolated AC components

☑ Slice Run-Length Encoding

PSNR values improve in all compression ratios.

Several well-known recent schemes also use information from adjacent blocks.

To beat these methods,
our goal is to increase the PSNR value by another 1 dB without adaptive processing.

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Acknowledgment

This work was supported in part by JSPS KAKENHI
(Grant numbers 21K11972).

References

[1] G.K.Wallace: The JPEG still picture compression standard, IEEE Trans. Consumer Electronics, 38 (1992), xviii–xxxiv.

[2] A.S. Lewis, G. Knowles: Image compression using the 2-D wavelet transform, IEEE Transactions on Image Processing, 1:2(1992), 244–250.

[3] K. Ashizawa, K.Yamatani, N.Saito: The method of hierarchical multi-neighbor predictors and residual orthogonal transforms and its application to image compression, Transactions of the Japan Society for Industrial and Applied Mathematics, 17:3 (2007), 239–257 (in Japanese).