# Performance Evaluation of Integer DCT for Image Compression (Invited Paper)

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# Agenda

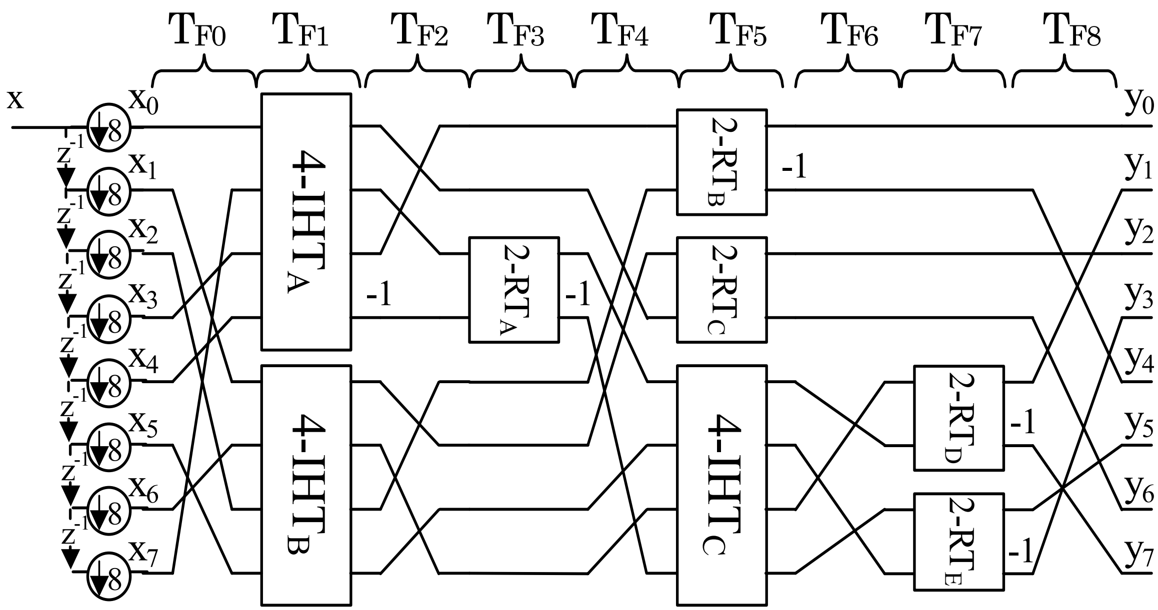
- Introduction + Motivation
- The Existing 1D Int-DCTs
- Lossless/Lossy Coding Criterion
- Simulation Results
- Conclusion

# Introduction + Motivation

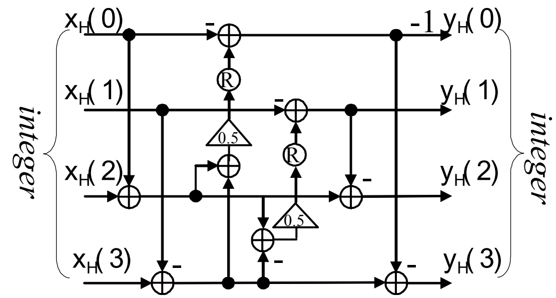
- The conventional DCT
  - A key transform in JPEG and MPEG
  - Can operate only lossy coding
- The Int-DCT
  - Has a compatibility with the conventional DCT
  - Can operate not only lossy coding but also lossless coding
  - Many kinds of Int-DCT have been proposed.
- Therefore, it's interesting to evaluate the existing Int-DCTs.

# The Existing 1D Int-DCTs

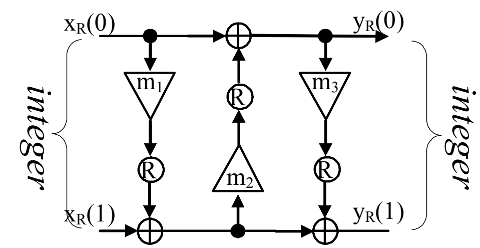
## 1. The Fukuma's 1D Int-DCT




**The Fukuma's 1D Int-DCT**




The 4-IHT



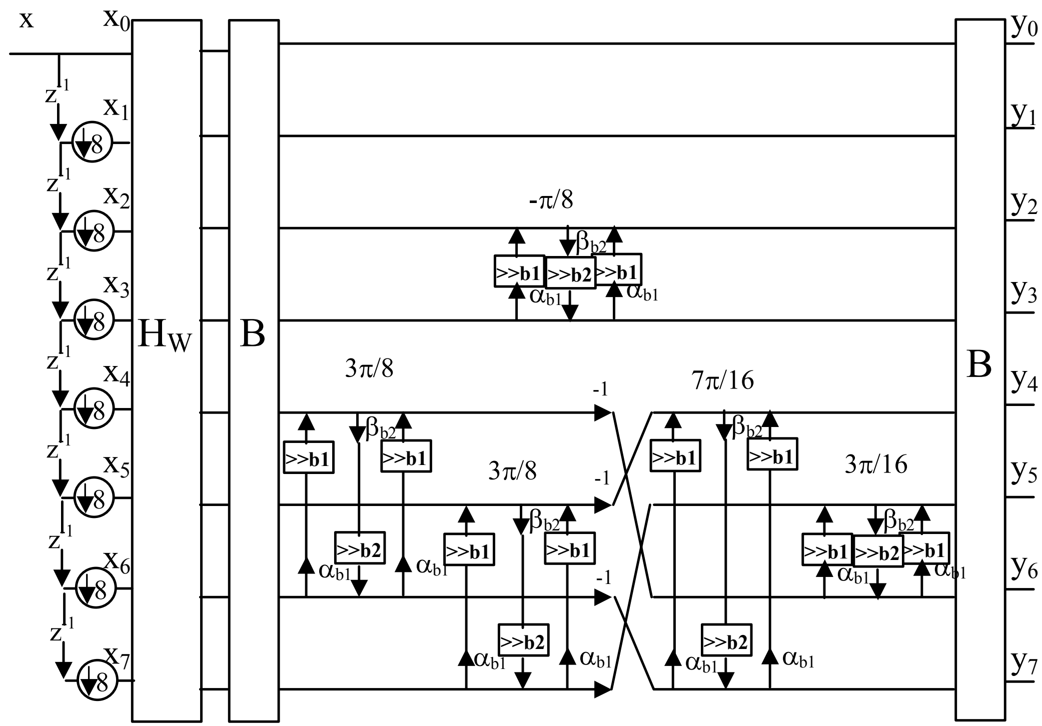

The 2-RT

# The Existing 1D Int-DCTs

## 2. The Y-J. Chen's 1D Int-DCT

$$\mathbf{H}_W = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \end{bmatrix}$$

$$\mathbf{B} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

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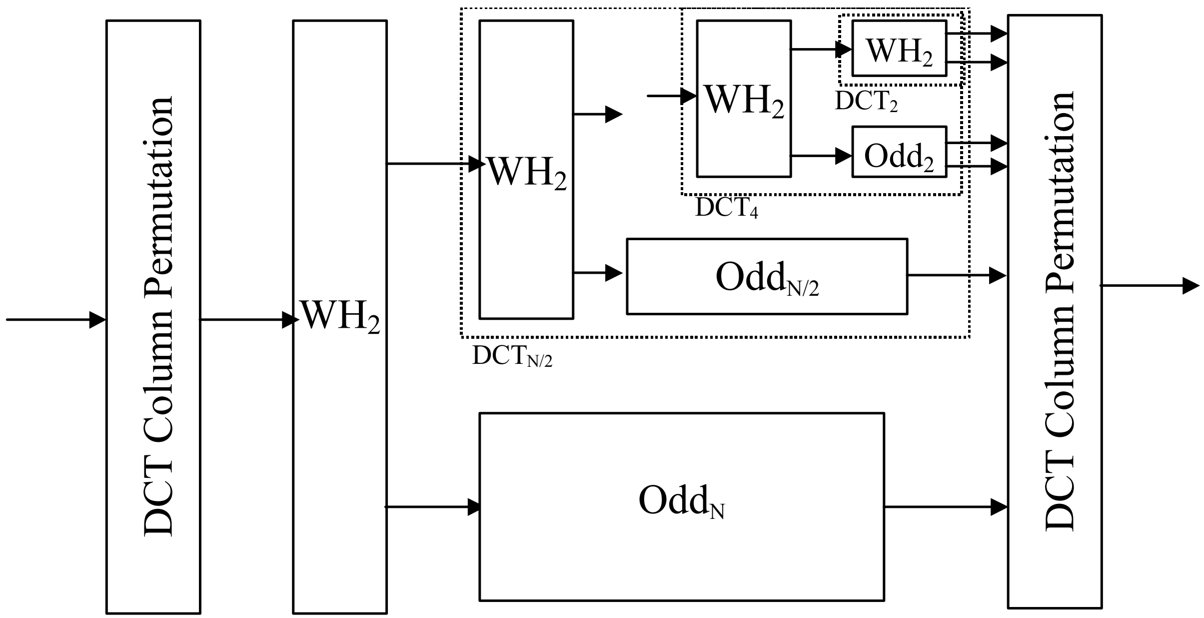
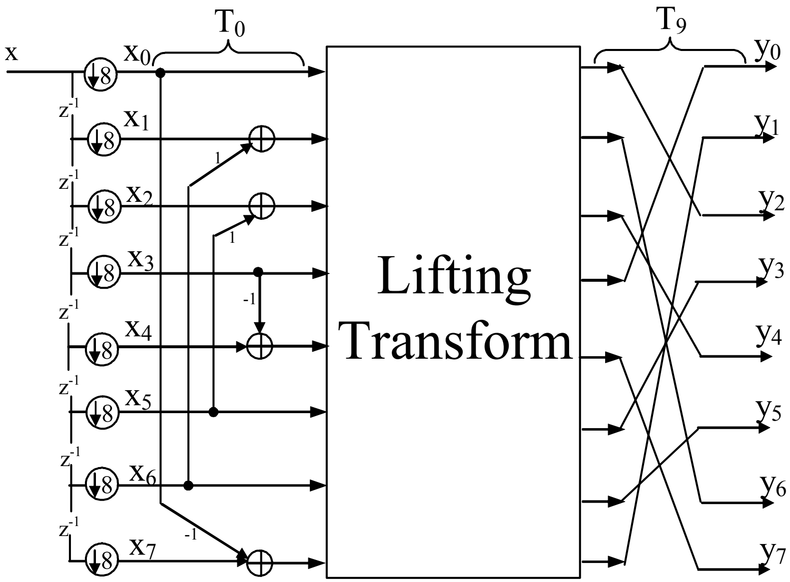
# The Existing 1D Int-DCTs

## 3. The Charith's N-point I2I-DCT-II

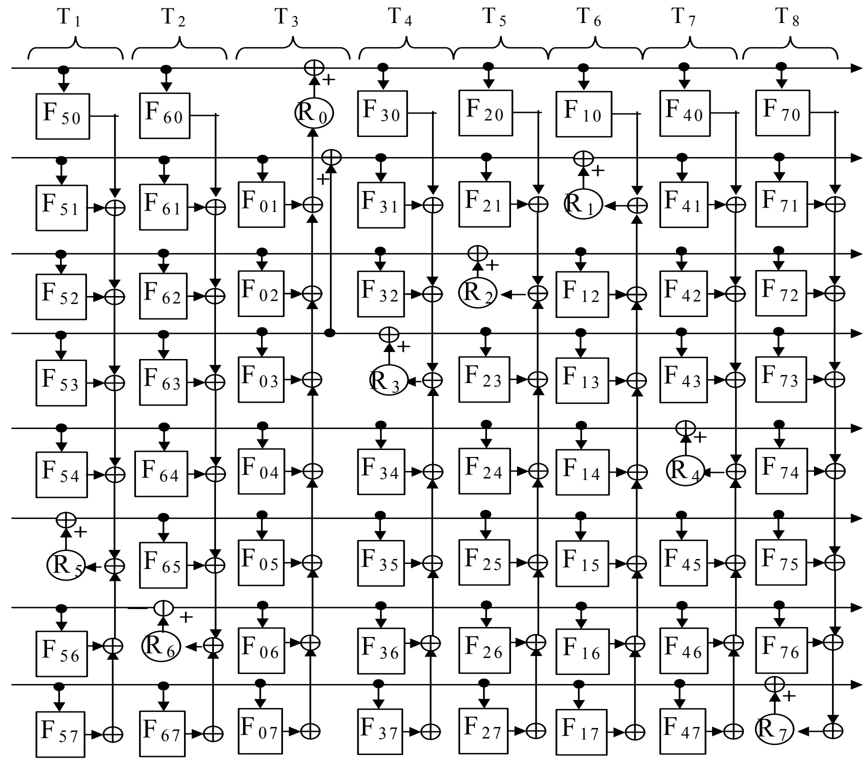


# The Existing 1D Int-DCTs

## 4. The Chokchaitam's 1D Int-DCT




The Chokchaitam's 8-point Int-DCT



Signal processing of lifting transformation

# The Existing 1D Int-DCTs

- **IDCT** matrix of the mentioned 8-point 1D Int-DCT

| Name of the Int-DCT | Transform matrix |
|---|---|
| The Fukuma's 1D Int-DCT | $\mathbf{IDCT_x}$ |
| The Y-J. Chen's 1D Int-DCT | $\sqrt{8}\ \mathbf{IDCT_x}$ |
| The Charith's 8-point I2I-DCT-II | $\mathbf{IDCT_x}$ |
| The Chokchaitam's1D Int-DCT | $\mathbf{IDCT_P}$ |

# The Existing 1D Int-DCTs

$$\mathbf{IDCT_X} = \begin{bmatrix} 1/\sqrt{8} & 1/\sqrt{8} & 1/\sqrt{8} & 1/\sqrt{8} & 1/\sqrt{8} & 1/\sqrt{8} & 1/\sqrt{8} & 1/\sqrt{8} \\ c_1(1) & c_1(3) & c_1(5) & c_1(7) & c_1(9) & c_1(11) & c_1(13) & c_1(15) \\ c_2(1) & c_2(3) & c_2(5) & c_2(7) & c_2(9) & c_2(11) & c_2(13) & c_2(15) \\ c_3(1) & c_3(3) & c_3(5) & c_3(7) & c_3(9) & c_3(11) & c_3(13) & c_3(15) \\ c_4(1) & c_4(3) & c_4(5) & c_4(7) & c_4(9) & c_4(11) & c_4(13) & c_4(15) \\ c_5(1) & c_5(3) & c_5(5) & c_5(7) & c_5(9) & c_5(11) & c_5(13) & c_5(15) \\ c_6(1) & c_6(3) & c_6(5) & c_6(7) & c_6(9) & c_6(11) & c_6(13) & c_6(15) \\ c_7(1) & c_7(3) & c_7(5) & c_7(7) & c_7(9) & c_7(11) & c_7(13) & c_7(15) \end{bmatrix}$$

$$c_i(m) = \cos(i * m * \pi/16)/2$$

$$\mathbf{IDCT_P} = \begin{bmatrix} 0.2929 & 0.2929 & 0.2929 & 0.2929 & 0.2929 & 0.2929 & 0.2929 & 0.2929 \\ 0.4809 & 0.4078 & 0.2725 & 0.0956 & -0.0956 & -0.2725 & -0.4078 & -0.4809 \\ 0.5 & 0.2071 & -0.2071 & -0.5 & -0.5 & -0.2071 & 0.2071 & 0.5 \\ 0.4239 & -0.0994 & -0.5 & -0.2832 & 0.2832 & 0.5 & 0.0994 & -0.4239 \\ 0.3536 & -0.3536 & -0.3536 & 0.3536 & 0.3536 & -0.3536 & -0.3536 & 0.3536 \\ 0.2725 & -0.481 & 0.0956 & 0.4078 & -0.4078 & -0.0956 & 0.481 & -0.2725 \\ 0.2133 & -0.5152 & 0.5152 & -0.2134 & -0.2134 & 0.5152 & -0.5152 & 0.2133 \\ 0.0995 & -0.2832 & 0.4239 & -0.5 & 0.5 & -0.4239 & 0.2832 & -0.0995 \end{bmatrix}$$

# Lossless/Lossy Coding Criterion

- **Lossless coding criterion**

$$C_{LSL} = 20\log_{10}\frac{2^{B_{PCM}}}{2^{B_{LSL}}}$$

- **Lossy coding criterion**

$$C_{LSY,Q} = 10\log_{10}\frac{\sigma^2_{PCM}}{\sigma^2_{N_Q}} \qquad C_{LSY,Q} = C_{LSL} - \Omega$$

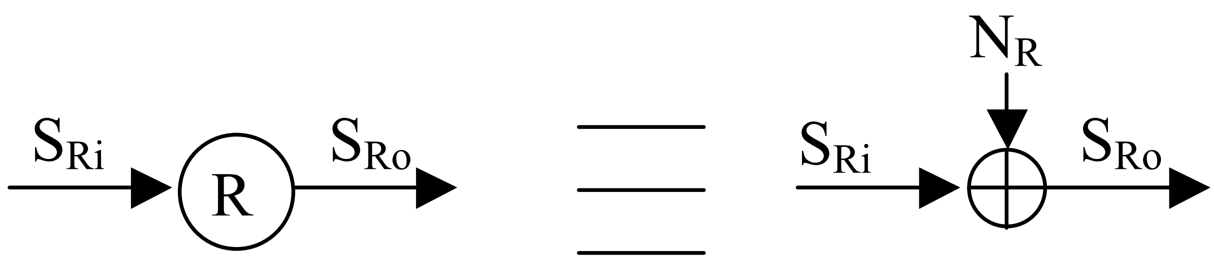
$$C_{LSY} = 10\log_{10}\frac{\sigma^2_{PCM}}{10^{-C_{LSY,Q}}\,\sigma^2_{PCM} + \sigma^2_{N_R}}$$

# Lossless/Lossy Coding Criterion

- **Assumption for calculating a variance of rounding error**

  1) correlations between each of the errors and the signals are zero (statistical independence)

  2) power spectrum of rounding error are flat.



# Simulation Results

- **Lossless coding criterion**

| Name of the Int-DCT | Average Lossless Coding criterion |
| --- | --- |
| The Fukuma's 1D Int-DCT | 6.95 |
| The Y-J. Chen's 1D Int-DCT | -8.39 |
| The Charith's 8-point I2I-DCT-II | 6.85 |
| The Chokchaitam's1D Int-DCT | 6.97 |

# Simulation Results

- **Lossy coding criterion**

| Name of the Int-DCT | No. rounding operation | A variance of rounding error | $\Omega_{opt}$ | Q-lossy coding gain |
|---|---|---|---|---|
| The Fukuma's 1D Int-DCT | 21 | 0.25 | 0 | 6.95 |
| The Y-J. Chen's 1D Int-DCT | 15 | 0.07 | -18.06 | 9.67 |
| The Charith's 8-point I2I-DCT-II | 51 | 0.54 | 0 | 6.85 |
| The Chokchaitam's 1D Int-DCT | 8 | 0.11 | 0 | 6.97 |

# Conclusion

| Name of the Int-DCT | Lossless Coding | Lossy Coding |
|---|---|---|
| The Fukuma's 1D Int-DCT | 2 | 3 |
| The Y-J. Chen's 1D Int-DCT | 4 | 1 |
| The Charith's 8-point I2I-DCT-II | 3 | 4 |
| The Chokchaitam's1D Int-DCT | 1 | 2 |

Thank you

Q &A