Image compression

Dr. Tushar Sandhan

Introduction

- Storage
  - memory devices are cheaper
  - compression & decompression add extra computational burden
  - do we really need compression?

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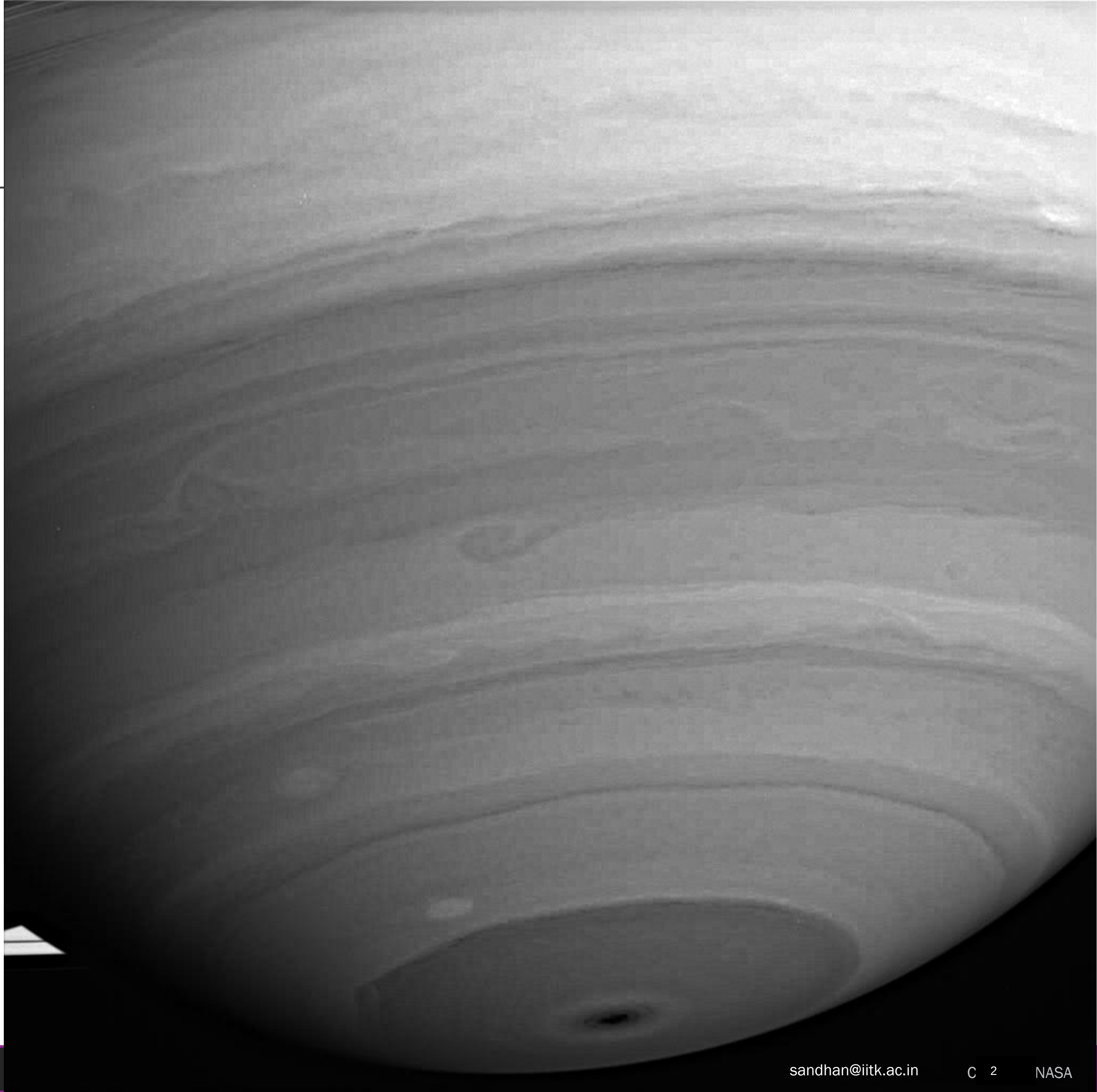
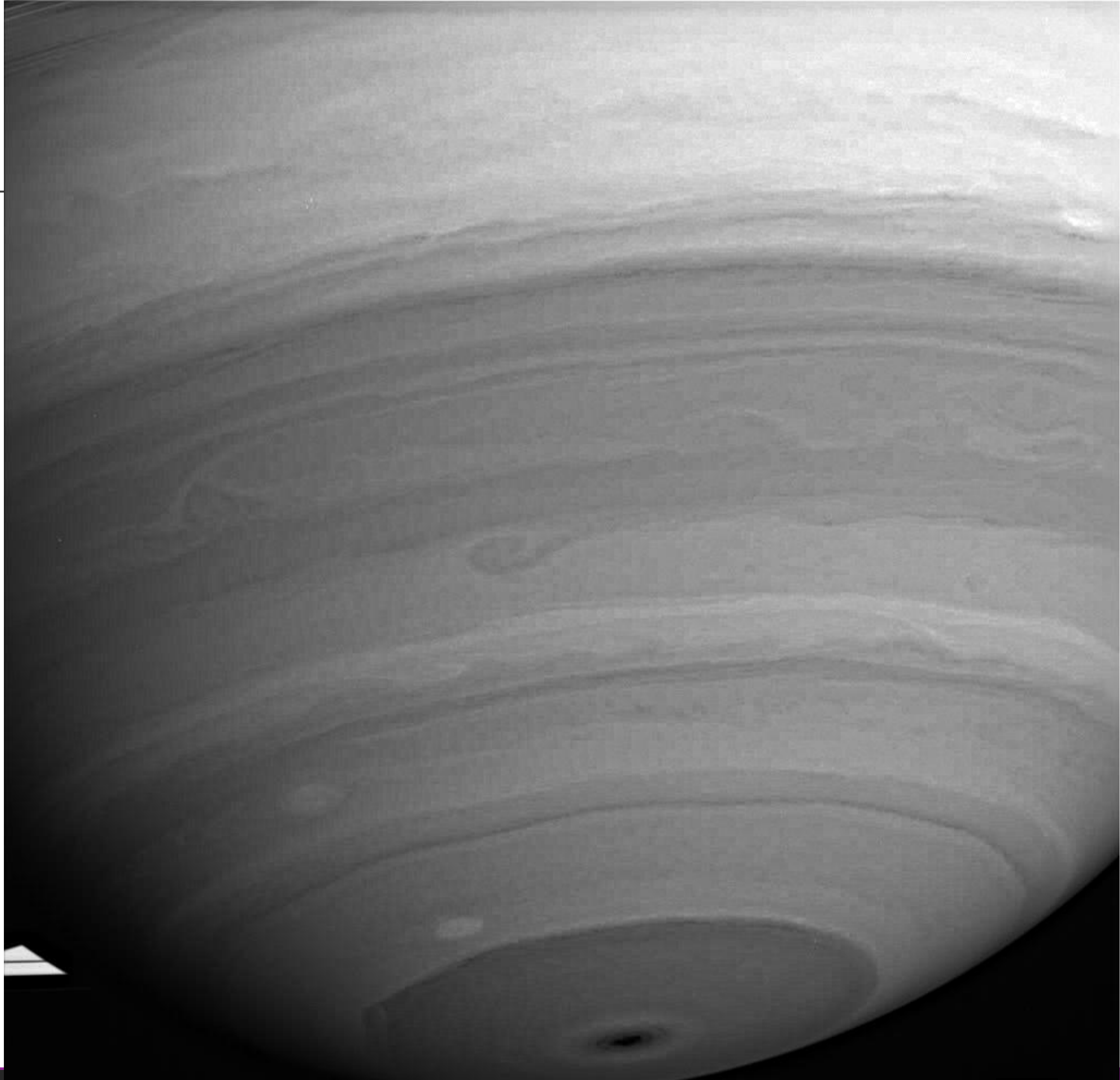

NASA

sandhan@iitk.ac.in

Introduction

- Storage
  - memory devices are cheaper
  - compression & decompression add extra computational burden
  - do we really need compression?

- Saturn
  - infrared view of southern hemisphere
  - by Casssini spacecraft
  - taken from 1.3 million Km
  - obtained ground resolution 77 Km



NASA

Compression need

- Storage & transmission
  - raw data occupies huge space
  - 1920 x 1080 image at 24 bits per pixels has a size of about 6.2 MB uncompressed
  - JPEG makes it 200KB
  - your 1hr long video lec recordings ~100MB

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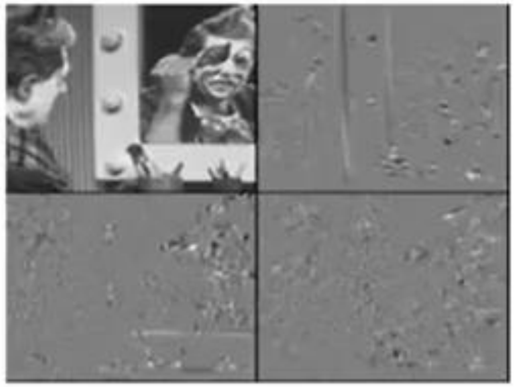
- We will see
  - sub-band compression
  - JPEG
  - JPEG2000

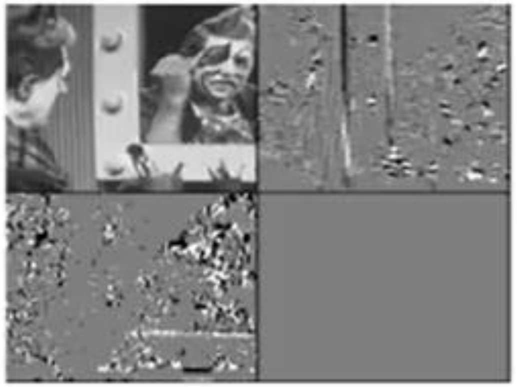
Sub-band coding compression

- Equi-rate sub-band coding

input



4 band decompose



quantized

compressed

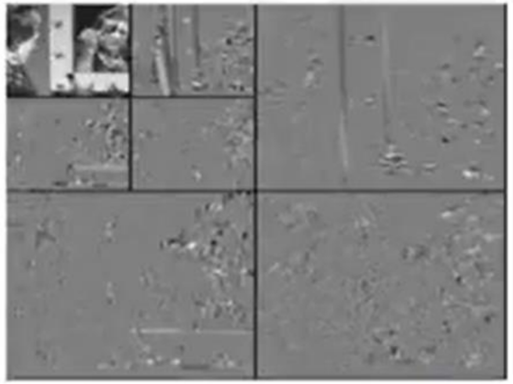
80% compression

PSNR 36.6dB

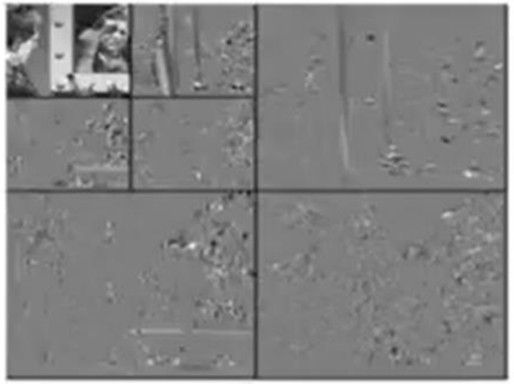
Sub-band coding compression

- Multi-rate sub-band coding

input



7 band decompose



quantized

compressed

80.6% compression

PSNR 36.2dB

JPEG

- Joint Photographic Experts Group
  - JPEG: a lossy compression algorithm
  - it's not a file format
  - standardized in 1992
  - a lossy compression

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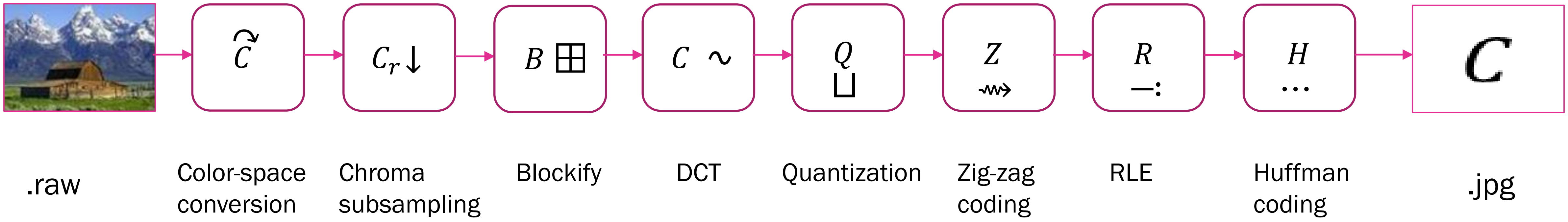
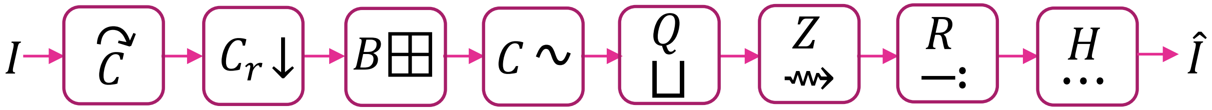


JPEG



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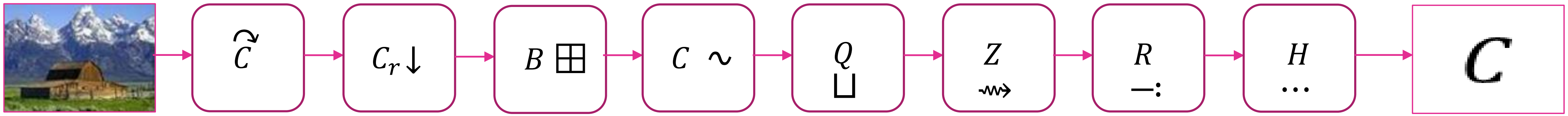
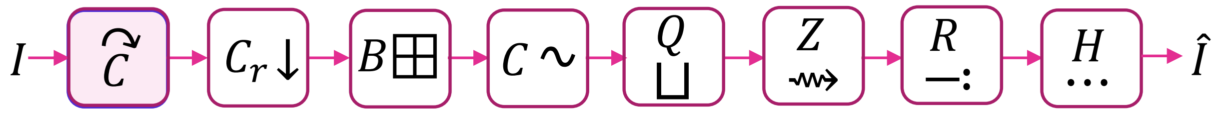


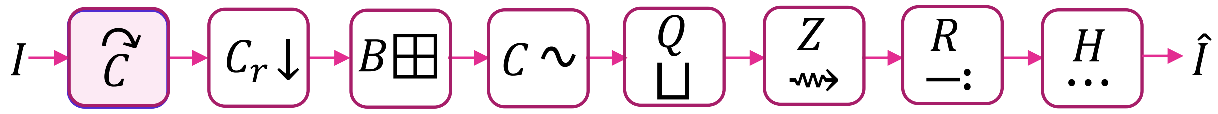
.raw | Color-space conversion | Chroma subsampling | Blockify | DCT | Quantization | Zig-zag coding | RLE | Huffman coding | .jpg

Color conversion



- RGB → YCbCr
  - Y – Luma
  - Cb – blue chroma
  - Cr – red chroma
  - used in TV, videos, JPEG, MPEG
  - allocate high bandwidth for Y & low for chromas
  - other variations:
    - YUV=PAL, YIQ=NTSE

Color conversion



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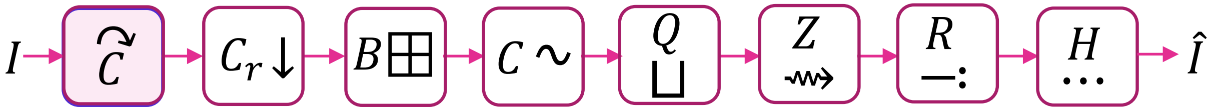
$$\begin{bmatrix} Y \\ C_B \\ C_R \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \frac{1}{256} \begin{bmatrix} 65.73 & 129.05 & 25.06 \\ -37.94 & -74.49 & 112.43 \\ 112.43 & -94.15 & -18.28 \end{bmatrix} \bullet \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Color conversion



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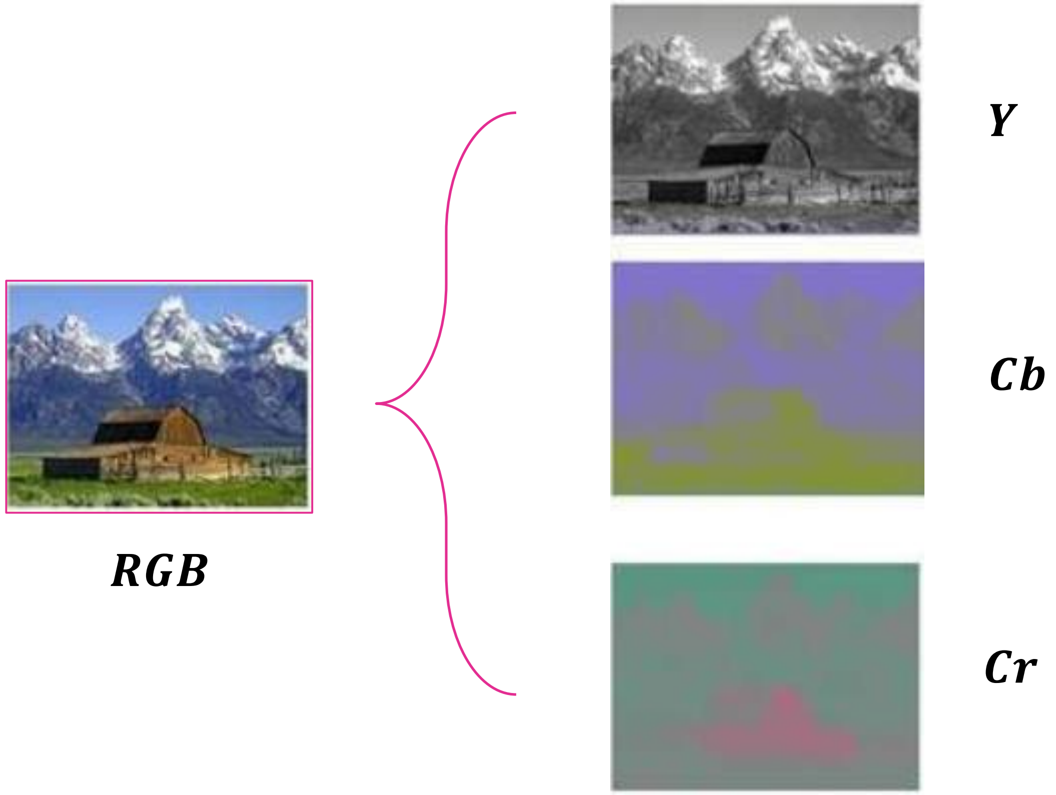
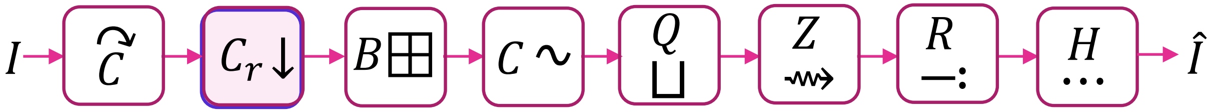
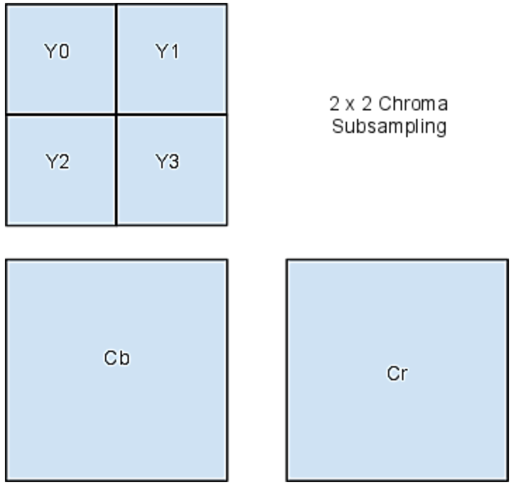


Chroma subsampling

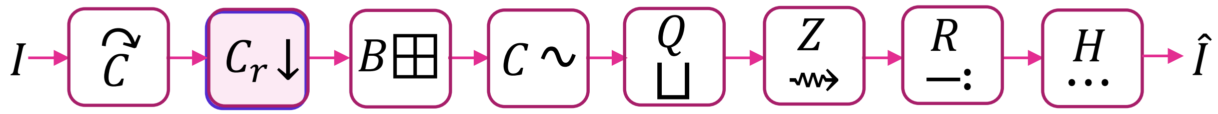


- Decimating only chroma
  - subsampling is done only in chroma
  - 4:2:0 JPG, video H.264 codec
  - Y is stored at full resolution



Y'_{00} Cb_{00} Cr_{00}	Y'_{10}	Y'_{20} Cb_{20} Cr_{20}	Y'_{30}
Y'_{01}	Y'_{11}	Y'_{21}	Y'_{31}

Chroma subsampling



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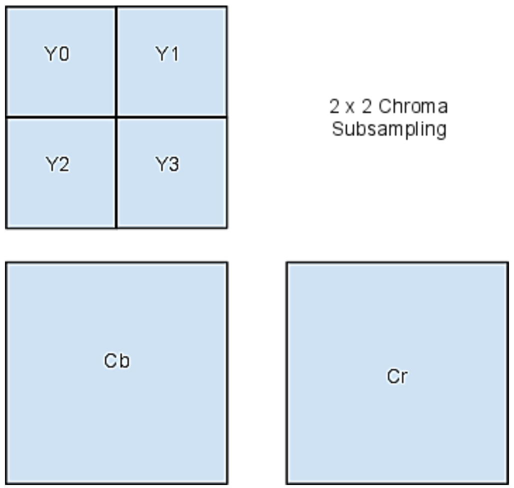

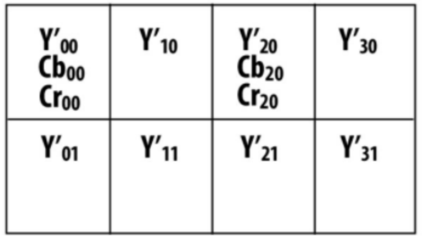

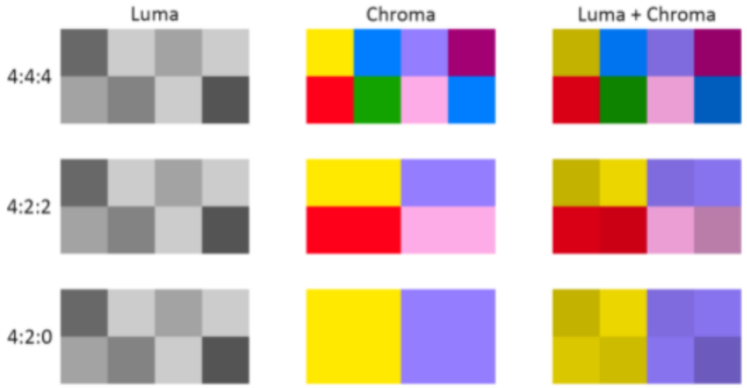

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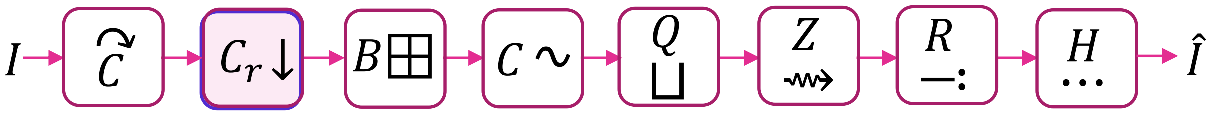

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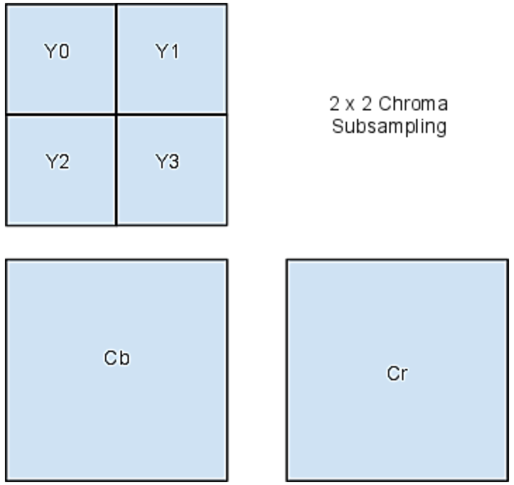
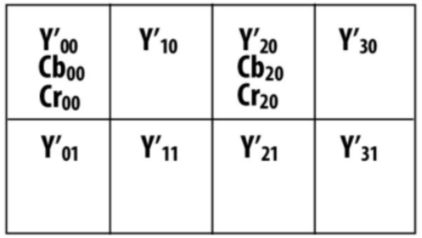
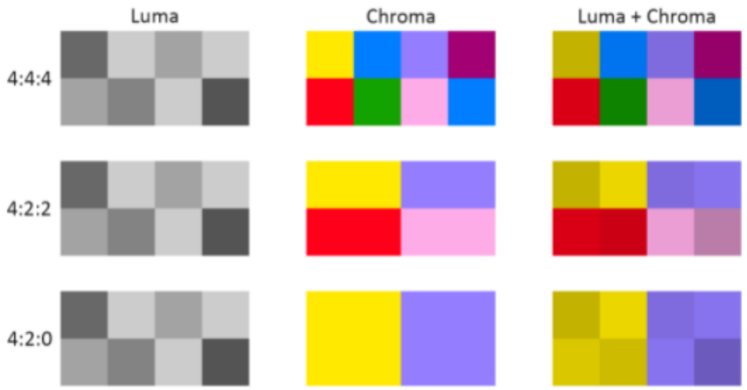
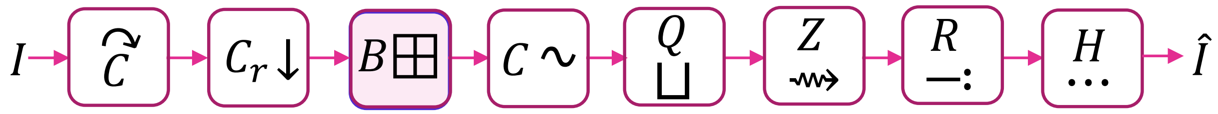
	Subsampling
PC	4:4:4
Movies	4:2:0
Video Games	4:4:4
Sports	4:2:0
TV Shows	4:2:0



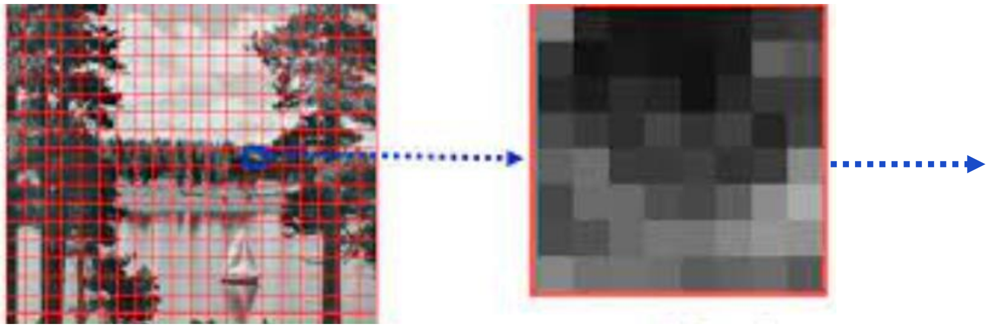




Blocking



- Analyze the image into smaller blocks
  - small blocks called subimage
  - subimage sizes 8x8, 16x16 etc.
  - Jpeg uses 8x8



42	28	35	28	42	49	35	42
49	49	35	28	35	35	35	42
42	21	21	28	42	35	42	28
21	35	35	42	42	28	28	14
56	70	77	84	91	28	28	21
70	126	133	147	161	91	35	14
126	203	189	182	175	175	35	21
49	189	245	210	182	84	21	35

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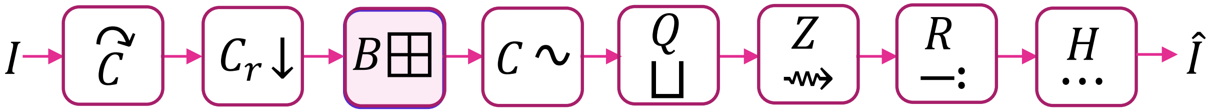

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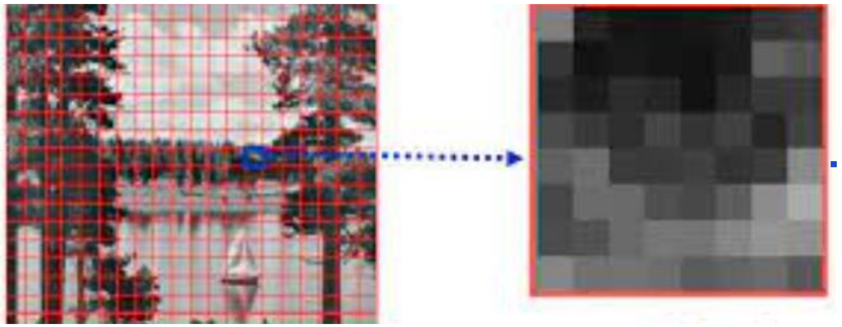

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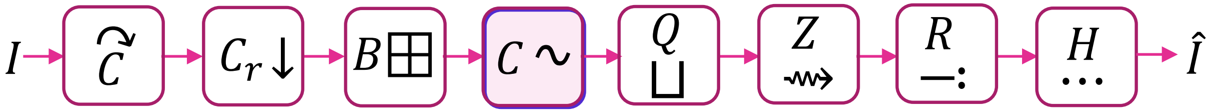
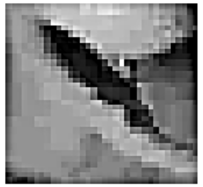
Blocking artifacts

DCT



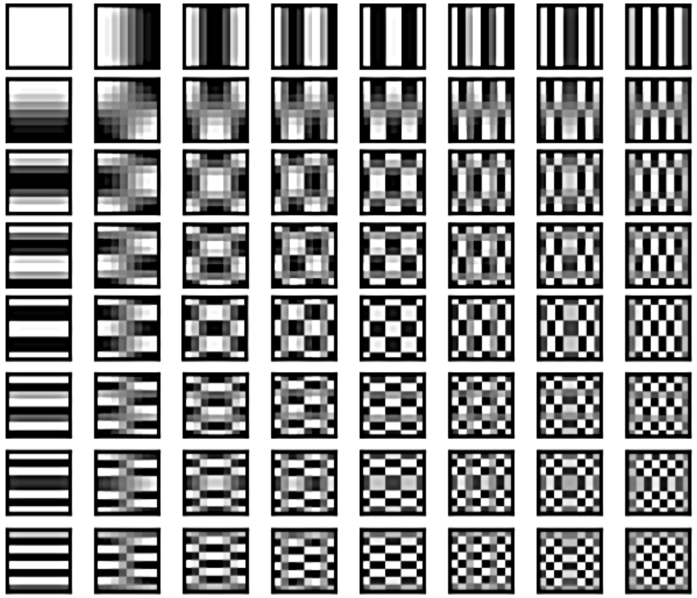
- Discrete cosine transform

$$\text{basis}[i,j] = \cos\left[\pi\frac{i}{N}\left(x+\frac{1}{2}\right)\right] \times \cos\left[\pi\frac{j}{N}\left(y+\frac{1}{2}\right)\right]$$



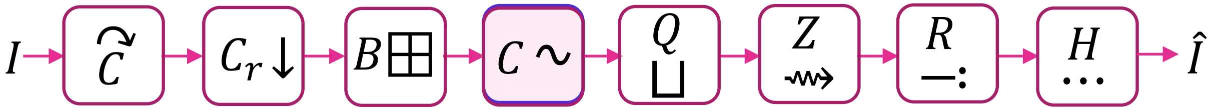
$$= \begin{bmatrix} -415 & -30 & -61 & 27 & 56 & -20 & -2 & 0 \\ 4 & -22 & -61 & 10 & 13 & -7 & -9 & 5 \\ -47 & 7 & 77 & -25 & -29 & 10 & 5 & -6 \\ -49 & 12 & 34 & -15 & -10 & 6 & 2 & 2 \\ 12 & -7 & -13 & -4 & -2 & 2 & -3 & 3 \\ -8 & 3 & 2 & -6 & -2 & 1 & 4 & 2 \\ -1 & 0 & 0 & -2 & -1 & -3 & 4 & -1 \\ 0 & 0 & -1 & -4 & -1 & 0 & 1 & 2 \end{bmatrix} \times$$

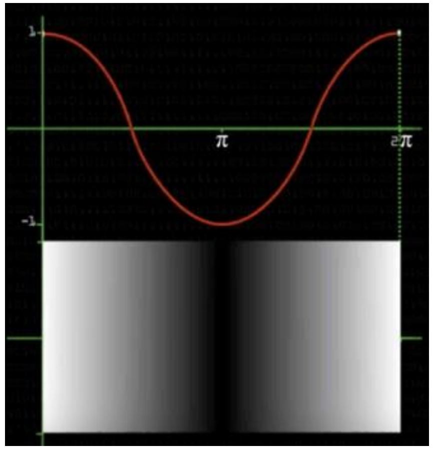
[0,0]

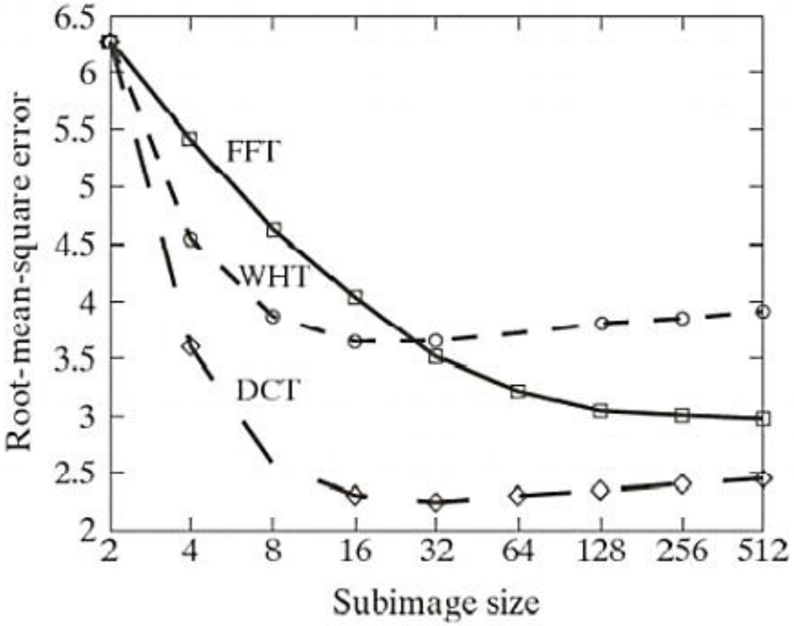


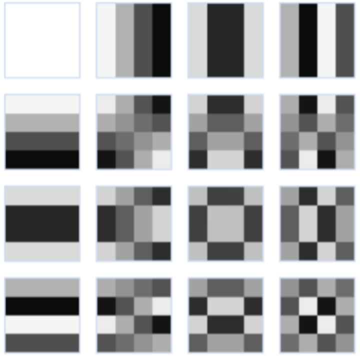
[7,7]

DCT









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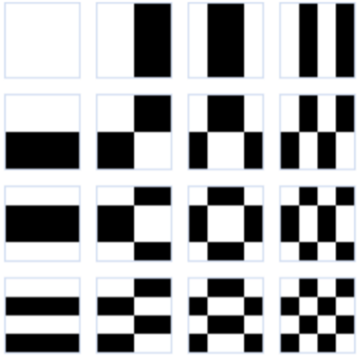
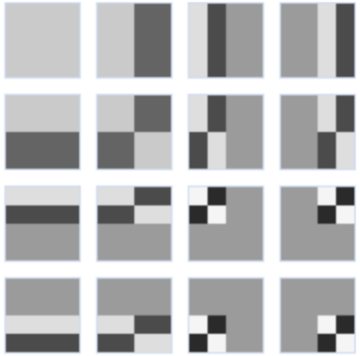
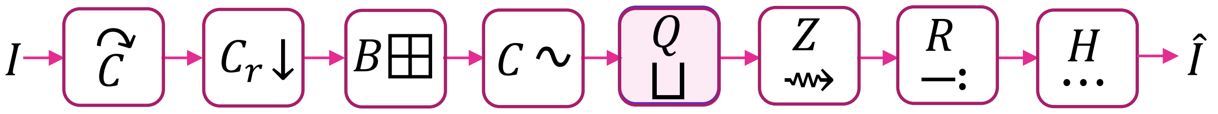


Walsh Hadamard



Haar wavelet

Quantization

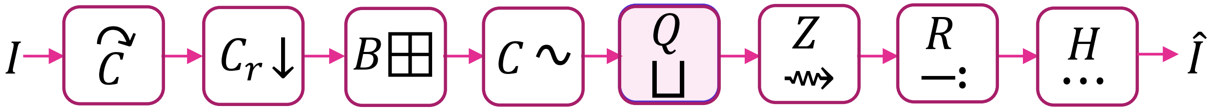


- Psycovisually-tunned quantization tables
  - experiments on human subjects to find quantization values

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

$$\hat{c}[k_1, k_2] = \text{round}(c[k_1, k_2]/Q[k_1, k_2])$$

Quantization



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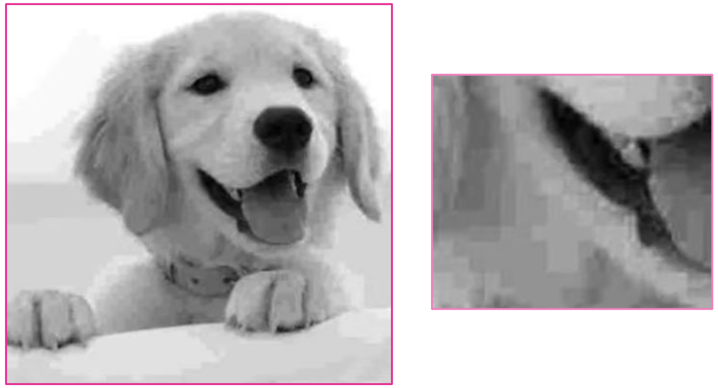
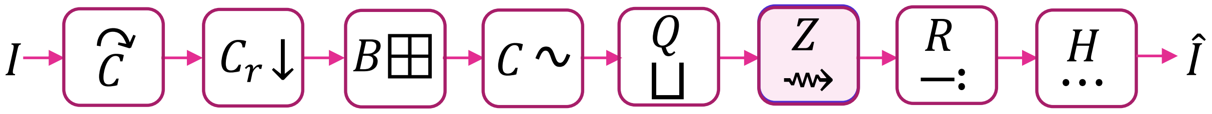
Uniform

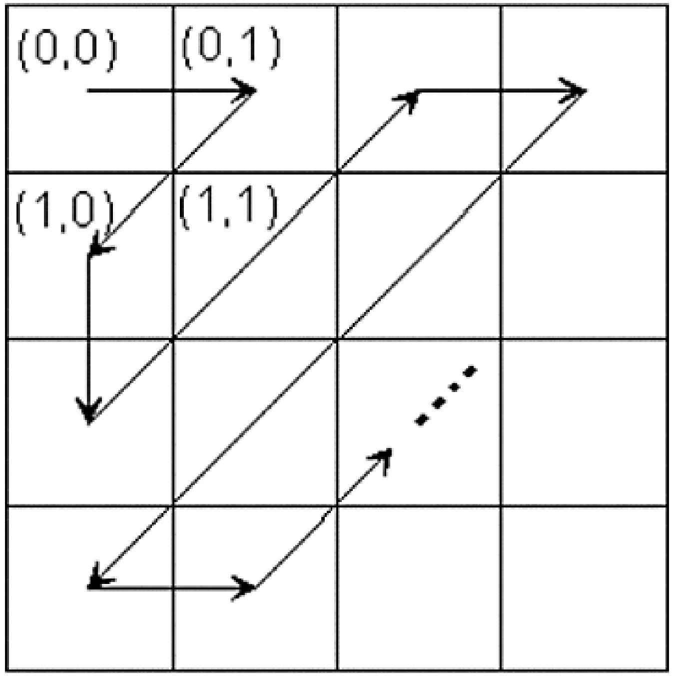
Q



Coding



- Zig-zag coding
  - what can we achieve?



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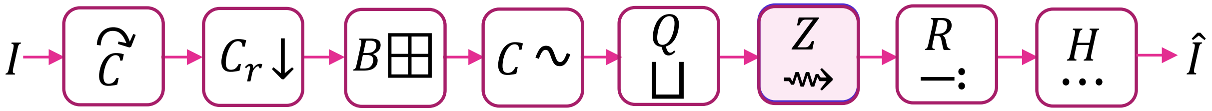
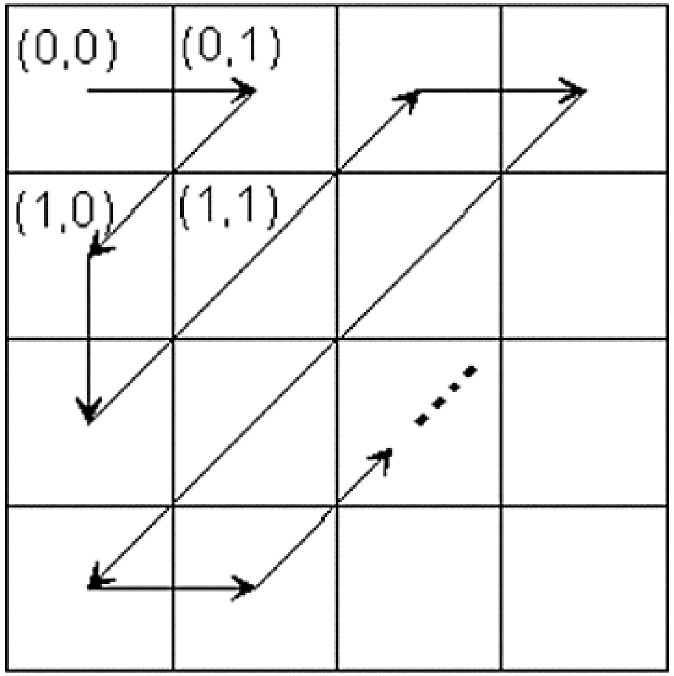
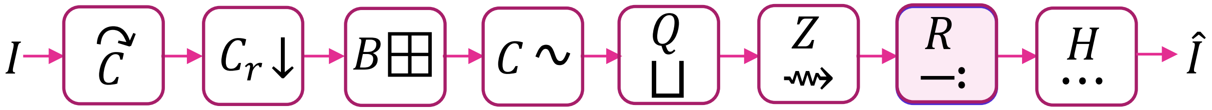


- Zig-zag coding
  - what can we achieve?

-24	-23	0	0	0	0	0	0
-19	4	1	0	0	0	0	0
5	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0



RLE: Runlength encoding



- Quantized: $\hat{C} =$

$$\begin{bmatrix} 100 & -60 & 0 & 6 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 13 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

- Coding:

100, -60, 0, 0, 0, 0, 6, 0, 0, 0, 13, 0, 0, 0, 0, 0, 0, 0, 13, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
0, 0, 0, 0, 0, 0, 0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0

Courtesy: EPFL

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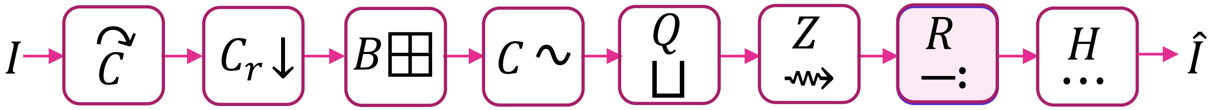

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- Coding:

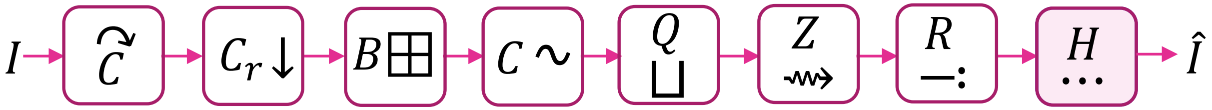
100, -60, 0, 0, 0, 0, 6, 0, 0, 0, 13, 0, 0, 0, 0, 0, 0, 0, 0, 13, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
0, 0, 0, 0, 0, 0, 0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0

- $[(r, s), c]$
  - c – current value
  - r – #of 0 before c
  - s – #bits needed to encode c
  - $0 \leq s \leq 11;\ \ 0 \leq r \leq 15$
  - $(r, s) \leftarrow$ 8 bits uchar

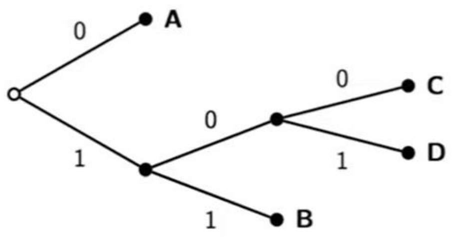
$[(0,7),\ 100],\ [(0,6),\ -60],\ [(4,3),\ 6],\ [(3,4),\ 13],\ [(8,1),\ -1], [(0,0)]$

Courtesy: EPFL

Hoffman coding

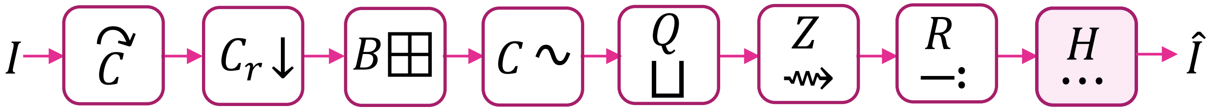


- Lossless coding method
  - RLE output can be coded by any lossless coding methods (e.g. methods from communications, networks etc.)
  - JPEG uses Hoffman coding (1952)
  - it's a variable length code



RLE: AABAABADC → 001100110101100

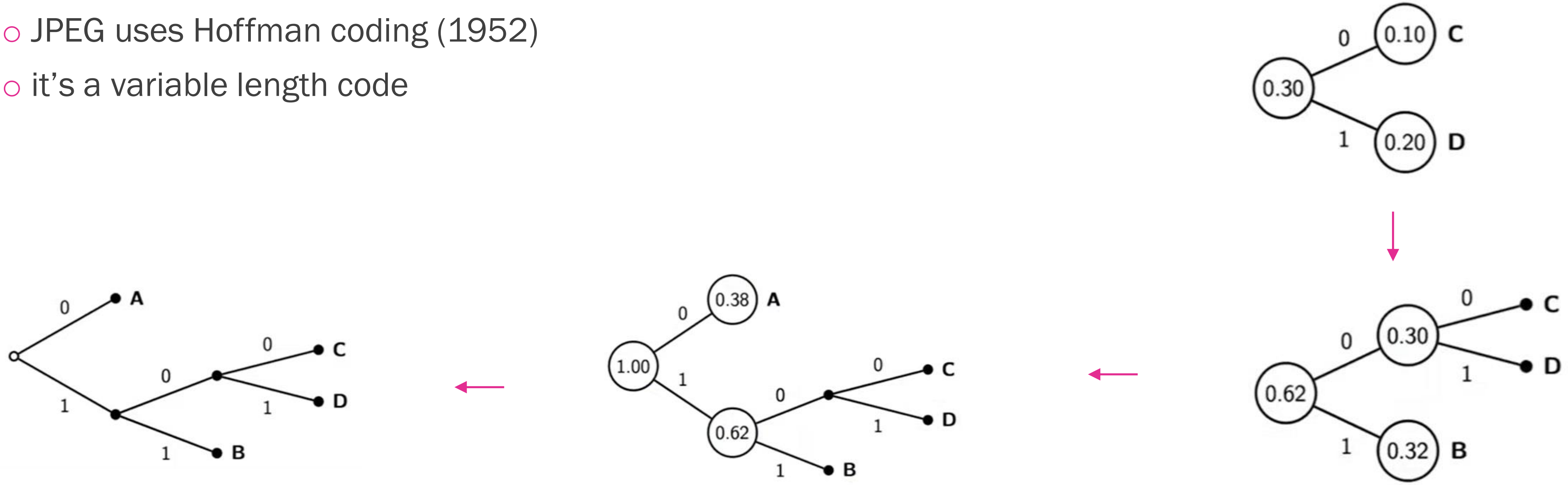
Hoffman coding



- Lossless coding method
  - RLE output can be coded by any lossless coding methods (e.g. methods from communications, networks etc.)
  - JPEG uses Hoffman coding (1952)
  - it's a variable length code

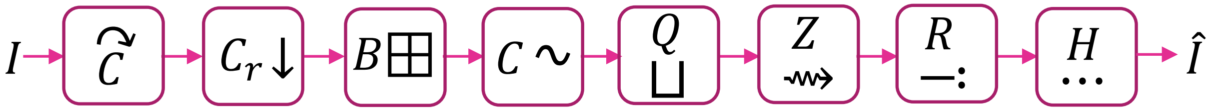
$p(A) = 0.38$ $p(B) = 0.32$

$p(C) = 0.1$ $p(D) = 0.2$



RLE: AABAABADC $\longrightarrow$ 001100110101100

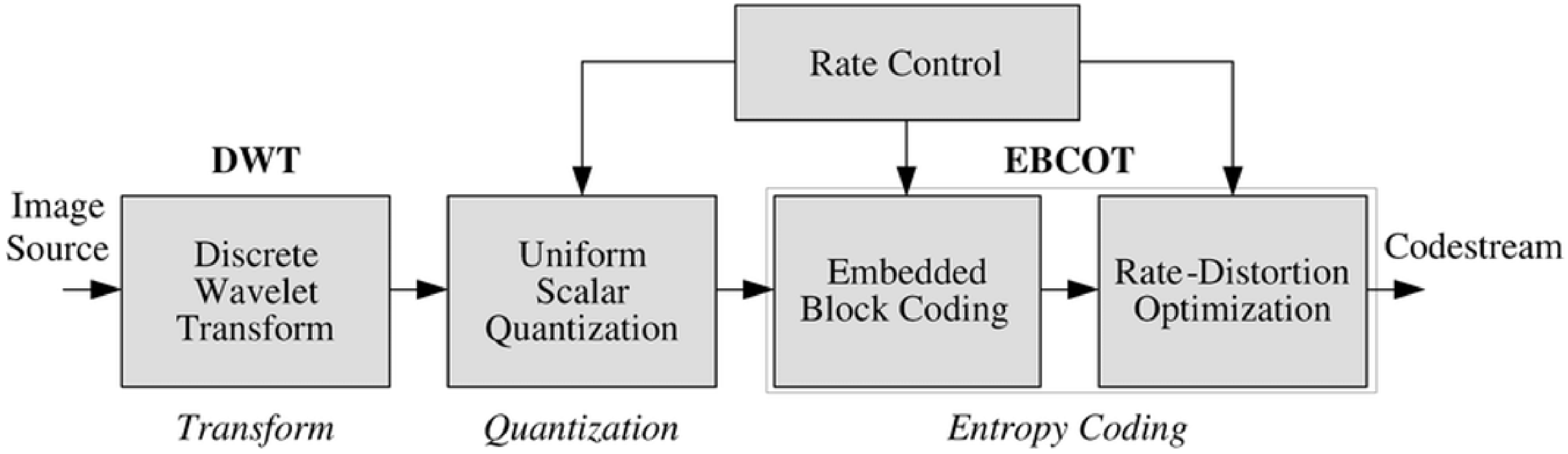
JPEG

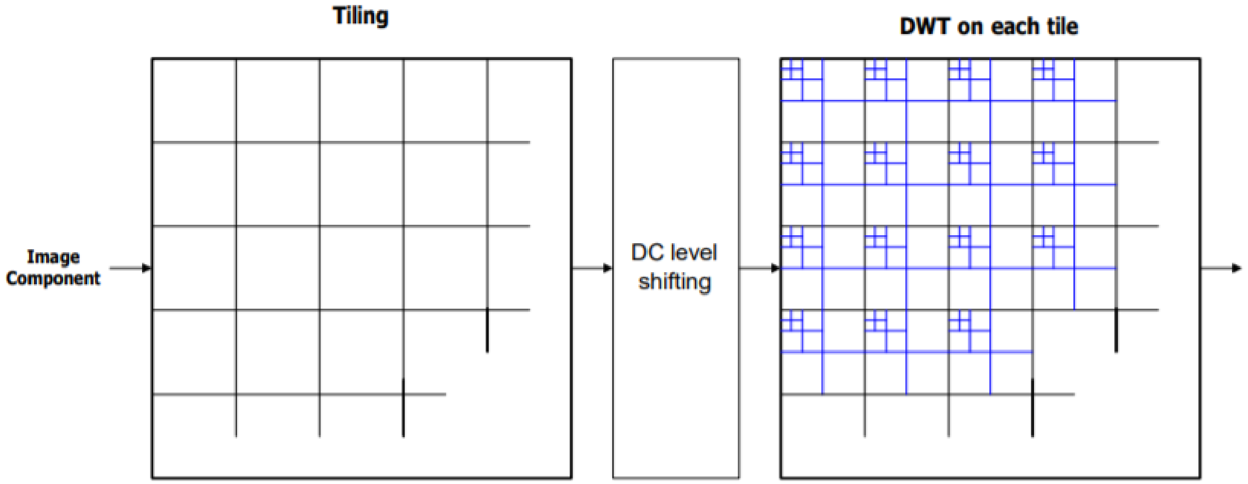


- Pseudocode

: $RGB \rightarrow YCbCr$
: $CbCr$ dessimation (4:2:0) to $Cb'Cr'$
: For each channel in $[Y, Cb', Cr']$:
        : blockify into 8x8 subblocks
        : For each subblock
                : get DCT
                : pyscovisually quantize
                : zig-zag coding
                : RLE
                : Huffman

JPEG 2000


Rate Control
DWT
EBCOT
Image Source
Discrete Wavelet Transform
Uniform Scalar Quantization
Embedded Block Coding
Rate-Distortion Optimization
Codestream
Transform
Quantization
Entropy Coding


Tiling
DWT on each tile
Image Component
DC level shifting

Comparison

JPEG

0.25bpp

JPEG 2000

0.25bpp

Courtesy: Christopoulos et al.

Comparison

JPEG	JPEG 2000
DCT	DWT
Blocks	Tiles
Less compression ratio	High compression ratio
Less computations	Relatively higher computations
Quality low at low bit rate	Better quality at low bit rate

Example

Uncompressed
378 KiB
1:1
JPEG JFIF
11.2 KiB
1:33.65
JPEG 2000
11.2 KiB
1:33.65

References

- Sub-bands
- Multi-Resolution Analysis (MRA)
- Denoise
- Compression

References

- Sub-bands
- Multi-Resolution Analysis (MRA)
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- Compression

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