Special Module on Media Processing and Communication

Dayalbagh Educational Institute
(DEI)
Dayalbagh Agra

PHM 961

Indian Institute of Technology Delhi
(IITD)
New Delhi

SIV 864

Recap

- Lecture 2
  - Definitions
    - Compression Ratio, Fidelity Measures
    - Data Redundancy
  - Compression Techniques
    - Symmetric and Asymmetric
    - Loss-less and Lossy
    - Loss-less
      - Variable length coding (Huffman Coding)

Image Compression

Run Length Coding

Run: a string of the same symbol

Example

input: AAABBCCCCCCCCCAA
output: A3B2C9A2

compression ratio = 16/8 = 2

Image Compression

Predictive Coding

Basic premise: Current pixel is similar to the previous pixel (coherence)

Differential Coding

$$d(x,y) = I(x,y) - I(x-1,y)$$

d(x,y) prediction error which is to be encoded.

Image Compression

Predictive Coding

Compression

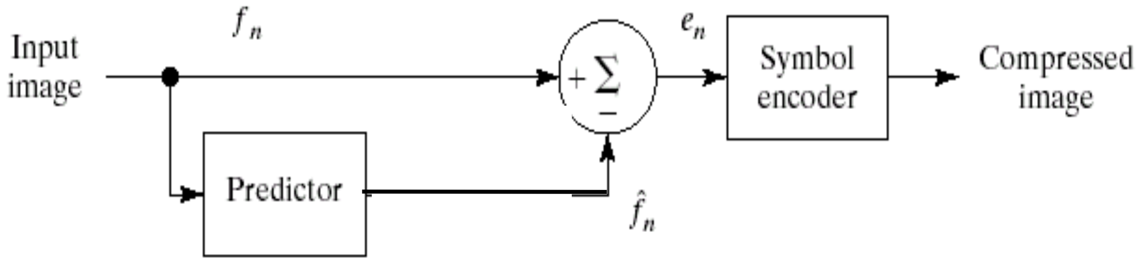


Image Compression

Predictive Coding

Decompression

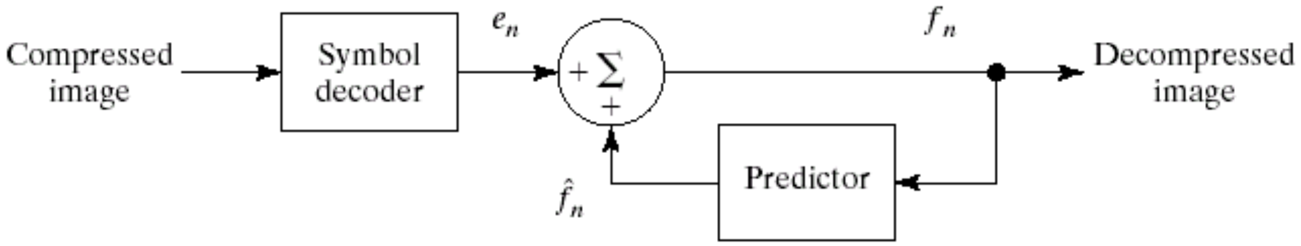
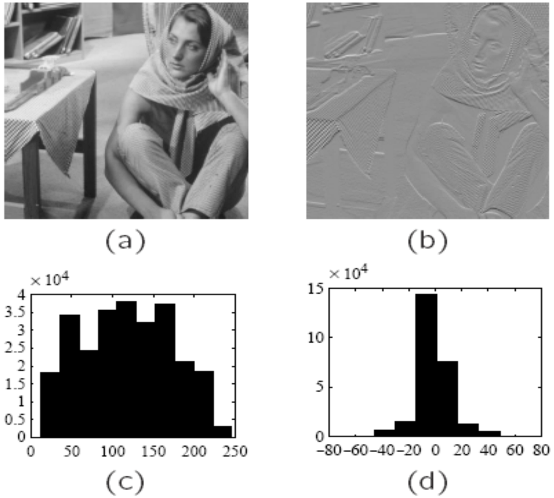


Image Compression

Predictive Coding



Distributions for Original versus Derivative Images. (a,b): Original gray-level image and its partial derivative image; (c,d): Histograms for original and derivative images.

Image Compression

Lossy

- Psychovisual redundancy
- Keep more important information
- Trade off between loss (degradation) and compression

Original

Compression Ratio: 7.7

Compression Ratio: 12.3

Compression Ratio: 33.9

Image Compression

Lossy

Original

Image Compression

Lossy

Compression Ratio 7.7

Image Compression

Lossy

Compression Ratio 33.9

Image Compression

Lossy

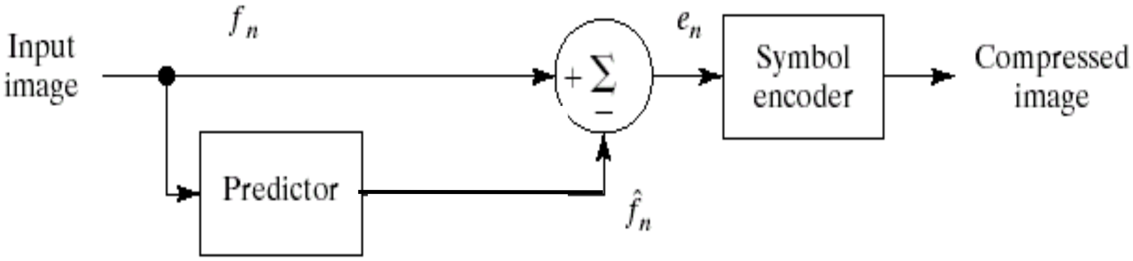
- Recall Quantization
  - Discrete value to represent range of values
  - Irreversible operation
  - Information loss !

- Predictive Coding
- Transform Coding

Image Compression

Predictive Coding: Loss-less (Revisit)

Compression



Decompression

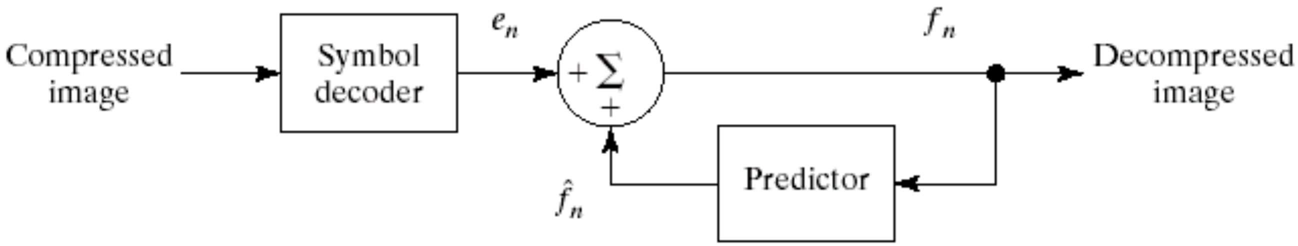
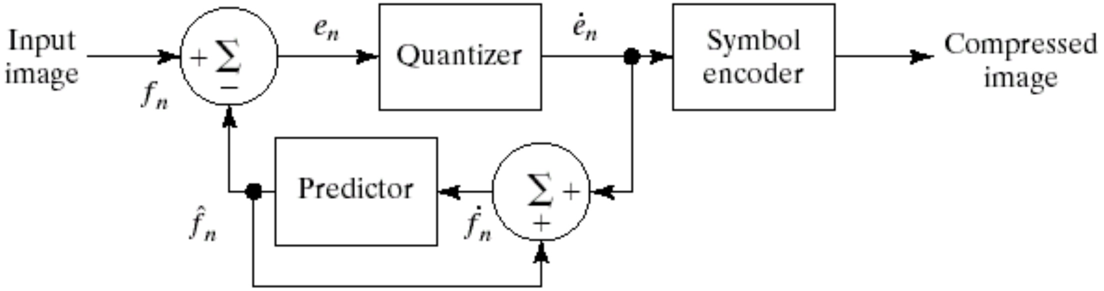


Image Compression

Predictive Coding: Lossy

Compression



Decompression

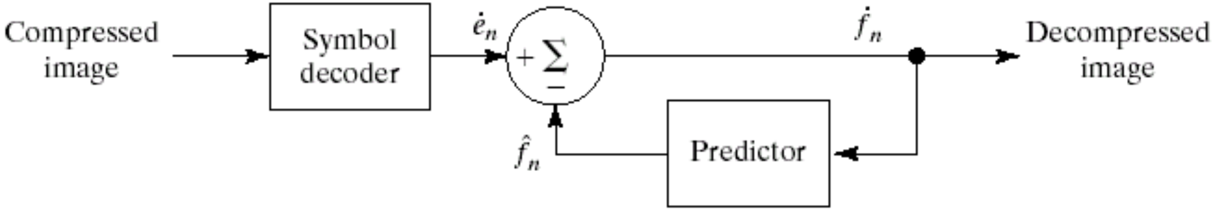


Image Compression

Predictive Coding: Lossy

Delta Modulation

Example:

$$\hat{f}_n = \alpha \dot{f}_{n-1}$$

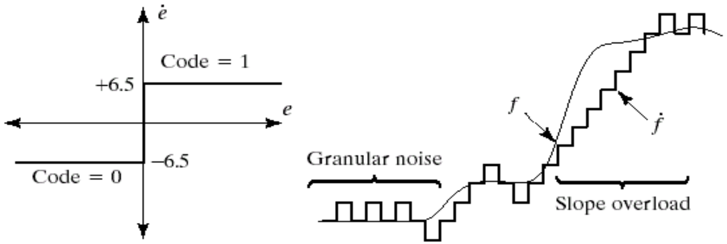
$0 < \alpha < 1$
prediction coefficient

and $$\dot{e}_n = \begin{cases} +\xi & e_n > 0 \\ -\xi & e_n < 0 \end{cases}$$

$$\dot{f}_n = \dot{e}_n + \hat{f}_n$$
$$= \dot{e}_n + \alpha \dot{f}_{n-1}$$

Image Compression

Predictive Coding: Lossy



a b
c

FIGURE 8.22 An example of delta modulation.

Input		Encoder				Decoder		Error
n	f	$\hat{f}$	e	$\dot{e}$	$\dot{f}$	$\hat{f}$	$\dot{f}$	$[f - \dot{f}]$
0	14	—	—	—	14.0	—	14.0	0.0
1	15	14.0	1.0	6.5	20.5	14.0	20.5	–5.5
2	14	20.5	–6.5	–6.5	14.0	20.5	14.0	0.0
3	15	14.0	1.0	6.5	20.5	14.0	20.5	–5.5
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
14	29	20.5	8.5	6.5	27.0	20.5	27.0	2.0
15	37	27.0	10.0	6.5	33.5	27.0	33.5	3.5
16	47	33.5	13.5	6.5	40.0	33.5	40.0	7.0
17	62	40.0	22.0	6.5	46.5	40.0	46.5	15.5
18	75	46.5	28.5	6.5	53.0	46.5	53.0	22.0
19	77	53.0	24.0	6.5	59.6	53.0	59.6	17.5
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.

Image Compression

Transform Coding

Transformation

- Represent information in anther space
- Identify and remove correlation
- Quantization of transform coefficients

Information loss!

Example

time/space frequency

(Fourier Transform)

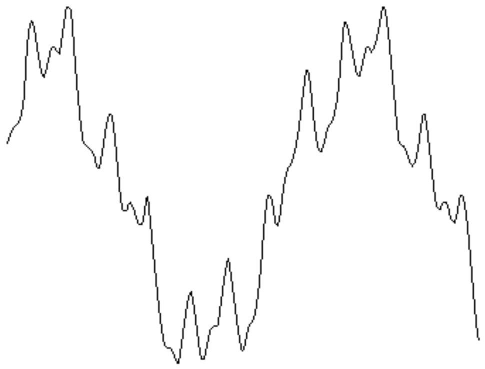
Inverse transformation

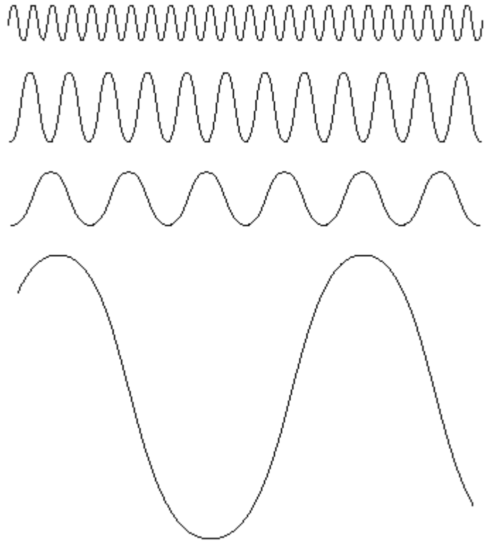
- Bring back information in the original space

Image Compression

Transform Coding

Fourier Transform (Review)





A function as sum of sines and cosines

Image Compression

Transform Coding

Fourier Transform (Review)

Mathematically

Forward

1-D:

$$F(u) \equiv \Im\{f(x)\} = \int_{-\infty}^{\infty} f(x) e^{-j2\pi ux} dx$$

Inverse

$$f(x) \equiv \Im^{-1}\{F(u)\} = \int_{-\infty}^{\infty} F(u) e^{j2\pi ux} du$$

2-D:

$$F(u,v) = \iint f(x,y) e^{-j2\pi(ux+vy)} \, dx \, dy$$

$$f(x,y) = \iint F(u,v) e^{j2\pi(ux+vy)} \, du \, dv$$

Discrete Fourier Transform

Fast Fourier Transform (FFT)

Image Compression

Transform Coding

Discrete Cosine Transform

Popular transform for its performance and efficiency

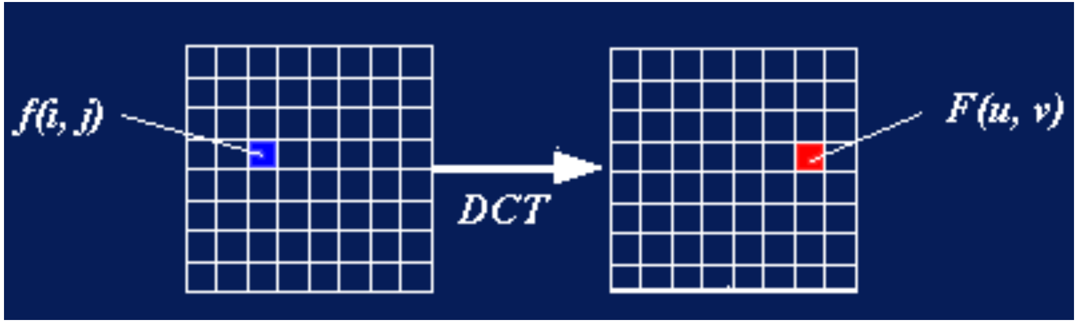


Image Compression

Transform Coding

Discrete Cosine Transform

Forward transform

$$F(u,v)=\frac{2}{N}C(u)C(v)\sum_{y=0}^{N-1}\sum_{x=0}^{N-1}f(x,y)\cos[\frac{(2x+1)u\pi}{2N}]\cos[\frac{(2y+1)v\pi}{2N}]$$

Inverse transform

$$f(x,y)=\frac{2}{N}\sum_{v=0}^{N-1}\sum_{u=0}^{N-1}C(u)C(v)F(u,v)\cos[\frac{(2x+1)u\pi}{2N}]\cos[\frac{(2y+1)v\pi}{2N}]$$

Image Compression

Transform Coding

Discrete Cosine Transform

Energy compaction

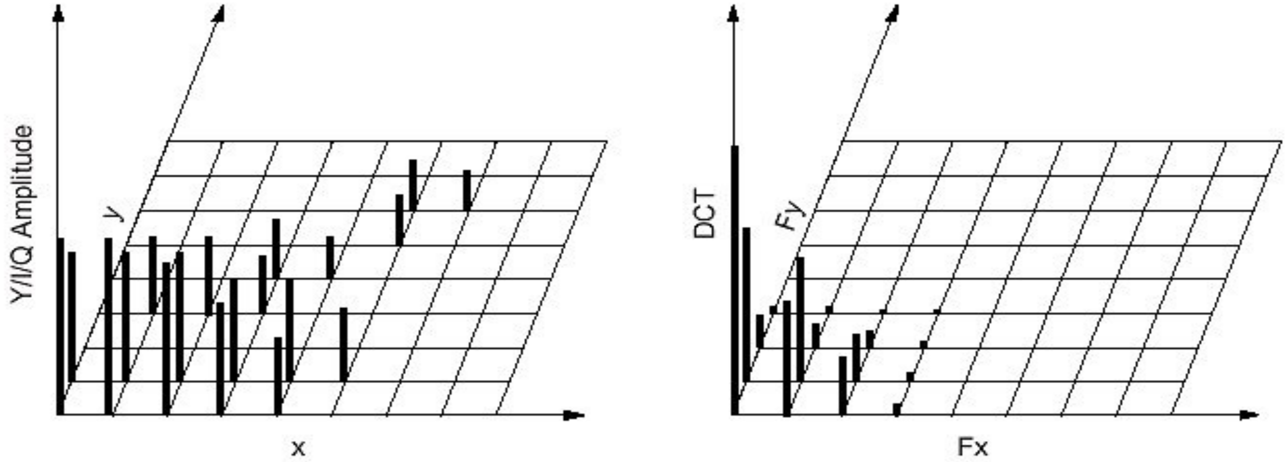


Image Compression

Transform Coding

Pipeline

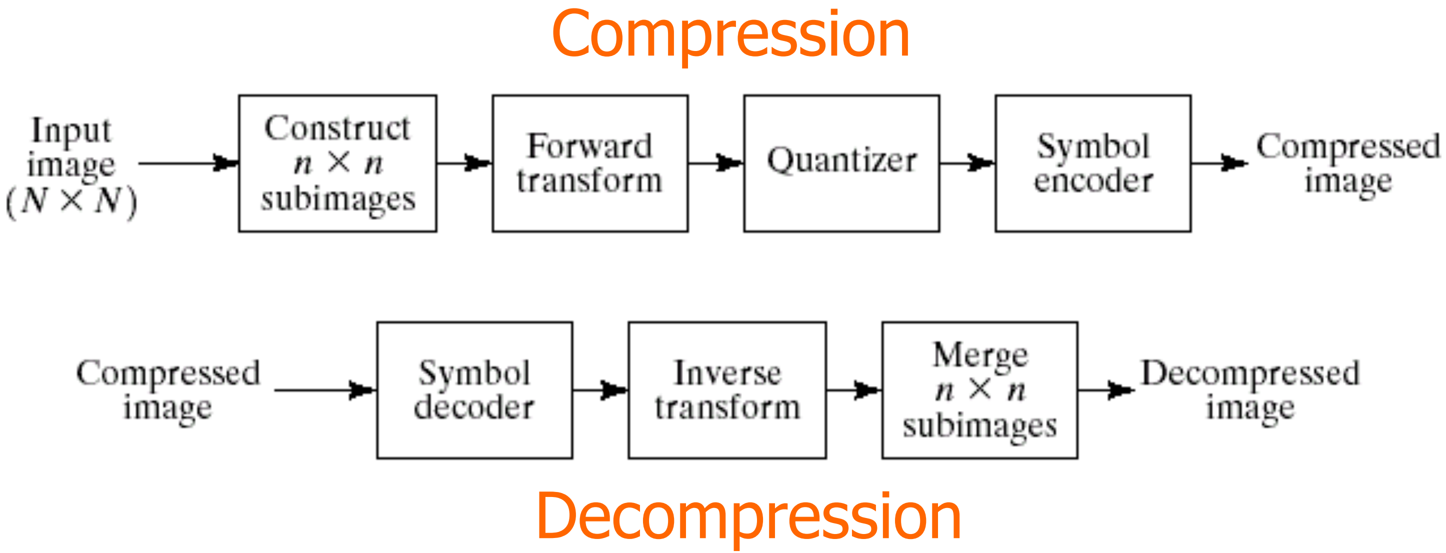


Image Compression

Transform Coding

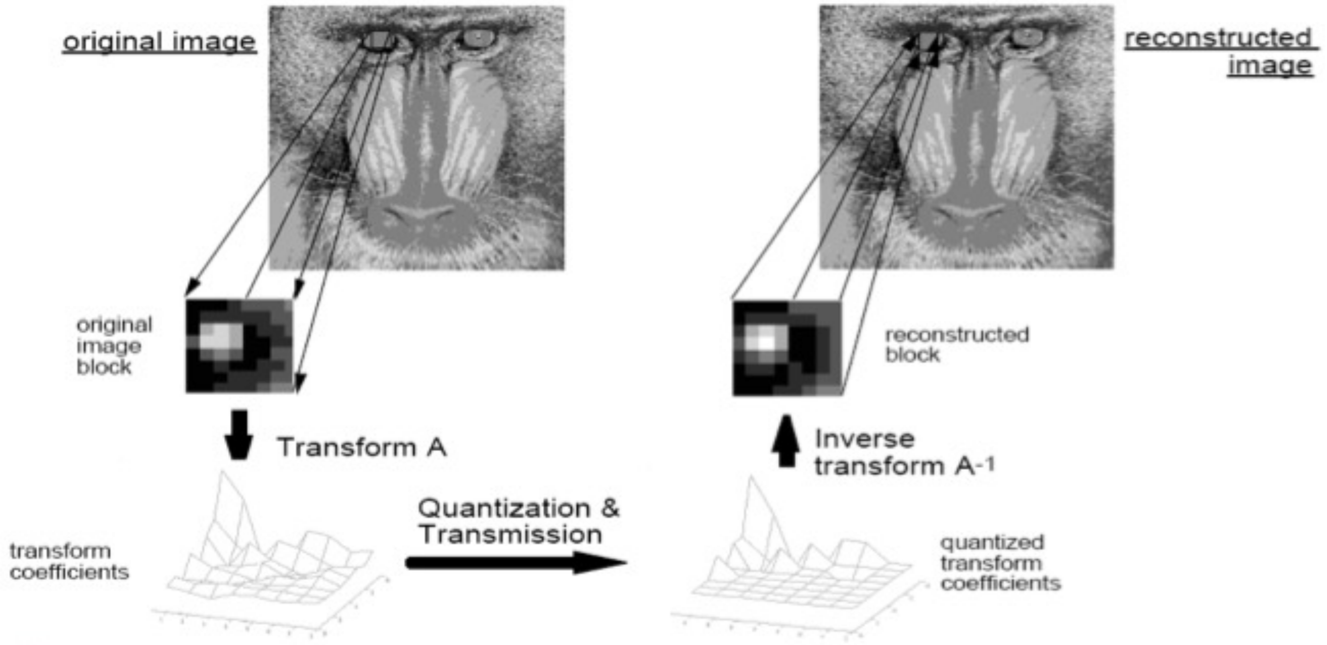


Image Compression

Transform Coding

Why sub image (nxn)?

- Computational benefit
- Typically 8x8, 16x16
- Error is not very high

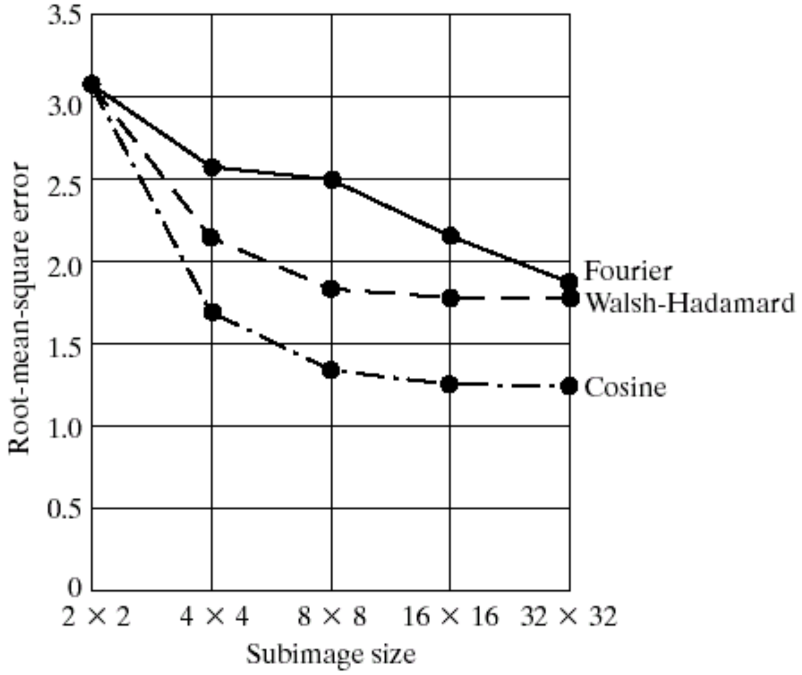


Image Compression

Transform Coding

Why sub image (nxn)?

- Computational benefit
- Typically 8x8, 16x16
- Error is not very high

Which transform?

- Low error for the same number of coefficients
- Computationally fast
- DCT is preferred

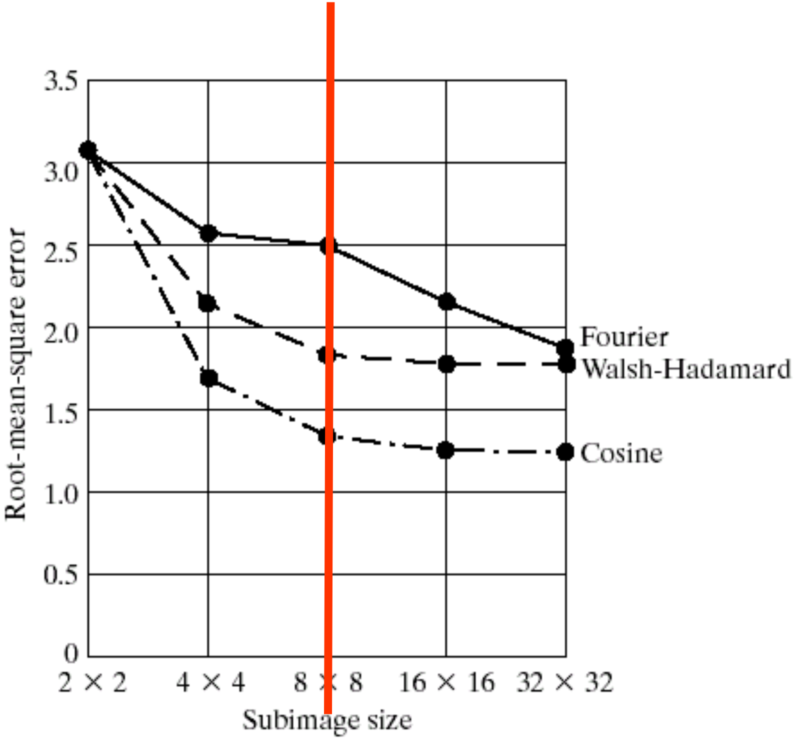


Image Compression

Transform Coding

Quantization Schemes

- Global thresholding
- Local thresholding
- For each block M out of N coefficients to retain

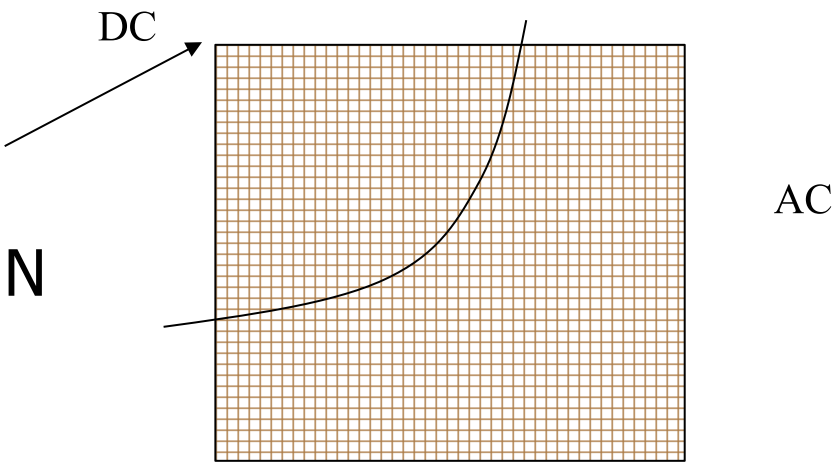


Image Compression

Recap Slides of Lecture 2

Compression Ratio

$$C_r = n_o/n_c$$

n_o = Number of carrying units (bits) in the original data (image)

n_r = Number of carrying units (bits) in the compressed data (image)

Also,

$$R_d = 1 - 1/C_r$$

R_d = Relative data redundancy

Variable Length Coding (Huffman Coding)

Sequence of symbols (a1, a2, a3, a4, a5) with associated probabilities (p1, p2, p3, p4, p5)

- Start with two symbols of the least probability
  - a1:p1
  - a2:p2
- Combine (a1 or a2) with probability (p1+p2)
- Do it recursively (sort and combine)
- A binary tree construction

Image Compression

Variable Length Coding (Huffman Coding)

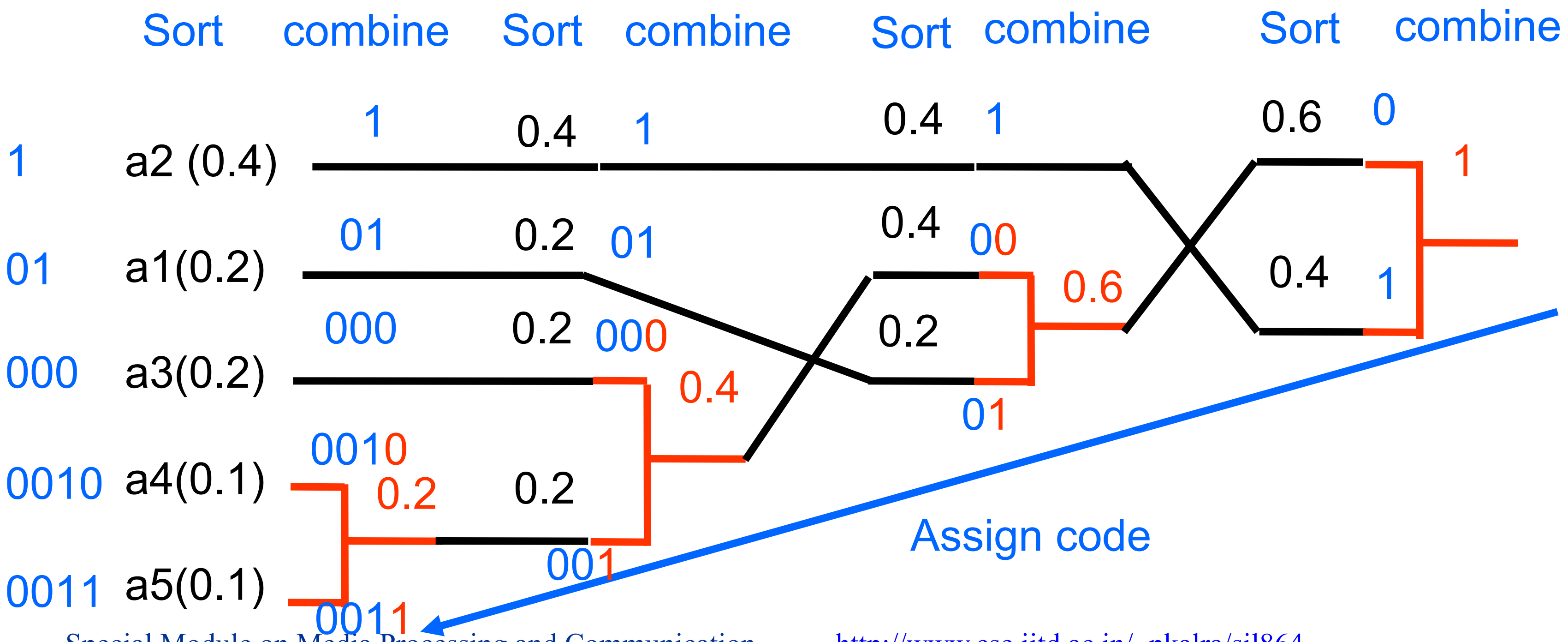


Image Compression

Variable Length Coding (Huffman Coding)

Example:

Avg length code:

0.4x1 + 0.2x2 + 0.2x3 + 0.1x4 + 0.1x4 = 2.2 bits

Entropy

A measure of information that captures uncertainity [I(e) = log (1/P(e))]

$$H = -\sum_{i=0}^{L-1} p(a_i) \log_2 p(a_i) \quad \text{bits / symbol}$$

Variable Length Coding (Huffman Coding)

Decoding

Example:

00111010001

?

Variable Length Coding (Huffman Coding)

Decoding

Example:

00111010001

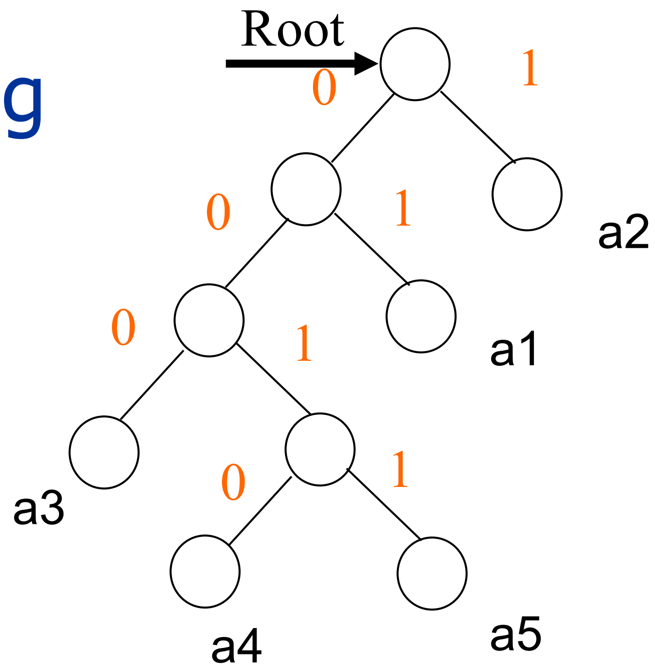


Image Compression

Variable Length Coding (Huffman Coding)

Decoding

Example:

0011101000l

a5

a2

a1

a3

a2