DCT Based, Lossy Still Image Compression

“Lenna”, Playboy Nov. 1972

NOT a JPEG artifact !

Lena Soderberg, Boston, 1997

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Update: April. 2009

http://www.lenna.org/

Image Compression: List of Topics

- Introduction to Image Compression (DPCM)
- Image Concepts & Vocabulary
- JPEG: An Image Compression System
- Basics of DCT for Compression Applications
- Basics of Entropy Coding
- JPEG Modes of Operation
- JPEG Syntax and Data Organization
- H/W Design Example (Based on Zoran Chip)
- **JOEG-LS:** A **Lossless** standard
- **JPEG2000:** A **Wavelets** based **lossy** standard

Image Compression: List of Topics (Cont'd)

- Other Compression techniques:
  - FAX (Binary Image Compression)
    - G3 / G4 Standards
    - JBIG Standard
  - Context based lossless compression
  - Wavelets Based Compression
  - Pyramidal Compression
  - Fractal Based Image Compression
  - BTC: Block Truncation Coding
  - Morphological Image Compression

Image Compression Standards

• G3/G4	Binary Images (FAX)
• JBIG	FAX and Documents
• JPEG	Still Images (b/w, color)
• JPEG-LS	Lossless, LOCO based
• JPEG2000	Lossy, Wavelets based

Introduction to Still Image Compression: DCT and Quantization

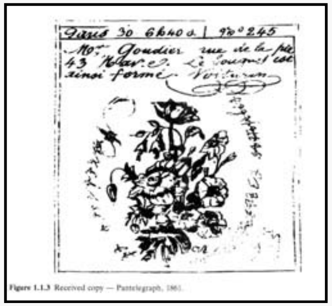
~5KB, 50:1 compression ratio

The Need for Compression

Still Image:

- B&W: 512x512x8 = 2Mb

- True Color: 512x512x24 = 6Mb



- FAX, **Binary** A4 DOC,

1728 pel/line, 3.85line/mm = 2Mb

Compression Techniques

- Lossless

Decompressed image is exactly the same as original image

≡

- Lossy

Decompressed image is as close to the original as we wish

≈

Lossless Compression

- Define the amount of information in a symbol
- Define Entropy of an image:

  "Average amount of information"
- Make a new representation, which needs less bits in average
- Make sure you can go back to original...

I'll find the difference even if it takes a year !

Known Lossless Techniques

- Huffman Coding
- Run-Length

Coding of strings of the same symbol

- Arithmetic (IBM)

Probability coding

- Ziv-Lempel (LZW)

Used in many public/commercial application such as ZIP etc...

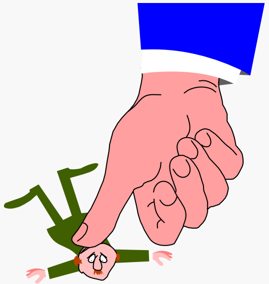
Lossless Features

- Pro's:
  - No damage to image (Medical, Military ...)
  - Easy (?) to implement (H/W and S/W)
  - Option for progressive
  - ease of use (no needs for parameters)
- Con's:
  - Compression ratio 1:1 - 2:1
  - Some are patented ...

Lossy Compression : Why ?!

- **More compression**

Up to an acceptable* damage to reconstructed image quality.



* "Acceptable": depends on the application...

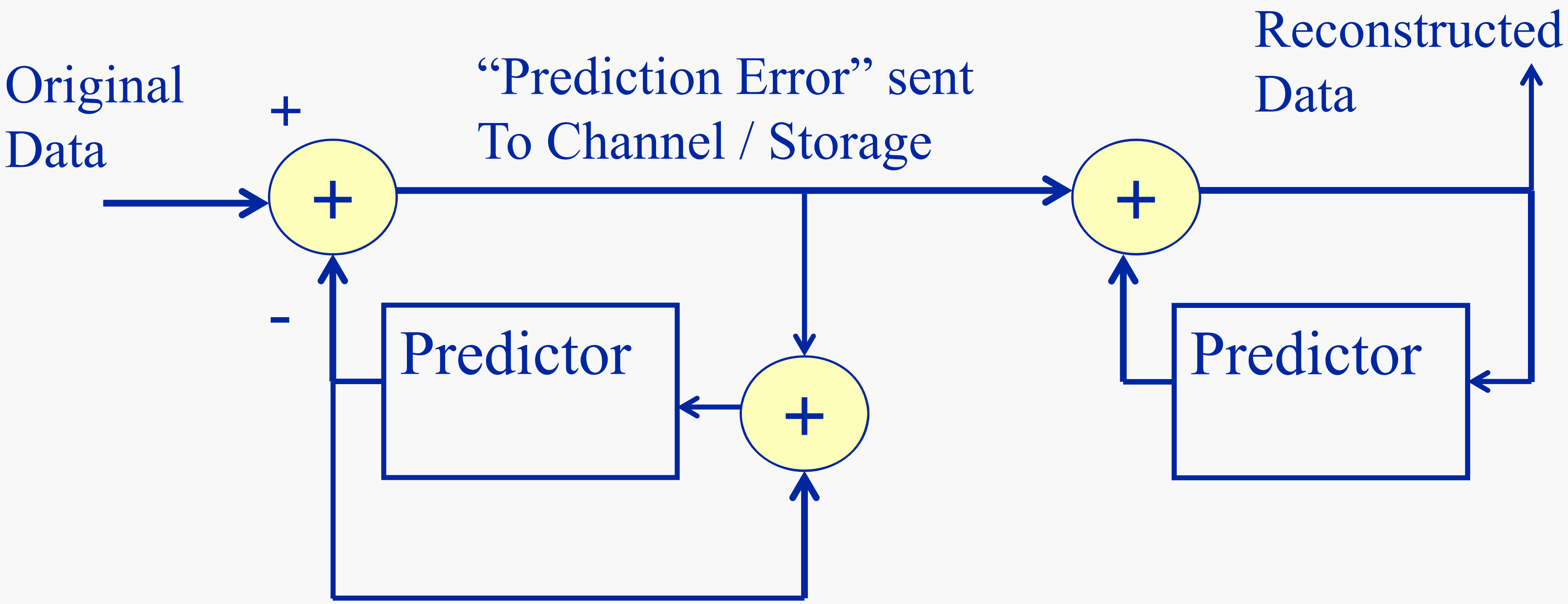
- Objective criterion: PSNR, but the human viewer is more important…

Lossy Compression (Cont'd)

Image Quality, Subjective Criterion – MOS:

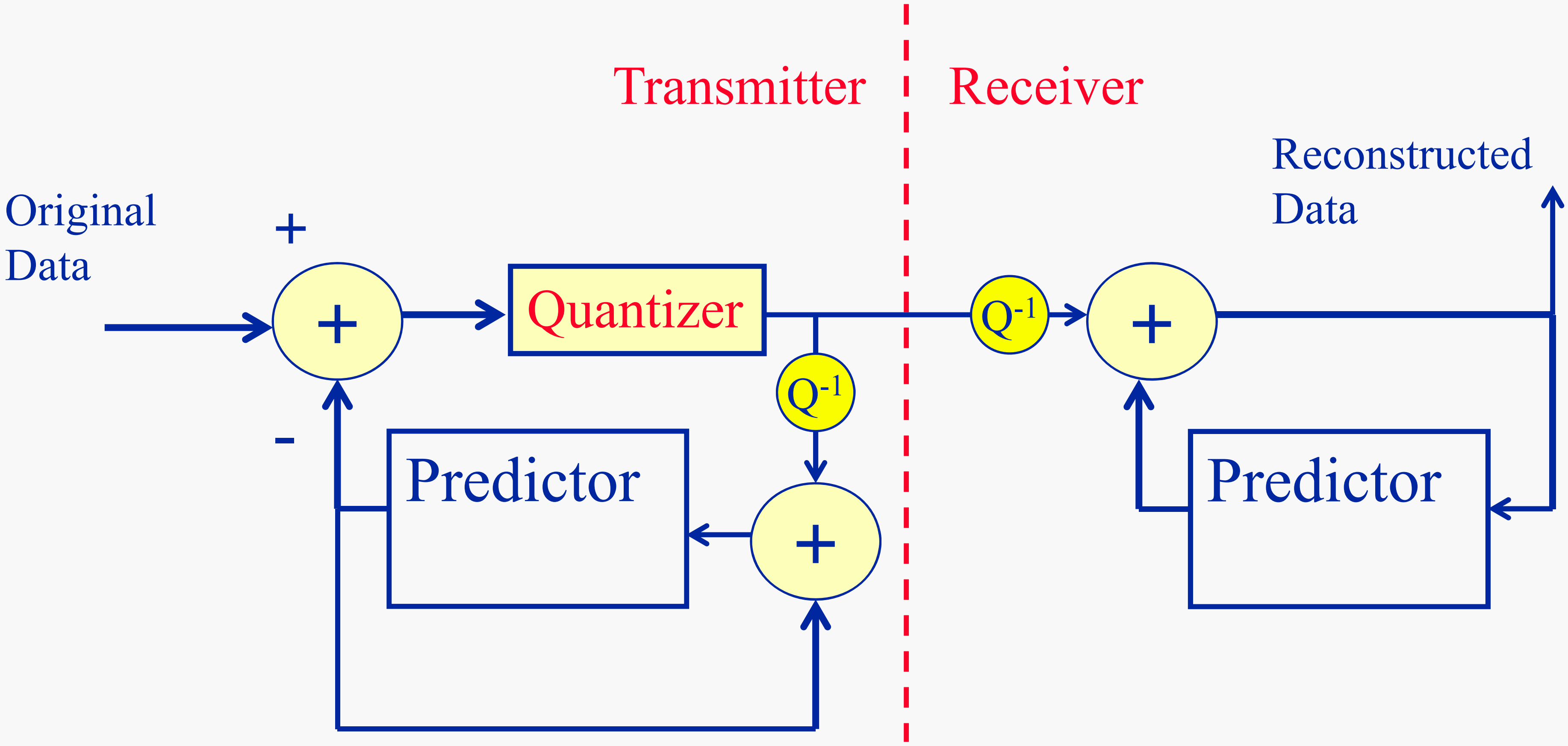
- Goodness Scale:		- Impairment Scale:	
Excellent	(5)	Not Noticeable	(1)
Good	(4)	Just Noticeable	(2)
Fair	(3)	⋮	
Poor	(2)		
Unsatisfactory	(1)	Definitely Objectionable	(6)
		Extremely Objectionable	(7)

Basic DPCM Scheme



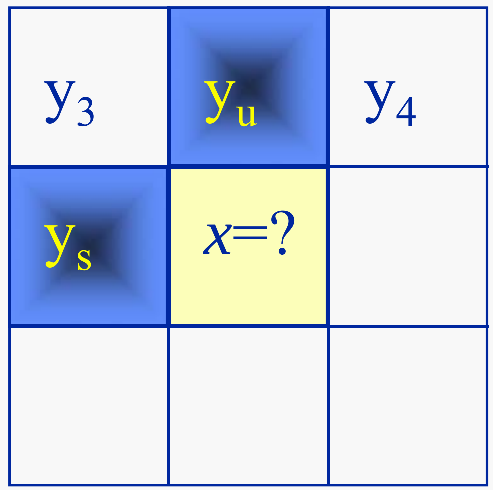
NOTE: this is still a LOSSLESS scheme !

Making DPCM A Lossy Scheme



Note: IQ Block is optional ! Where ???

Linear Predictor



- Casual predictor:

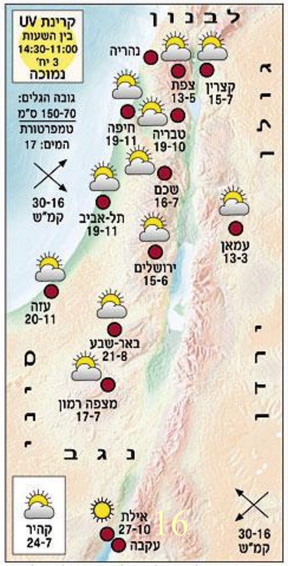
$$x=h_1 y_s+h_2 y_u+h_3 y_3+h_4 y_4+\ldots$$

Adaptive Prediction

- Predictor coefficients change in time.

- Adaptation - e.g. : the LMS method

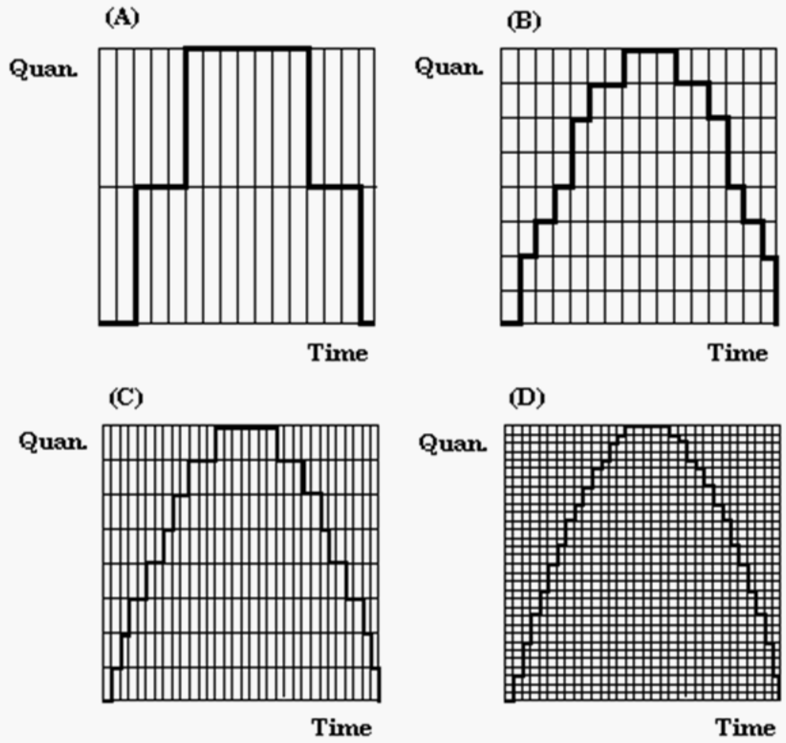
- Higher order predictors can be used



Quantization

Compression is achieved by Quantization of the un-correlated values (frequency coefficients)

<u>Quantization</u> is the ONLY reason for both **compression** and **<u>loss of quality</u>** !



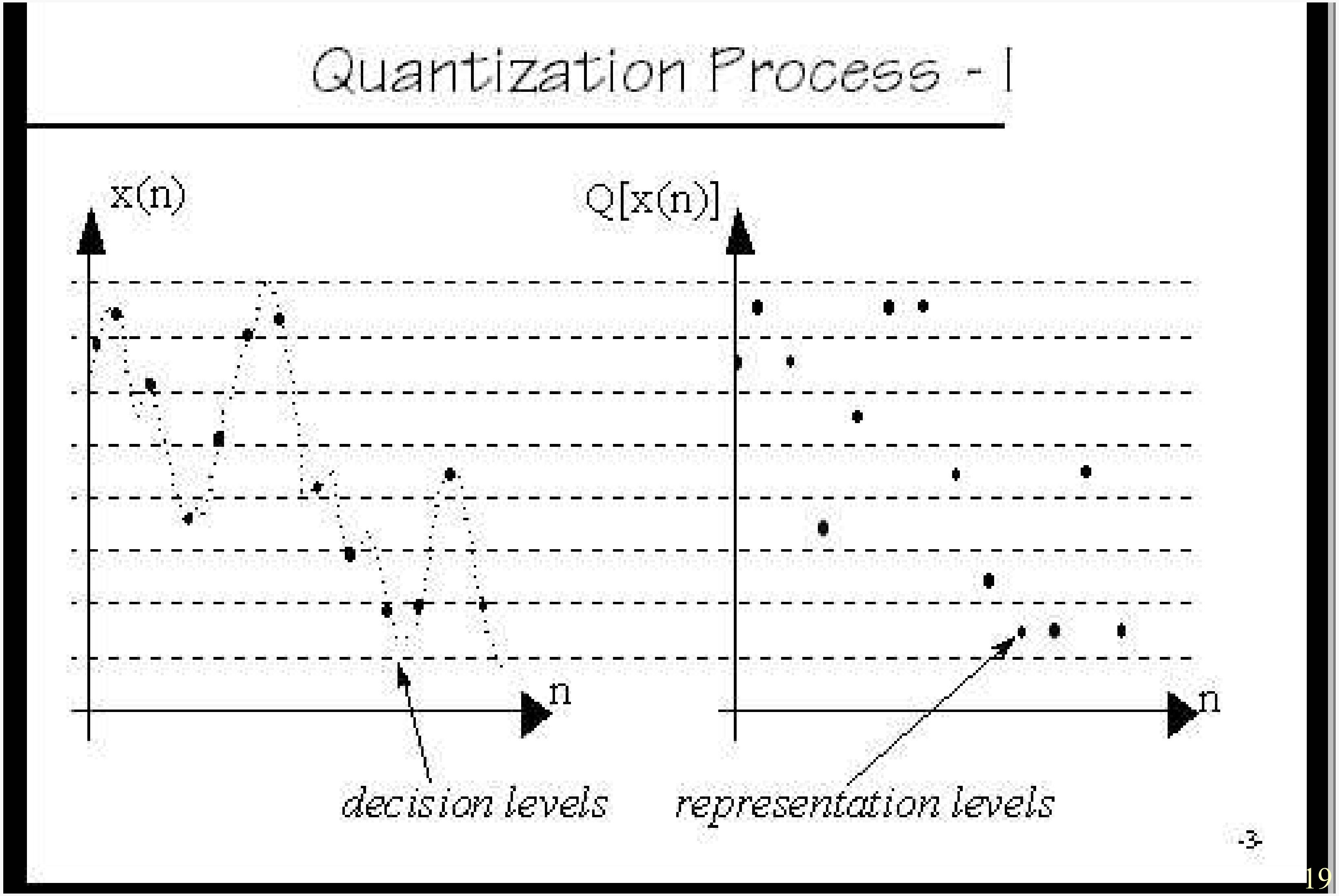
What is Quantization ?

- Mapping of a continuous-valued signal value *x(n)* onto a limited set of discrete-valued signal *y(n)* : ***y(n) = Q [x(n)]***

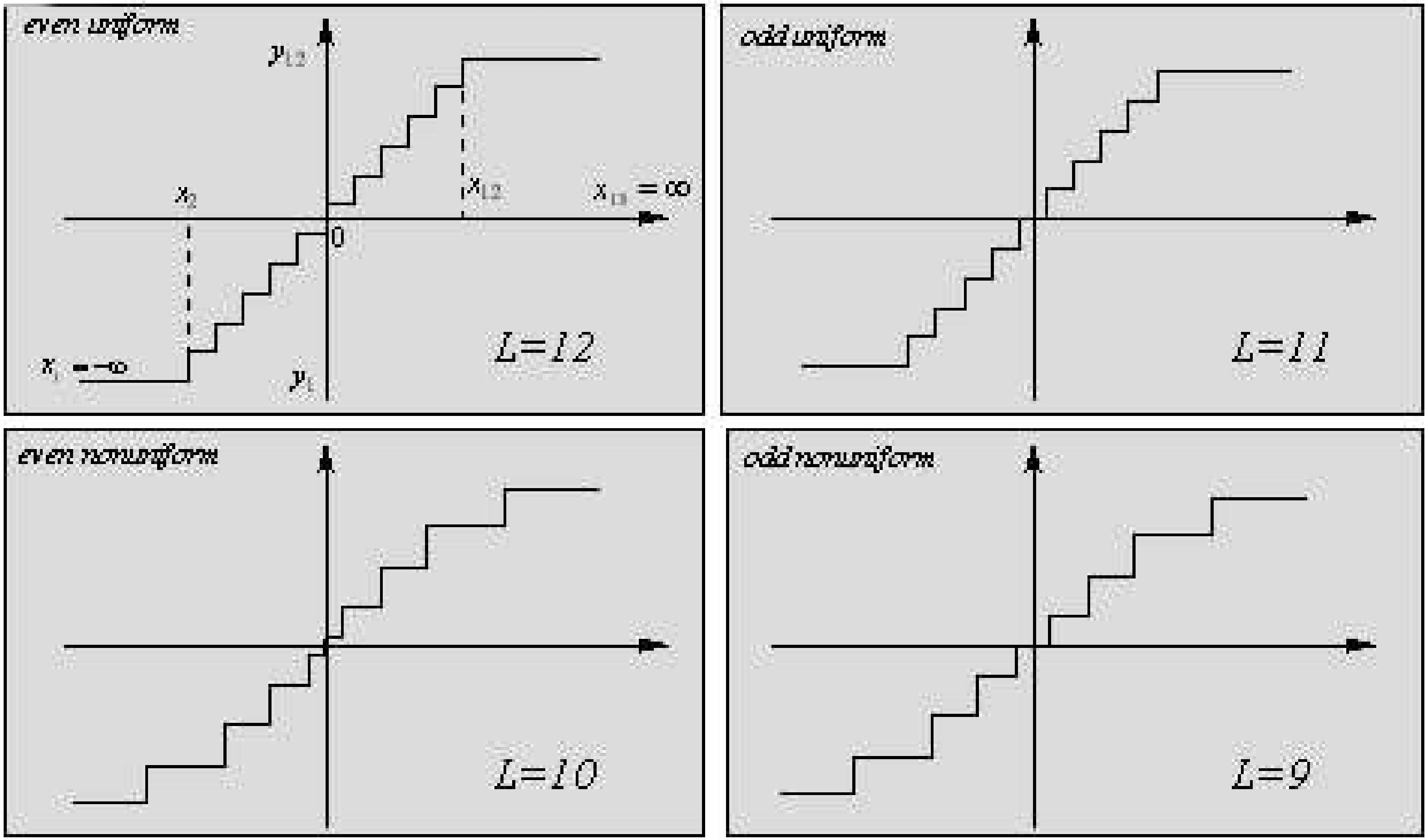
such as ***y(n)*** is a "good" approximation of ***x(n)***

- *y(n)* is represented in a limited number of bits
- <u>Decision levels</u> and <u>Representation levels</u>

Decision levels Vs. Representation levels



Typical Quantizers - II



Quantization Noise

- Define Signal to Noise Ratio (SNR):

$$SNR = 10\log_{10}\left(\frac{\sigma_s{}^2}{\sigma_n{}^2}\right) = 10\log_{10}\left(\frac{\sum_i\sum_j (s_{ij} - E_s)^2}{\sum_i\sum_j (n_{ij} - E_n)^2}\right)$$

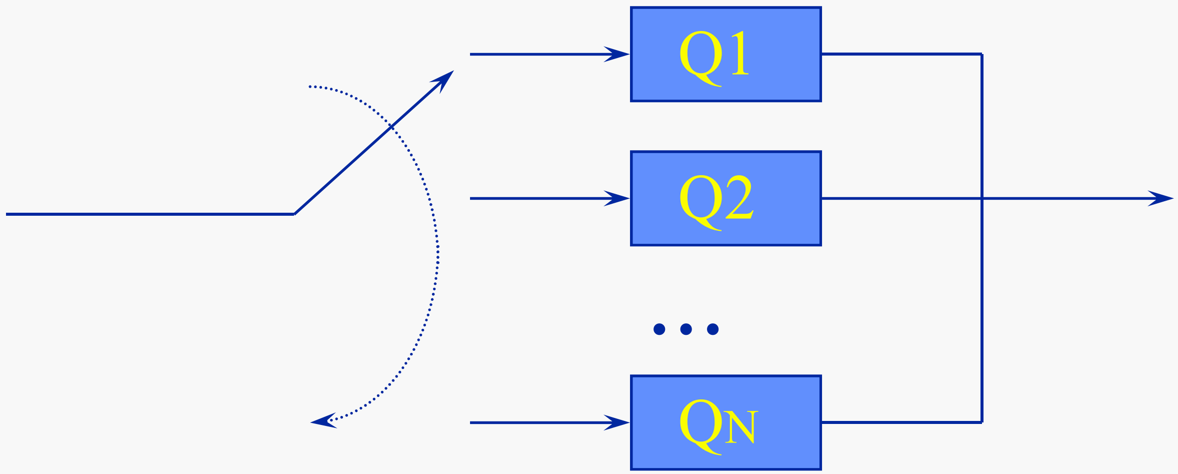
$$PSNR = 10\log_{10}\frac{\left(2^n - 1\right)^2}{MSE}$$

Optimal Non-Uniform Quantizer

- Max-Lloyd Quantizer:

Iterative algorithm for optimal quantizer, in the sense of minimum MSE

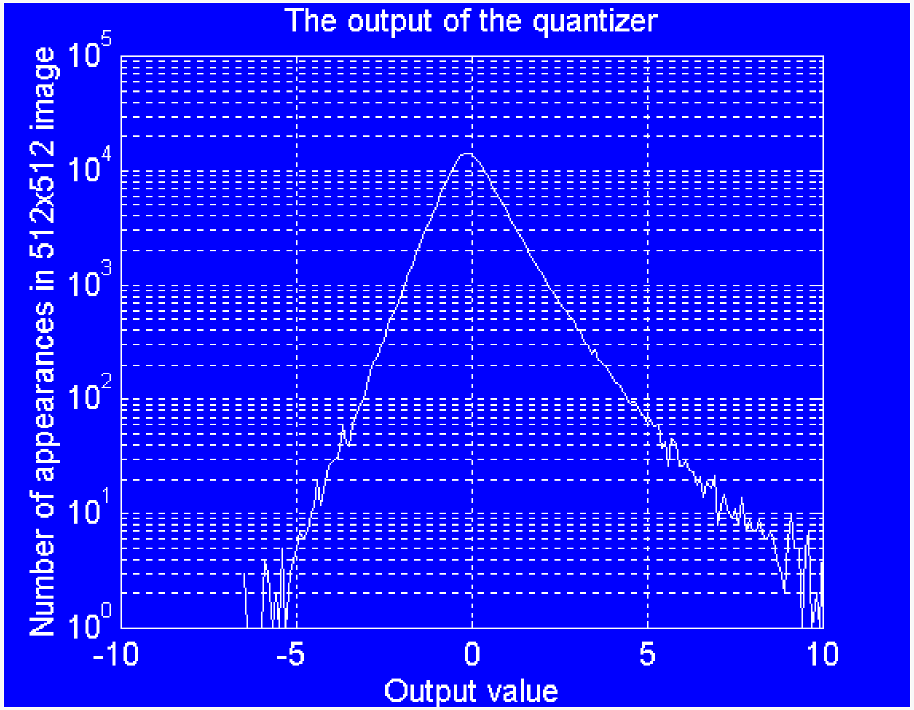
Adaptive Quantizer



- Change of Delta , Offset, Statistical distribution (Uniform/Logarithmic/…) etc.

Laplacian Quantizer

value probability in the output of a uniform quantizer



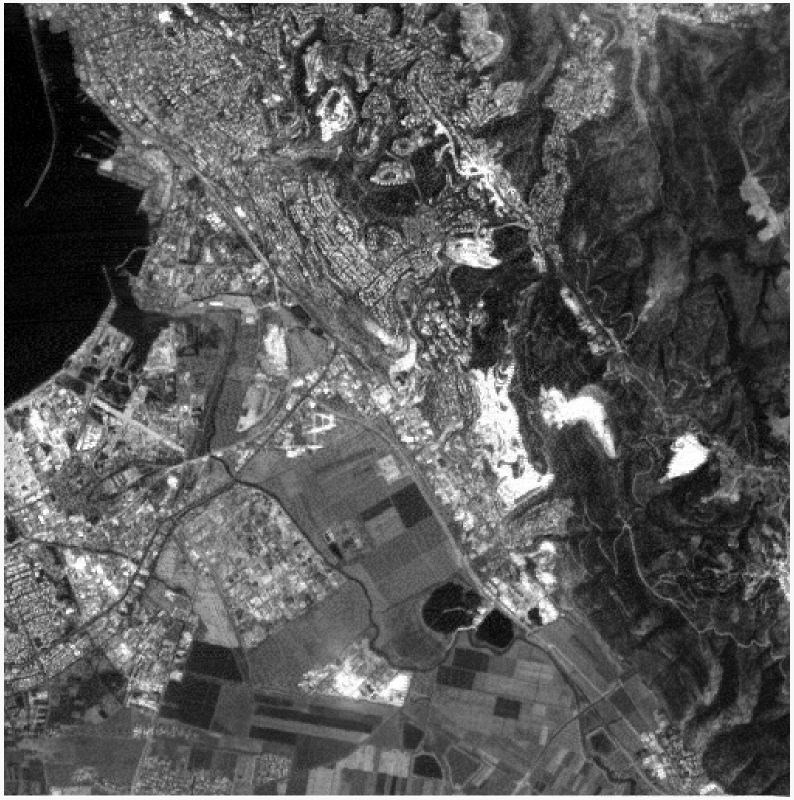
- For Natural Images !

Uniform Quantizer, simple predictor (2bpp, 22dB)

Original

Reconstructed

Laplacian-Adaptive (2-4-6 levels) Quantizer, Adaptive, second order predictor (2bpp, 26.5dB)



Lossy Compression (Cont'd)

- Transform Coding :

  Coefficients can be quantized, dropped and coded causing a controlled damage to the image.

Possible Transforms:

KLT, DFT, DCT, DST, Hadamard etc.

- Mixed Time-Frequency presentations e.g.: Gabor, Wavelets etc...

Transform Coding (Cont'd)

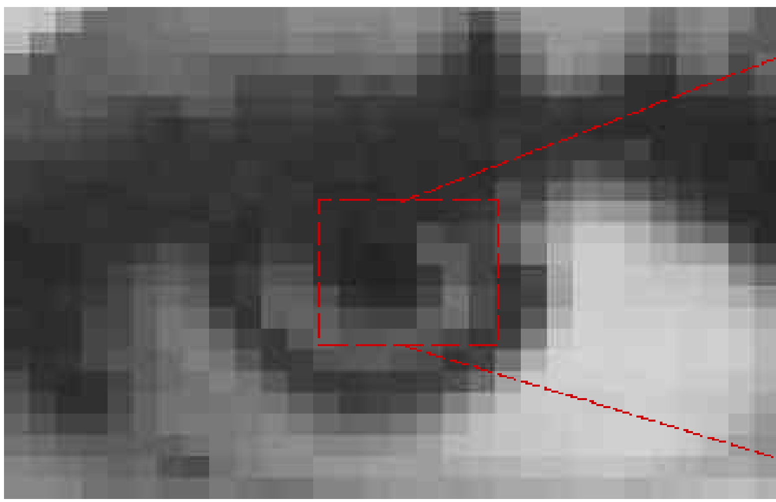
Transform Coding Technique:

1. Split the K_1xK_2 image into M NxN* blocks
2. Convert each NxN correlative pixels (Block) to un-correlative NxN values
3. Quantize and Encode the un-correlative values

* The NxN nature is a convention, but there are non-square transforms !

The “Small Block” Attitude

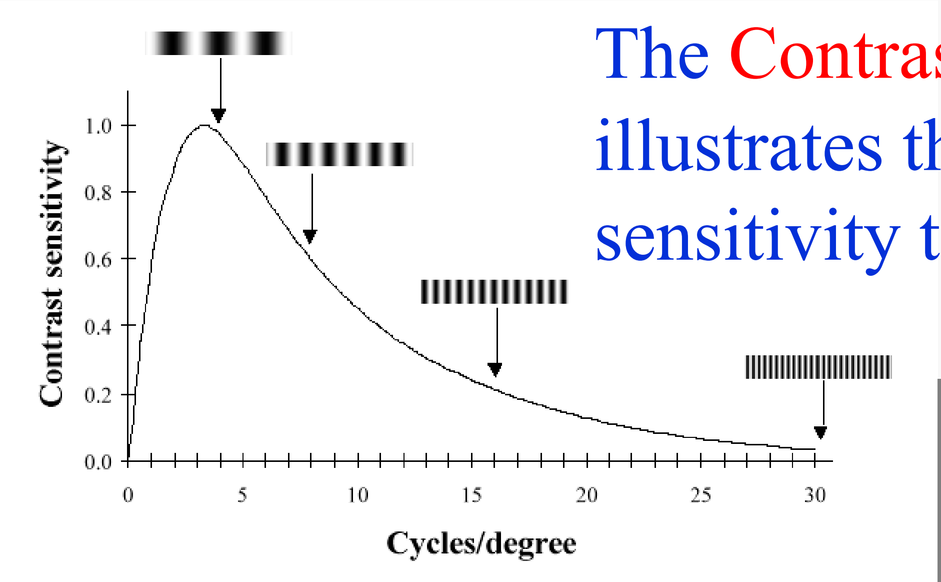
- What is the value of the missing pixel? (It is 39)
- How critical is it to correctly reproduce it?



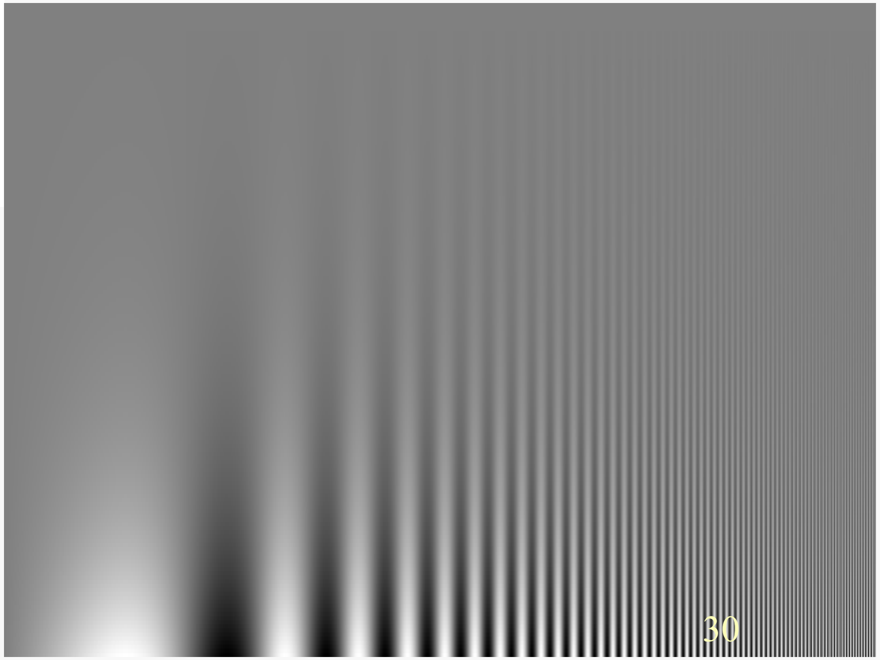
46	44	46	47	44	50	56
50	40	46	48	76	62	69
45	39	36	40	88	87	65
48	38	36	?	56	90	65
76	48	41	43	69	112	77
90	72	66	66	90	108	74
98	86	86	91	83	72	57

Spatial Redundancy & Irrelevancy

What About the Contrast ?



The Contrast Sensitivity Function illustrates the limited perceptual sensitivity to high spatial frequencies

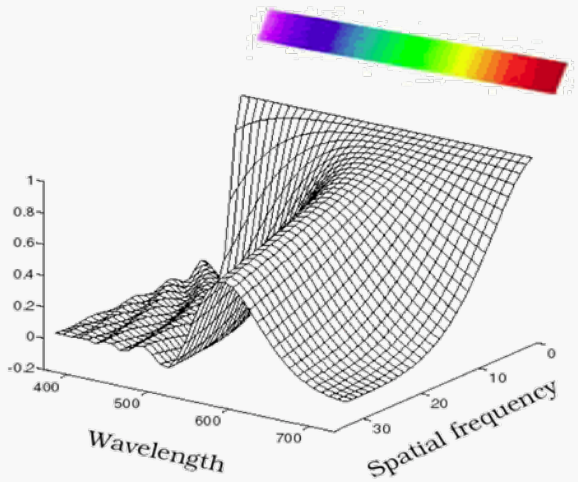


Visual Masking

Images and Human Vision

<u>"Natural" images are</u>

- Spatially redundant
- Statistically redundant



Chromatic Modulation Transfer Function

<u>Human eyes are</u>

- Less sensitive to high spatial frequencies
- Less sensitive to chromatic resolution
- Less sensitive to distortions in "busy" areas

So ?

- Lets go to "small blocks"
- JPEG, MPEG : 8x8 Pixels Basic blocks for the transform