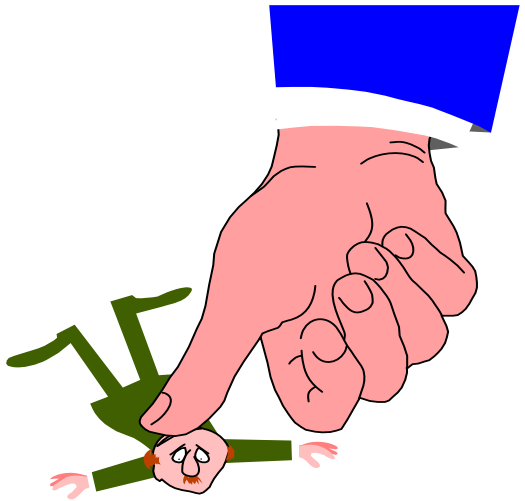
JPEG:
An Image Compression System

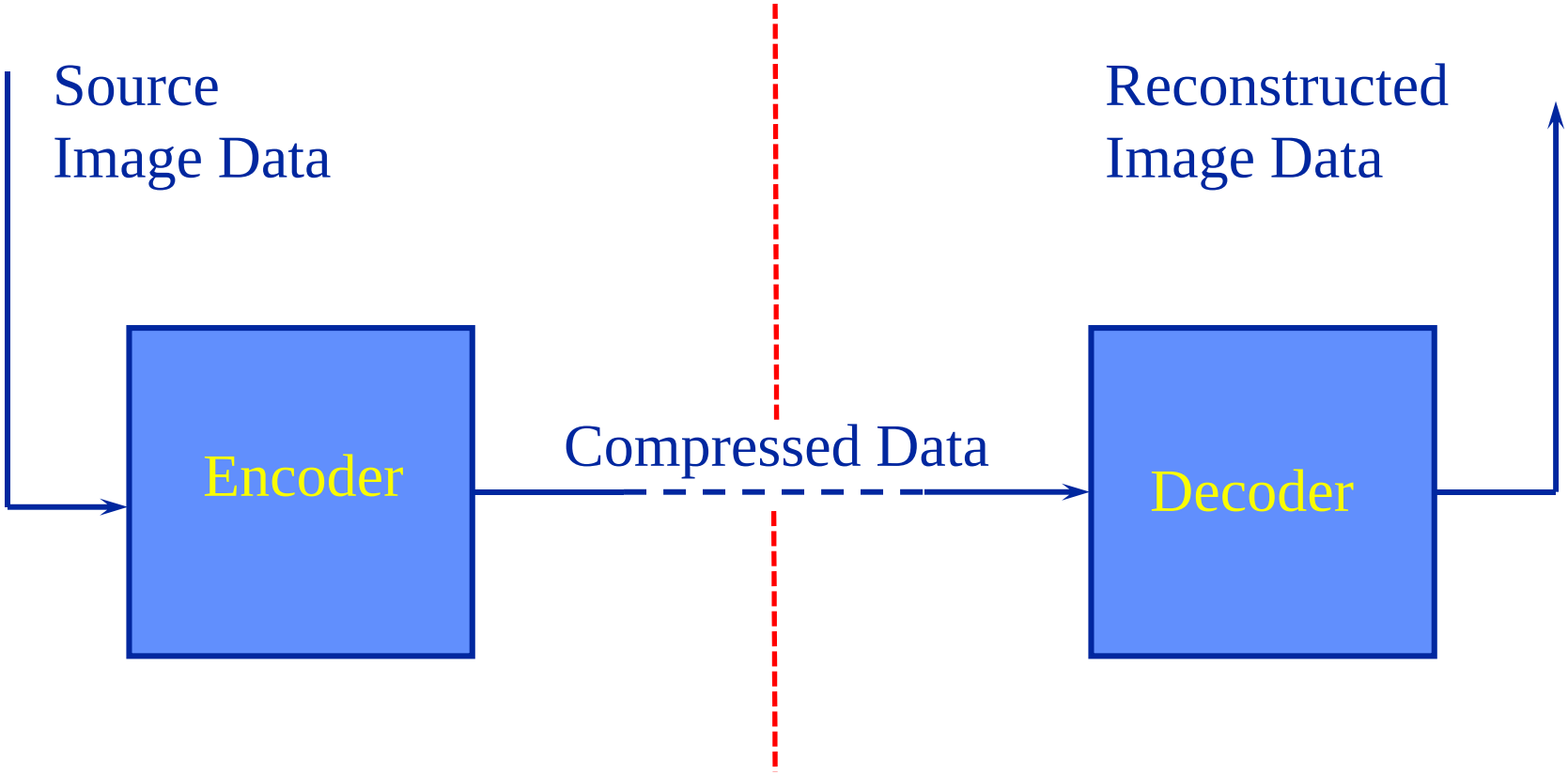
ISO/IEC DIS 10918-1
ITU-T Recommendation T.81
http://www.jpeg.org/

Nimrod Peleg

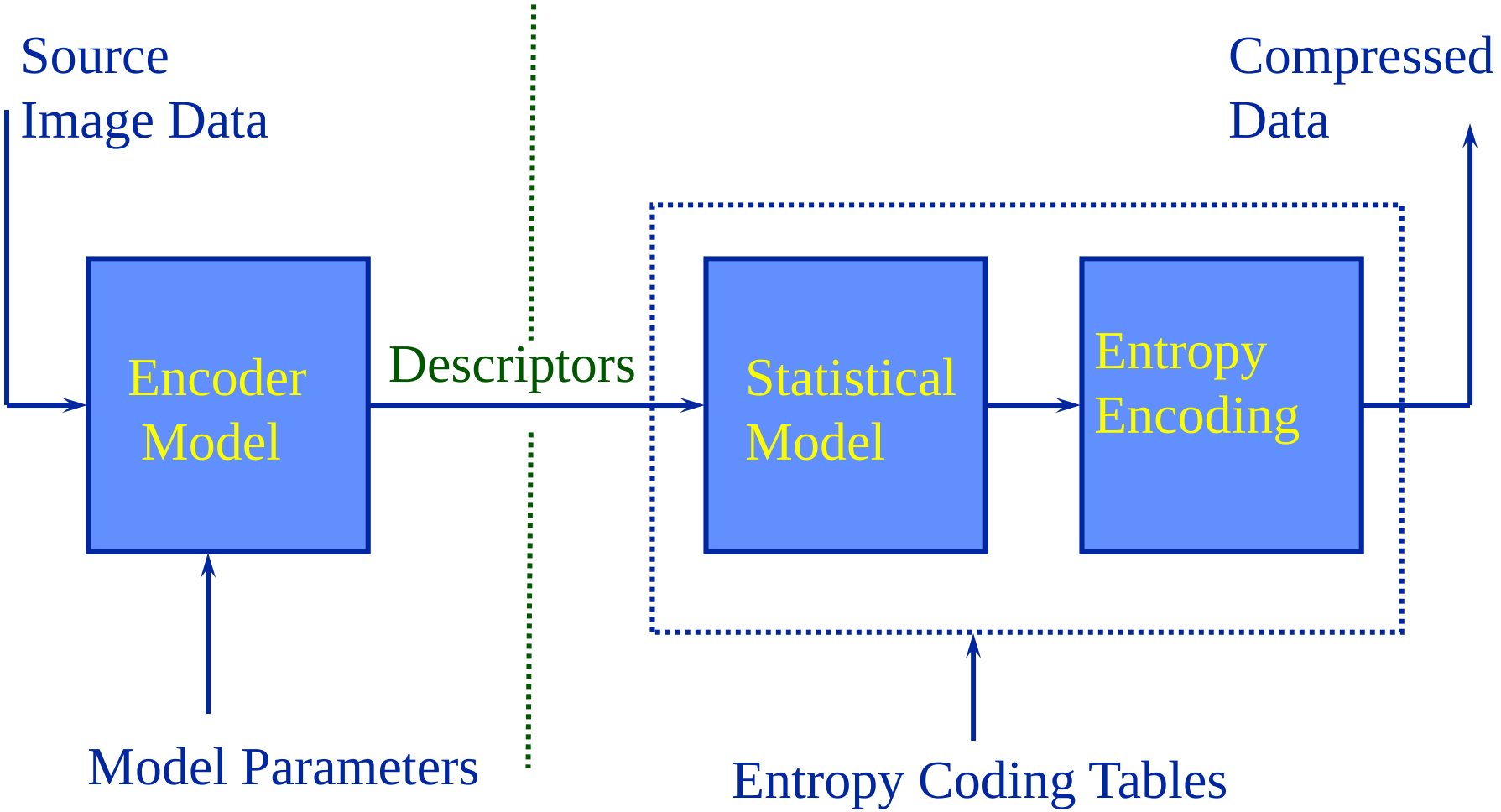
update: April 2009



Basic Structure



Encoder Structure



Decoder Structure

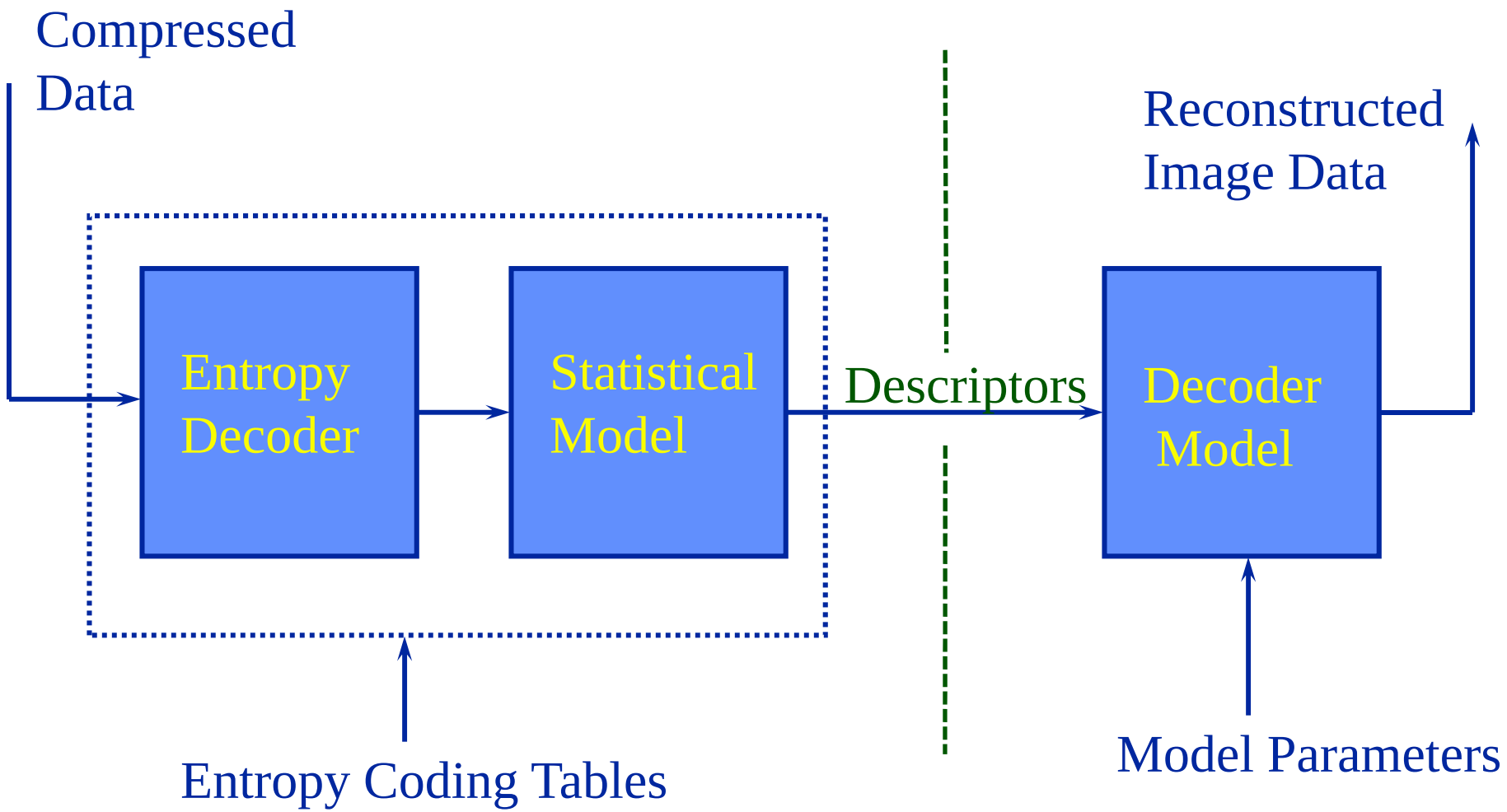


Image Compression Models

- A Unit that generates a set of “descriptors”
- The simplest model:

send the data itself to the entropy encoder:

PCM

The set of descriptors is all possible values of the samples

Compression Models: DPCM

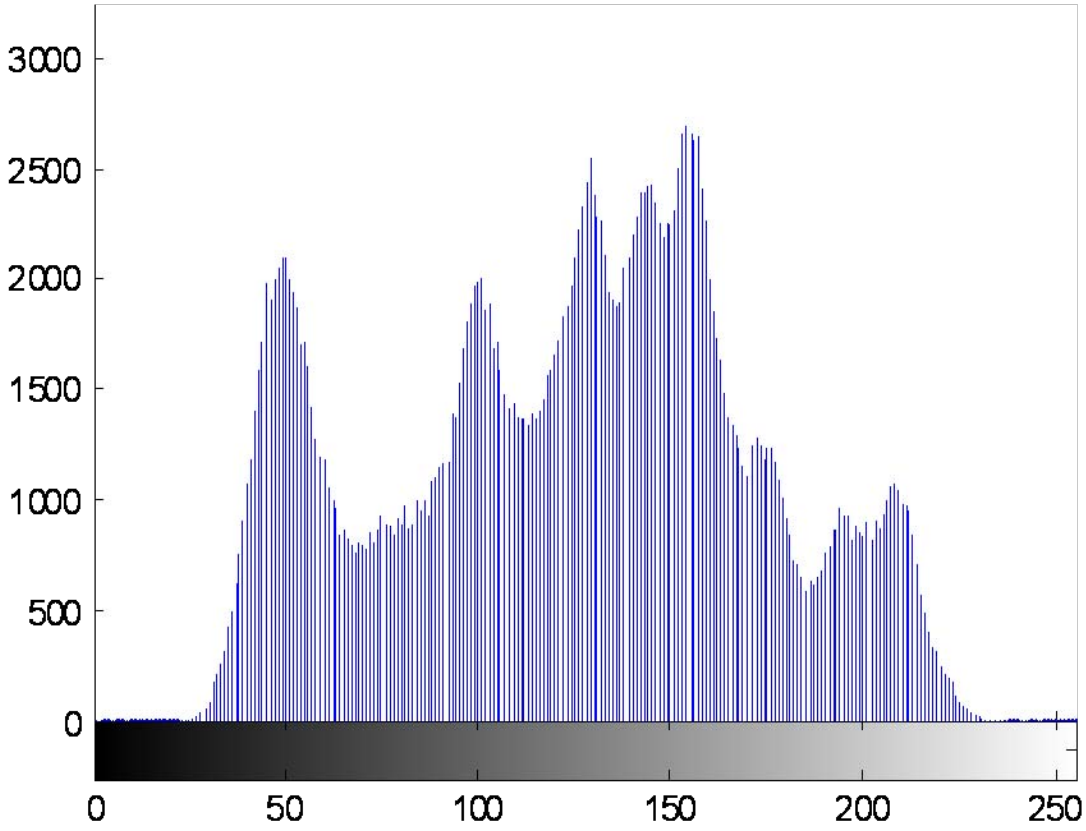
A simple predictor:

We use the former sample(s) to **predict** the current one, and send (to the entropy encoder) the difference between the predicted and real value:

"prediction error"

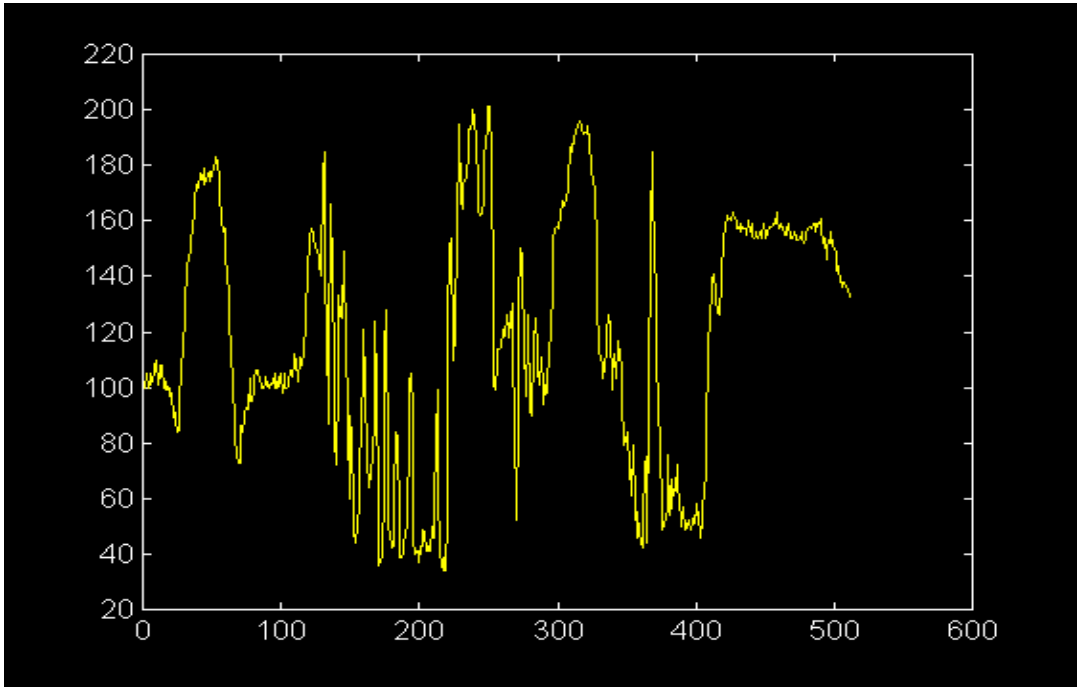
Lena: The original

Histogram of Lena



Matlab: imhist

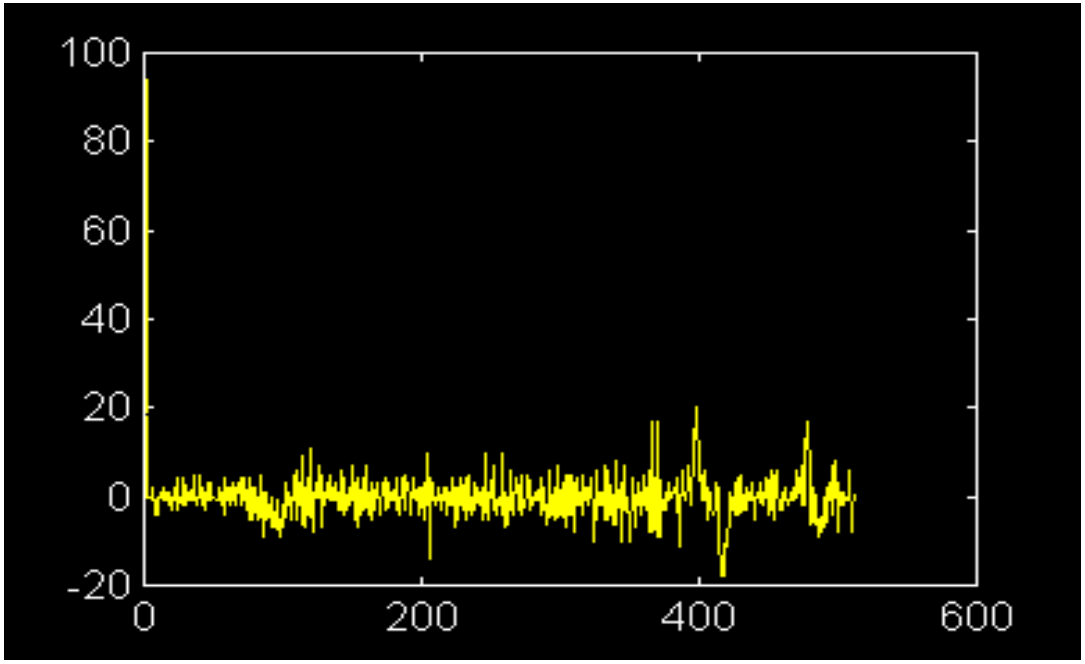
Sample Intensity



1 Line Histogram

Sample Position

Intensity of difference

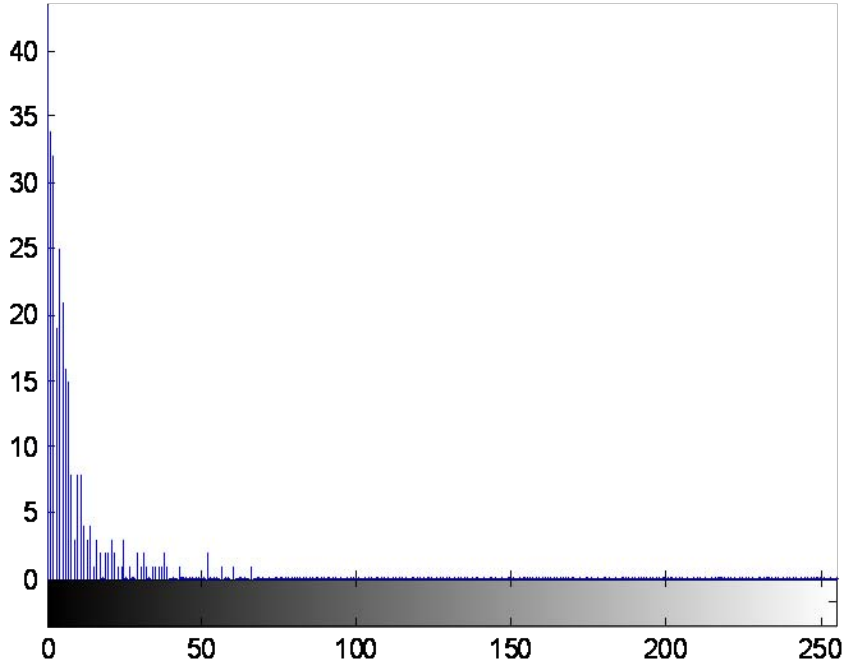


Difference Sample Position

DPCM (Cont'd)

The better performance of DPCM relative to PCM is due to the high degree of correlation found in most images

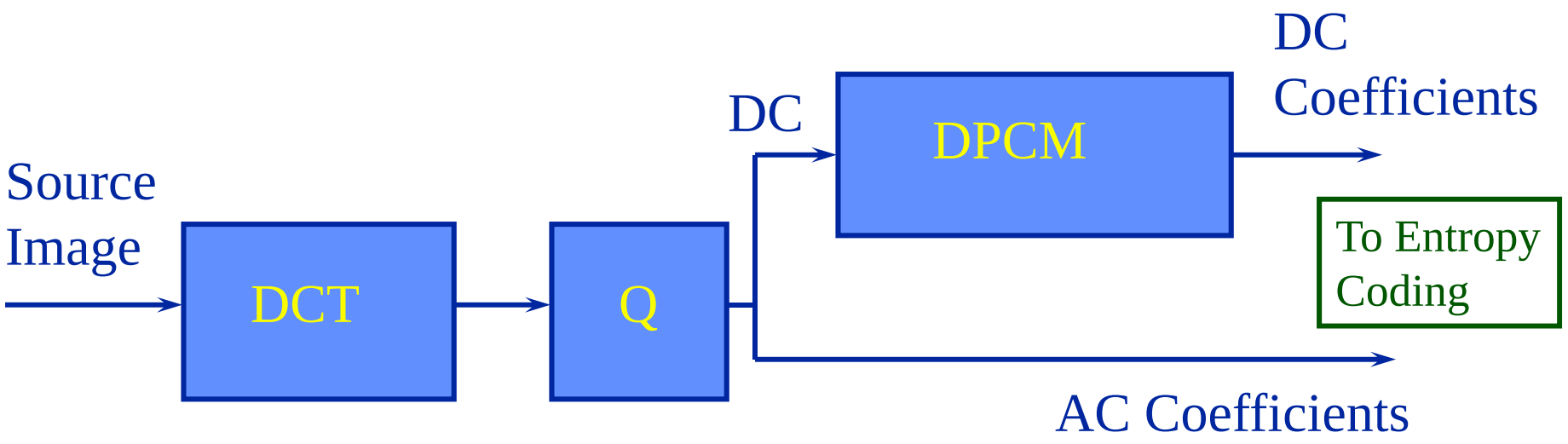
Note that this model is lossless !



Histogram of differences
(Lena, one neighbor to the left predictor)

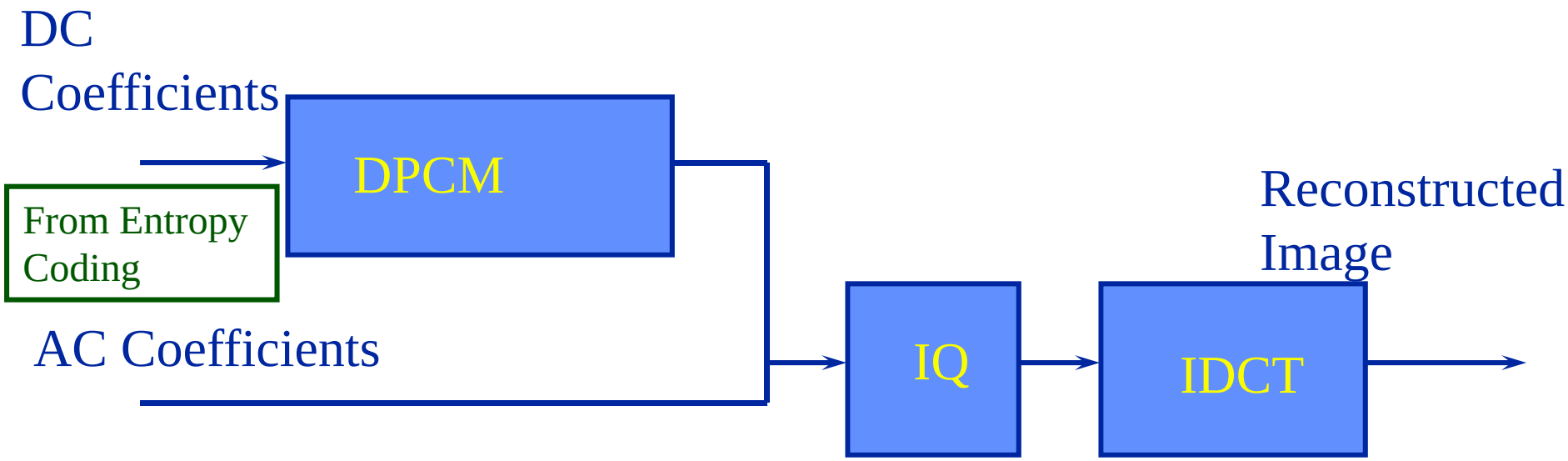
DCT Encoder Model

- Used in Lossy JPEG modes
- Output is fed to Entropy encoder



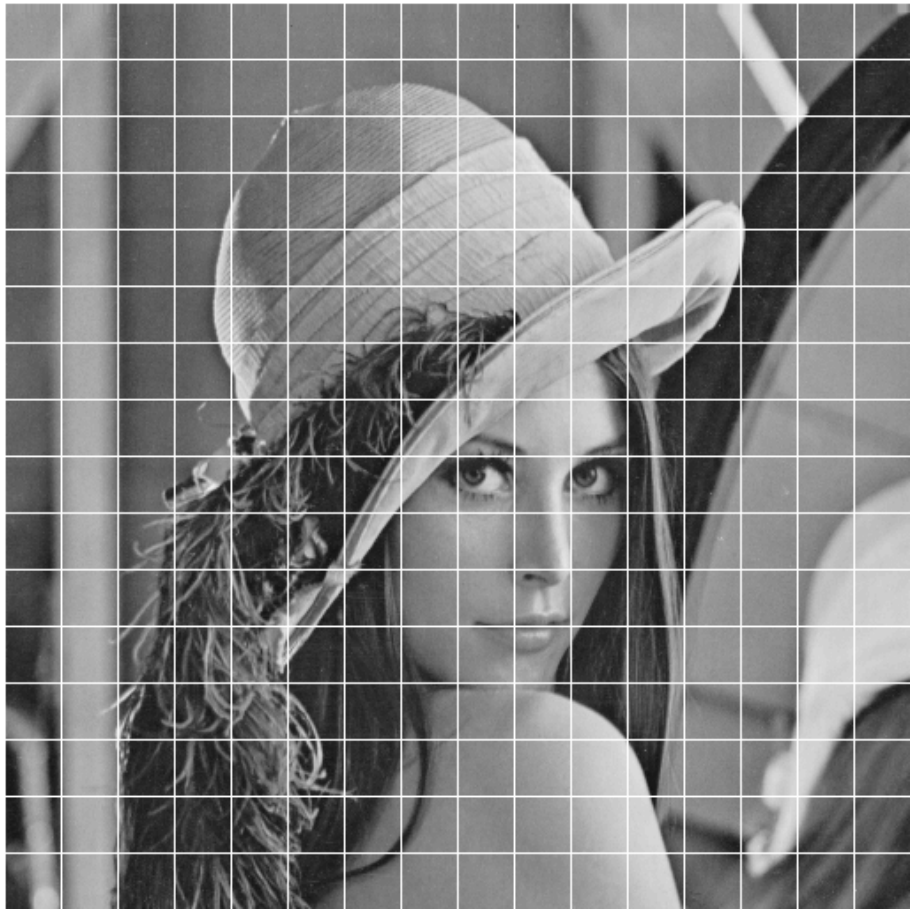
DCT Decoder Model

- Quantization is the principal source of distortion to the reconstructed image.
- Q is done to each coeff. independently, so it can match the HVS response.



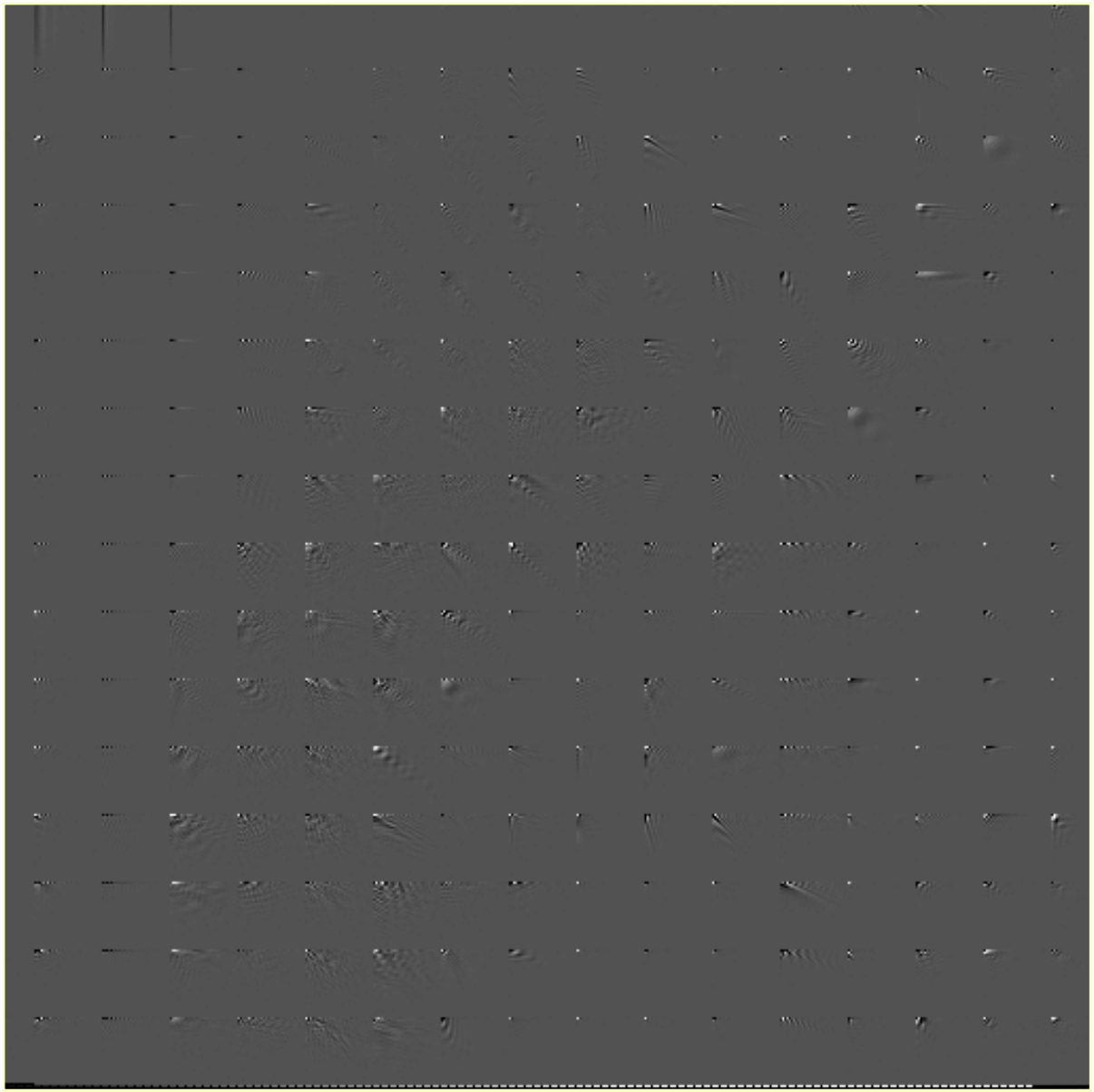
Block Oriented DCT Reconstruction
(A too strong quantization effect)

32x32 block

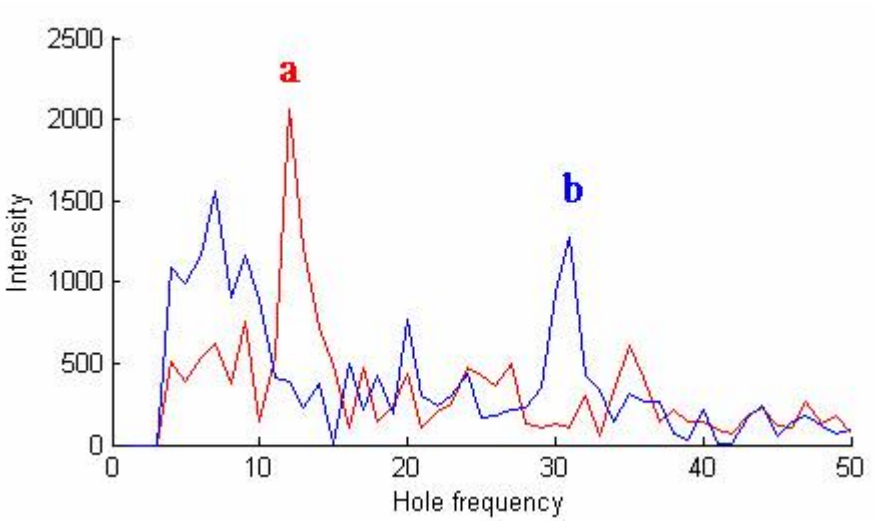


A strong quantization

The “DCT” Coefficients Image



2D DFT….The Jewish Case



Fourier analysis shows us

a) Typical horizontal lines with appropriate frequency (12 lines in height) [red]

b) High frequencies for the small holes (30 per line) [blue]

c) No signs for Chamets !

Quantization – Color Example

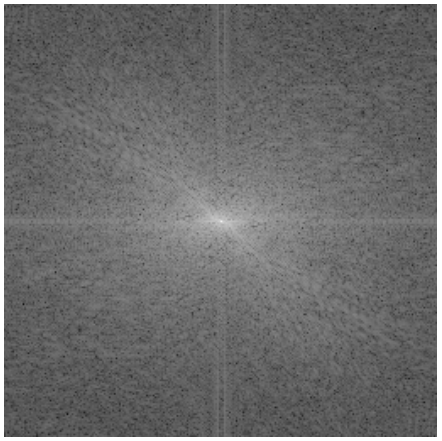
Fine quantization

Coarse quantization

Reconstruction from Fourier Magnitude or Phase

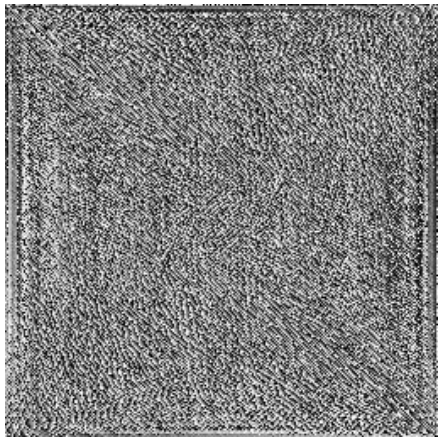
Original

DFT



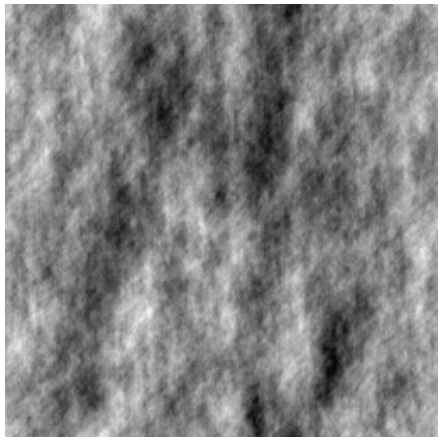
+

Magnitude



Phase

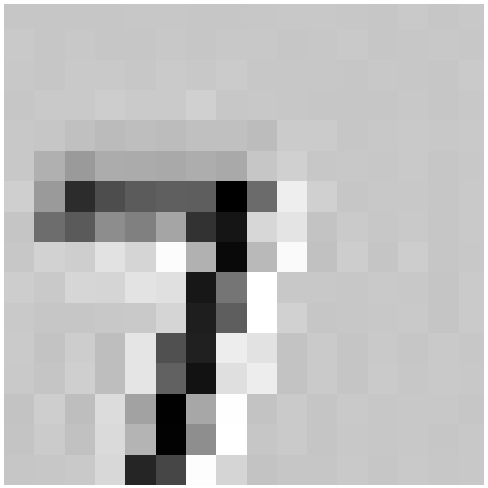
IDFT with constant Phase



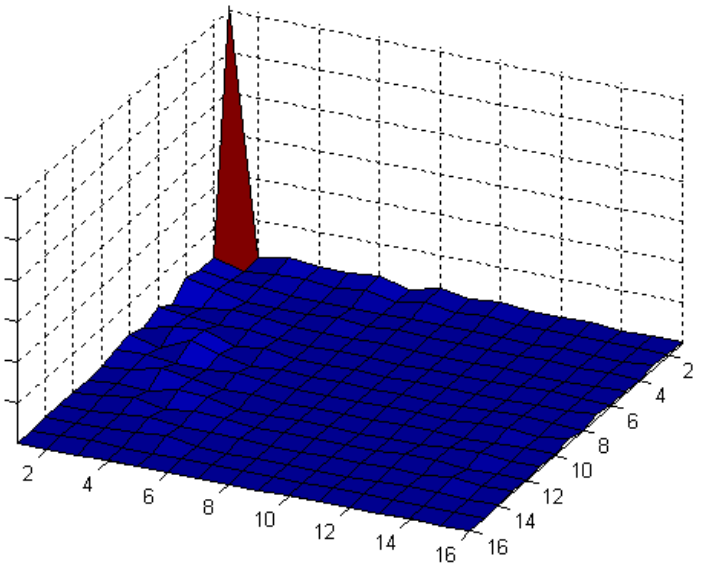
IDFT with constant Magnitude

Transform Coding - Example

16×16 block of pixels



DCT coefficients

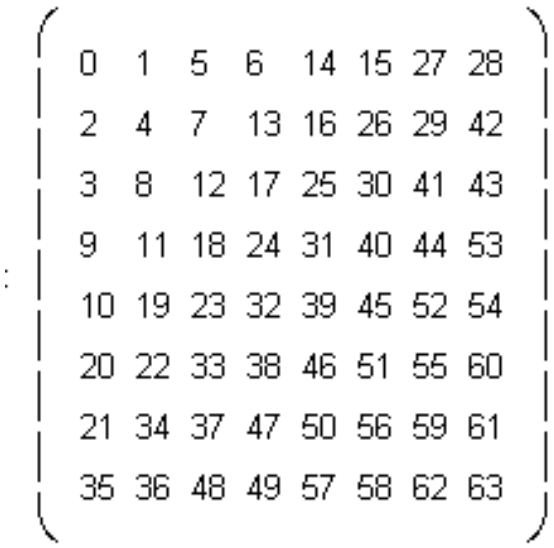


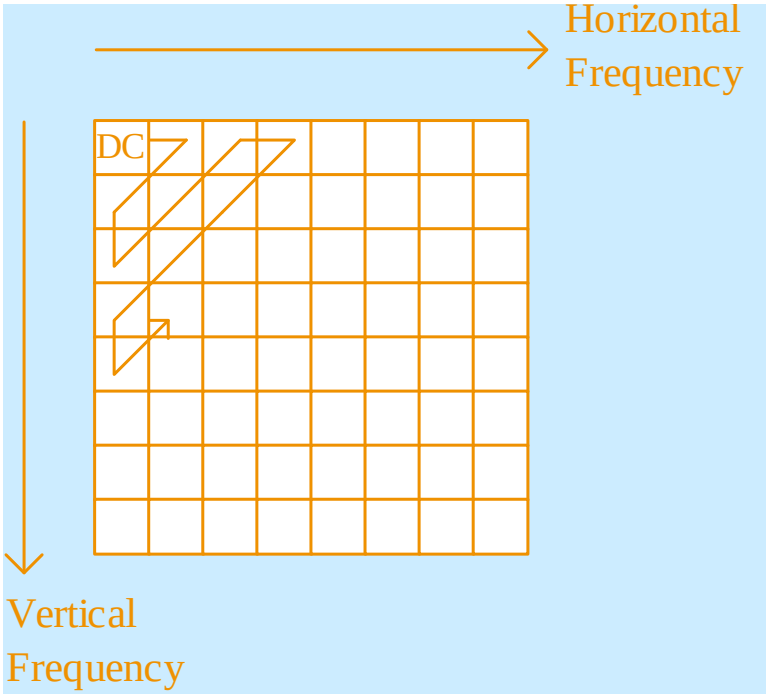
Other Compression Models

- Other models were candidates for JPEG:
  - Block Truncation Coding (BTC)
  - Vector quantization (VQ)
  - Other Transform Coding (TC) schemes
  - Sub-band coding (SBC)
  - Other predictive coding models
- The DCT model provided (Jan.1988) best **average** image quality for a given bit-rate

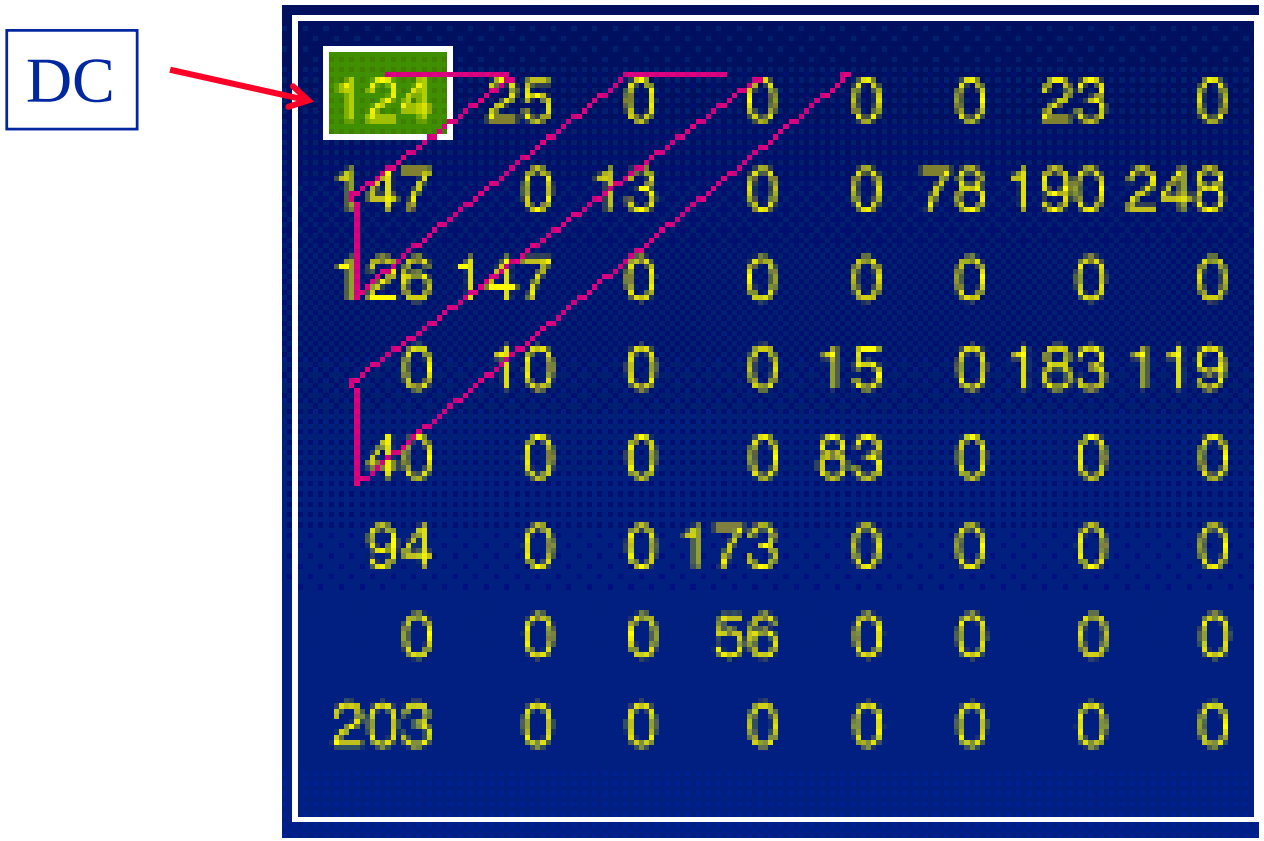
Coding Model

Zig-Zag scan (instead of Raster scan) achieves longer “zero coefficients sequences”, after quantization.





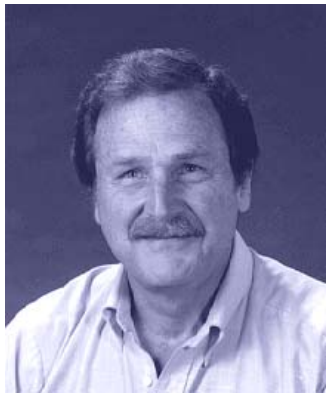
Zig-Zag example



Entropy Encoding/Decoding

2 entropy coding structures used in JPEG:

- Huffman coding:
  - Good old wine … (1952)
  - Computationally simpler
  - Implementation simpler
  - Requires known / calculated code tables
- Arithmetic Coding
  - About 10% higher performance
  - Code book adapts dynamically to coded data
  - IBM Patented...



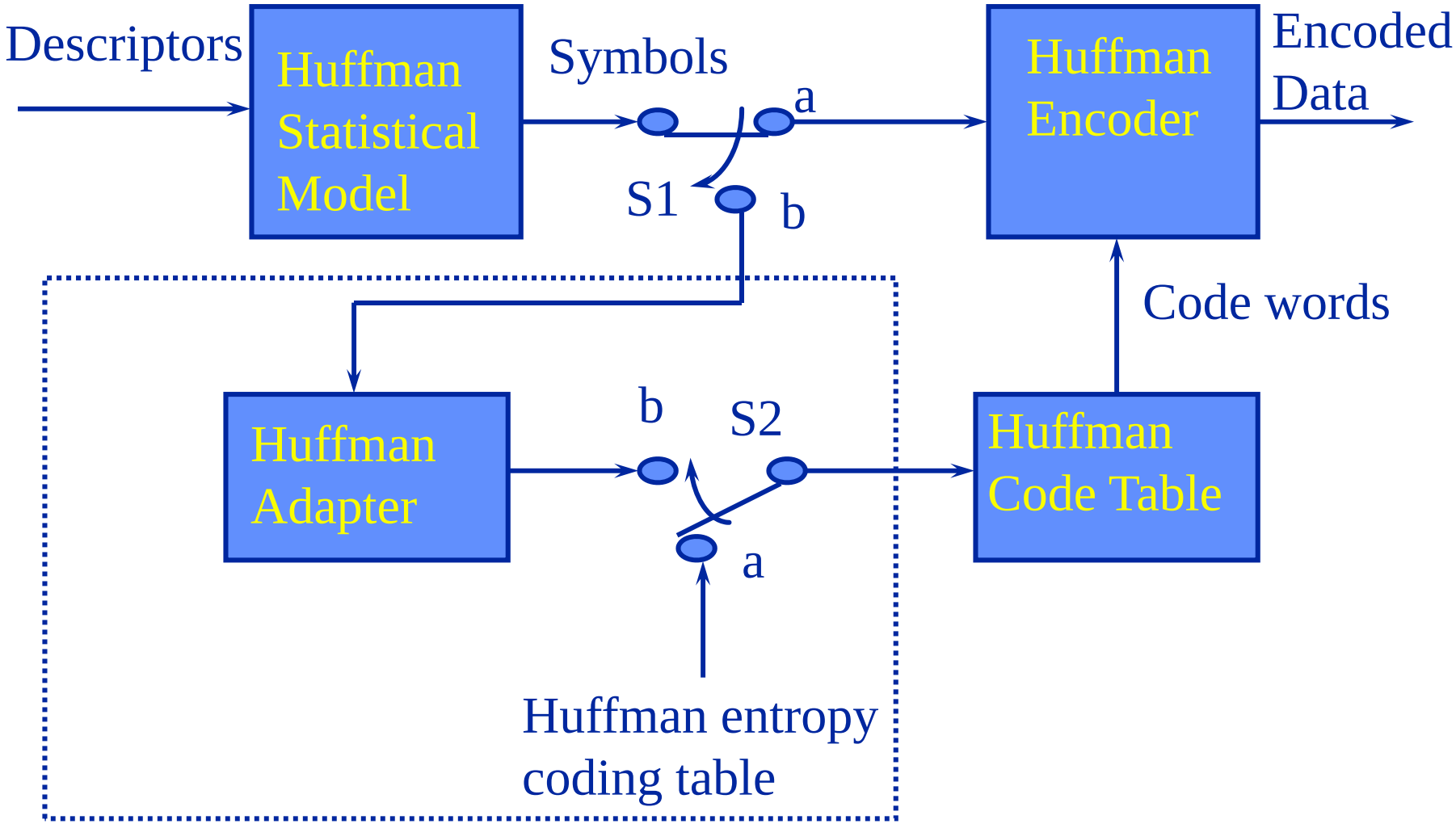
David A. Huffman
1925-1999

Huffman Entropy Encoder

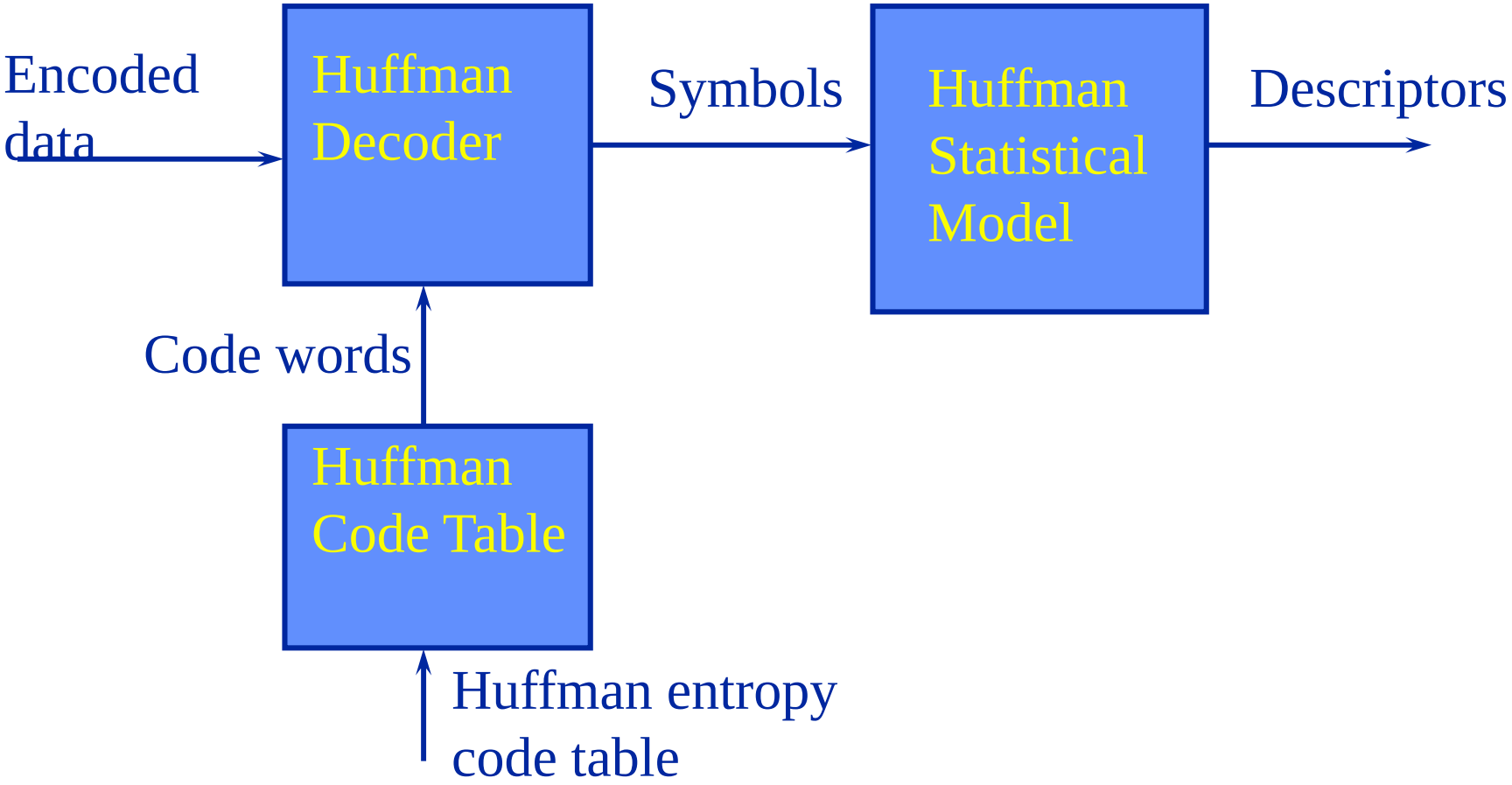
- Statistical model: converts descriptors into symbols, each assigned to particular code word
- Adapter: responsible for the assignments of code words needed by the encoder
- Code Tables: can be fixed or adapted to data to improve efficiency by a few percent

- Note that 1 pass (fixed tables) or 2 passes (adaptive table) are options

Huffman Encoder Scheme



Huffman Decoder Scheme



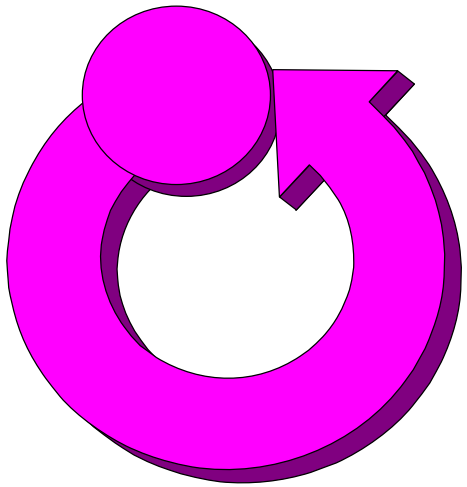
Arithmetic Coding

- One pass adaptive binary coder.
- Achieves about 10% better compression.
- More complicated then Huffman.
- Option to transcoding between the two.
- Almost not in use in JPEG (used in JBIG)
- IBM Patent.

JPEG Lossless Mode

- Based on DPCM only (without DCT and Q)
- Poor compression relative to Lossy mode (1:1 Vs. 20:1 for color natural image)
- (Almost) Not in use

Since 1997: JPEG-LS



Progressive Mode

- Allows the user to preview a rough version of the image
- Two or more passes through data
- Approximation of entire image coded first
- Finer details are coded with each succeeding scan
- Decoder follows same order in decoding
- Identical compression and quality (sometimes even better)

JPEG Base-line Scheme (Lossy)