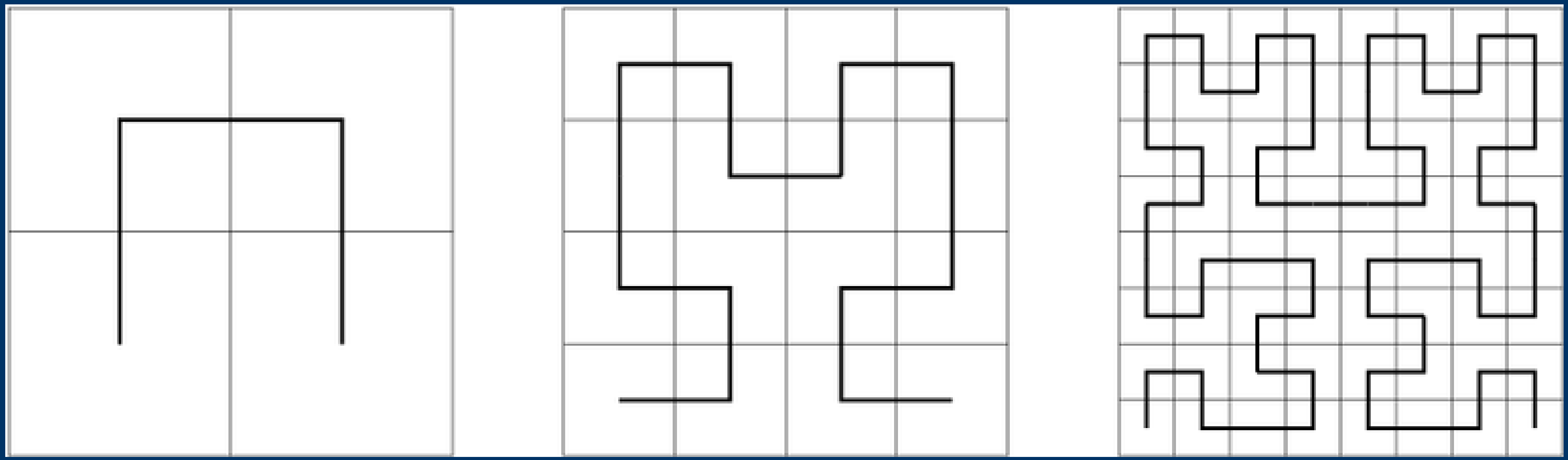
Image Coding and Data Compression

Part 2 : Data Compression

Boyana Nenova
Jayaprakash Rajasekharan

Image Scanning

- Space Filling Curve - map a line on to a 2D space
- Peano-Hilbert Curve
- Peano scanning



Peano-Hilbert Curve

- 2D local statistics are preserved in 1D data stream.
- Higher correlation between pixels in stream.
- Scanning and reconstruction is lossless.
- Improved Image data compression.
- Continuous and not differentiable.
- Does not pass through any point more than once.
- Recursive nature, easy to implement.
- Image dimensions must be $2^n \times 2^n$

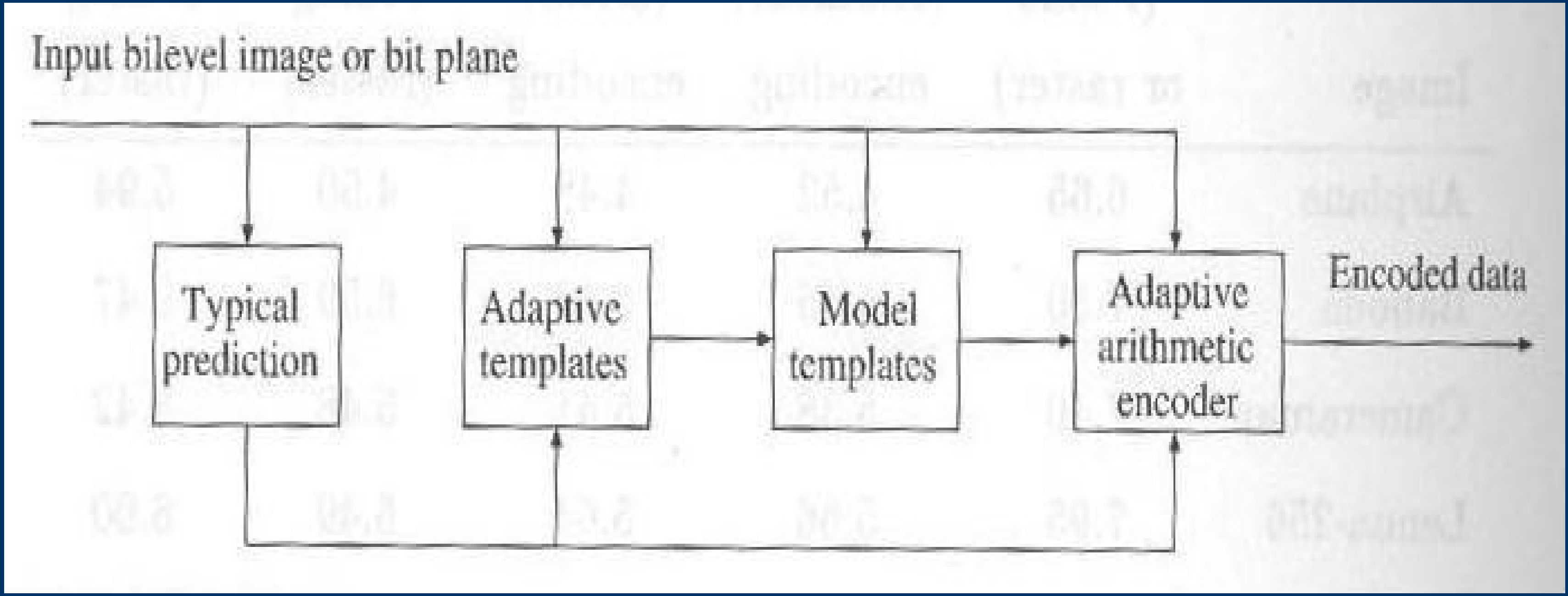
Image Compression Standards

- JBIG – Joint Bi-level Image Experts Group
- JPEG – Joint Photographic Experts Group
- MPEG – Moving Pictures Experts Group
- ACR/NEMA – American College of Radiology/ National Electrical Manufacturers Association.
- DICOM – Digital Imaging and Communications in Medicine

JBIG

- Standard for progressive coding of bi-level images
  - Progressive coding
  - Sequential coding
  - Single-layer coding
    - Prediction step
    - Adaptive template
    - Model template
    - Adaptive arithmetic encoder

JBIG

- 

- 3 levels of decorrelation
- 1D JBIG coding uses run length coding

Enhanced JBIG

- PSV = 7

$$\tilde{f}(m,n) = \frac{f(m-1,n) + f(m,n-1)}{2}$$

- F1 Transform

$$v_1 = F_1(v) = \begin{cases} 0; & v = 0 \\ 2\mathrm{v} - 1; & v \leq 2^{K-1} \\ 2(2^K - v); & v > 2^{K-1} \end{cases}$$

- Enhanced JBIG - PSV7-F1-JBIG

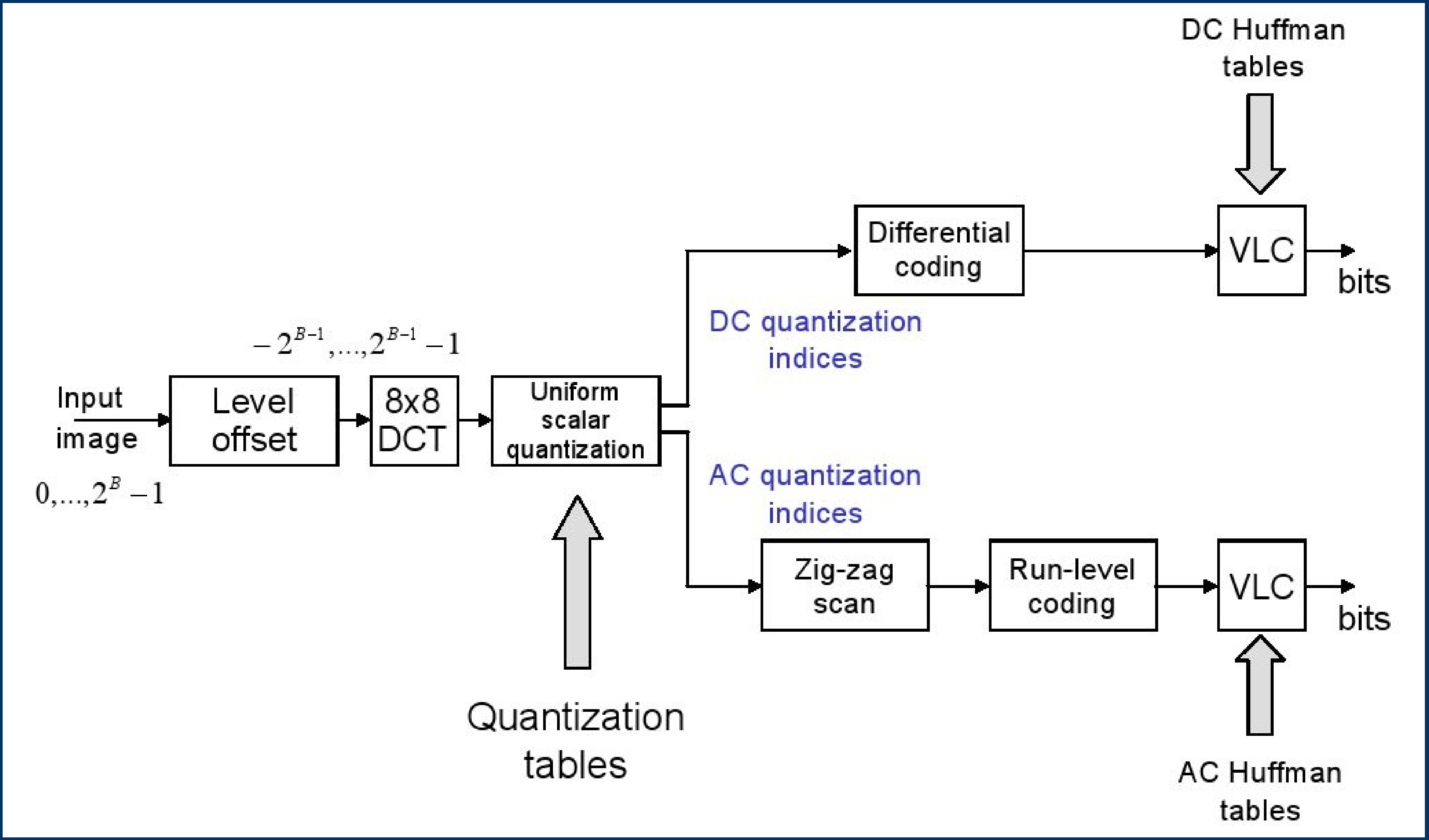
JPEG

- Flexible standard for monochrome and color image compression.
- Digital compression and coding of continuous-tone still Images.
- Work started in mid-1980's
- Draft international standard 1991
- Intra-frame coding scheme, optimized for still images.
- Coding of color components separately, arbitrary color spaces possible, best compression for YCbCr.

JPEG

- Variable compression ratio
- Compression ratio up to 24:1 for ITU-R 601 images without loss of quality
- Widely used for image exchange, WWW, and digital photography
- Supports both lossless and lossy coding
  - Baseline coding – Block-wise DCT
  - Extended coding
  - Lossless independent coding

JPEG


DC Huffman tables
Differential coding
VLC
bits
DC quantization indices
$-2^{B-1},\ldots,2^{B-1}-1$
Input image
Level offset
8x8 DCT
Uniform scalar quantization
$0,\ldots,2^{B}-1$
AC quantization indices
Zig-zag scan
Run-level coding
VLC
bits
Quantization tables
AC Huffman tables

JPEG

- Different weighting matrices are standardized, adapted to human visual contrast sensitivity.

Luminance

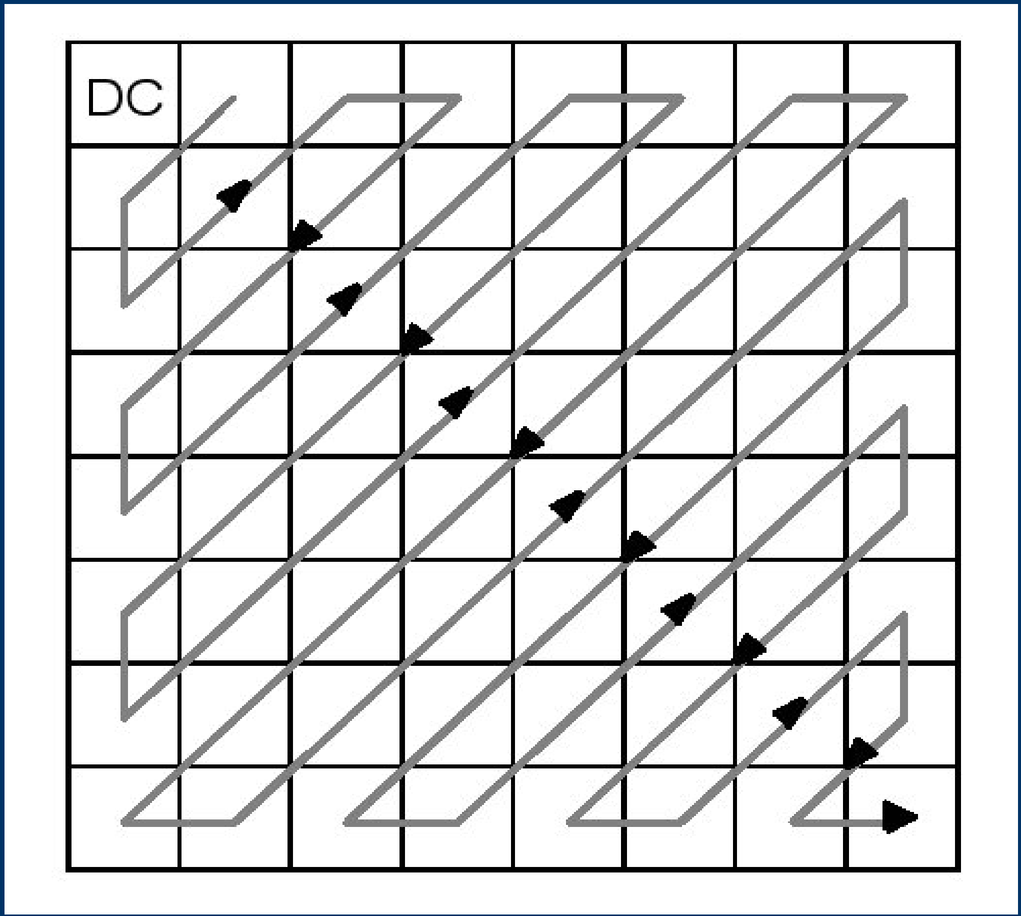
16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Chrominance

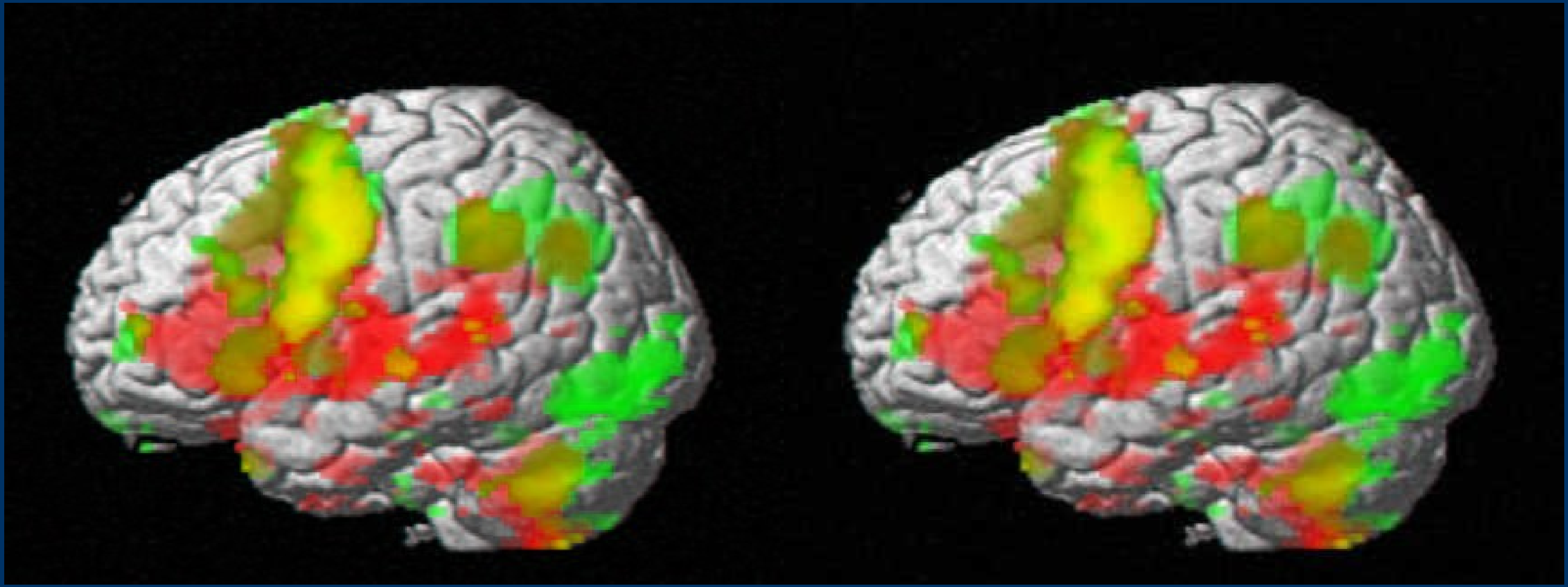
17	18	24	47	99	99	99	99
18	21	26	66	99	99	99	99
24	26	56	99	99	99	99	99
47	66	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99

JPEG

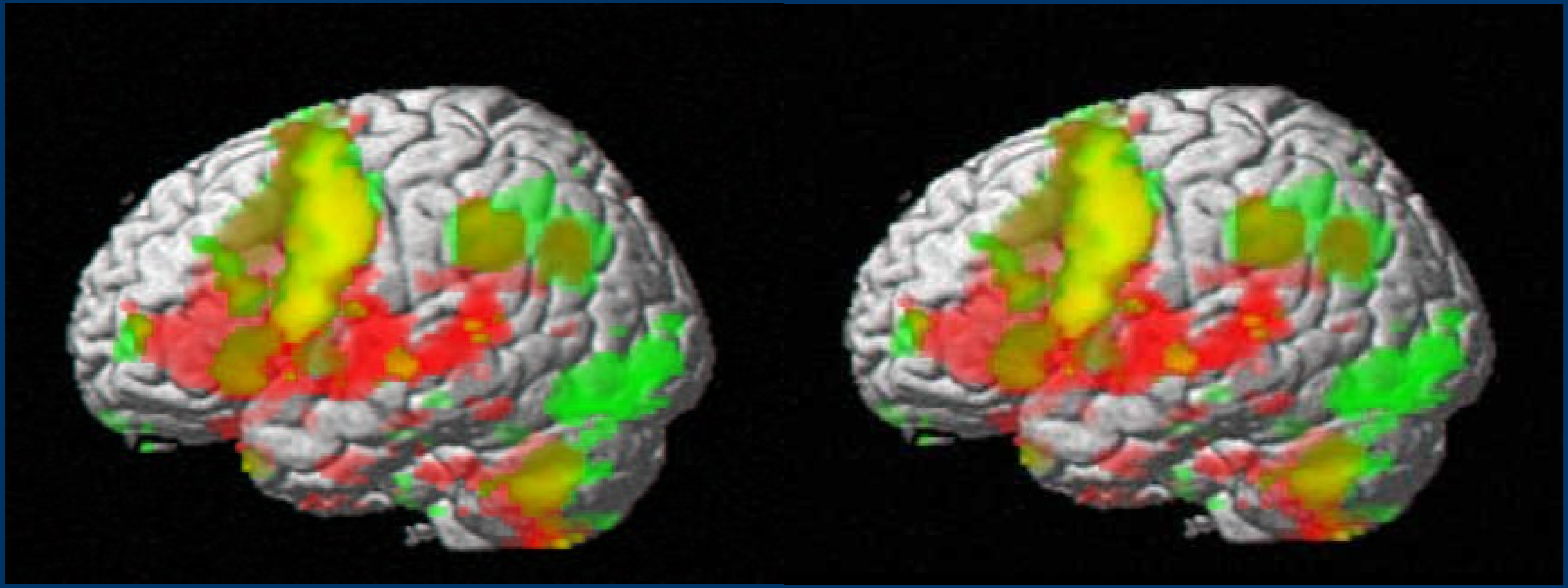
- Zig-Zag Scanning



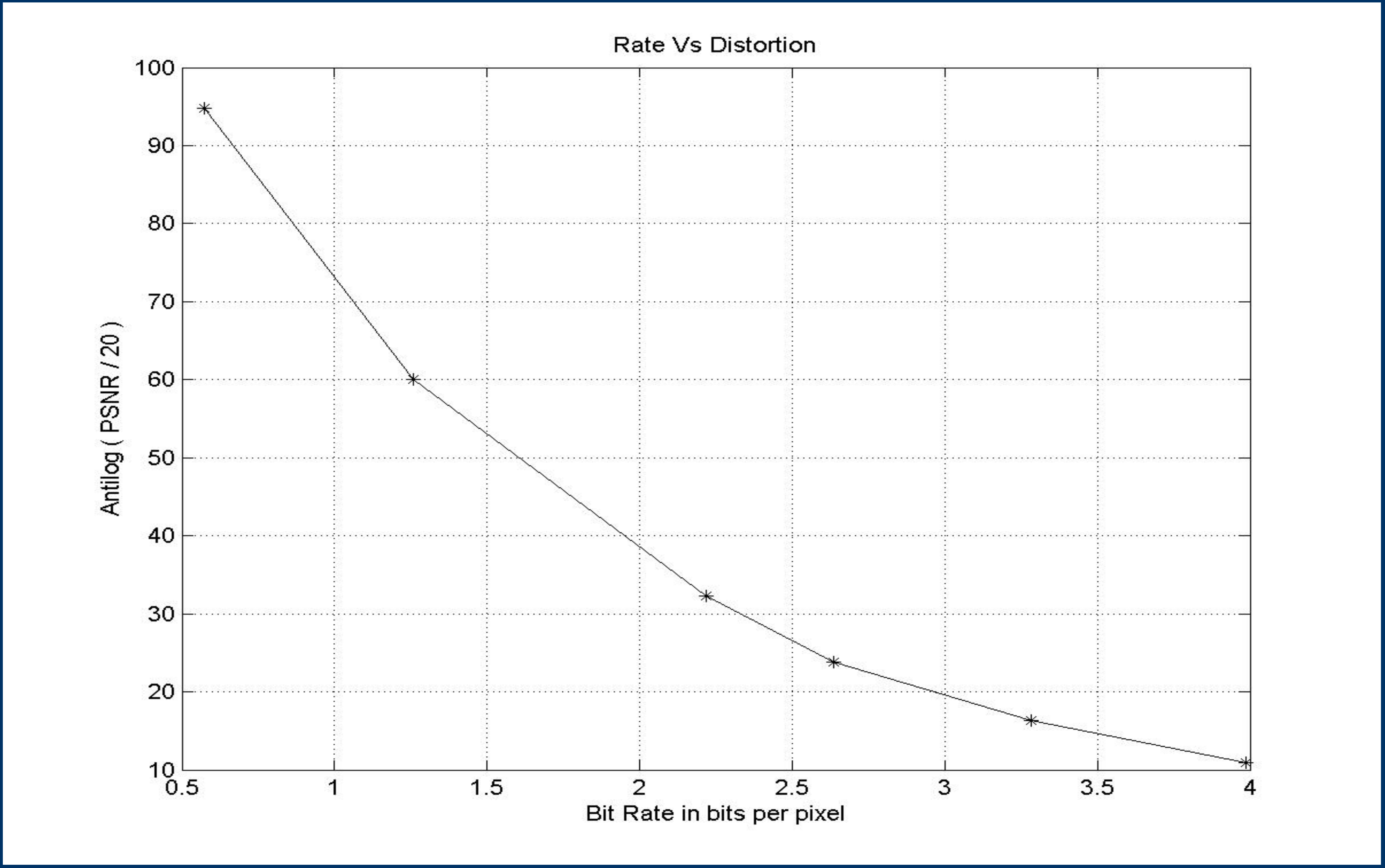
Illustrations - Baseline JPEG

- 
- Original Image : 368 x 432 x 3 = 466 KB (8 bpp)
- Transmitted Stream = 21,995 bytes = 21.5 KB
- Compression Ratio = 22:1
- PSNR = 35.299 dB , MSE = 19.195

Illustrations - Baseline JPEG

- 
- Original Image : 368 x 432 x 3 = 466 KB (8 bpp)
- Transmitted Stream = 15,300 bytes = 15 KB
- Compression Ratio = 31:1, Subsampled Chrominance
- PSNR = 32.525 dB , MSE = 36.354

Illustrations - Baseline JPEG



Quote

- Perfection is reached,
  not when there is no longer anything to add,
  but when there is no longer anything to take away.
  - Antoine de Saint-Exupery

Segmentation-based Adaptive Scanning

- Segmentation-based Lossless Image Coding – SLIC
- Segment the image into nearly homogeneous regions surrounded by contours representing individual objects in the image – Region Growing Approach
- Encode contour and texture information and discontinuity map and error image separately using gray codes.
- JBIG Encoding

Lower-limit Analysis of Lossless Data Compression

- Lowest limit of bit rate in lossless compression can not be determined practically.
- Difficult to judge various compression algorithms.
- Zeroth-order entropy is a useful metric.
- Higher order entropy values can provide a better estimate to the lower bound bit rate.

Memoryless Entropy

- Memoryless source
- Successive pixels are statistically independent
- M^{th} order entropy

$$H_m(A) = H_m(a_{i_0}, a_{i_1}, a_{i_2}, \ldots\ldots, a_{i_m})$$

$$= -\sum_{A^m} p(a_{i_0}, a_{i_1}, a_{i_2}, \ldots\ldots, a_{i_m}) \log_2 p(a_{i_0}, a_{i_1}, a_{i_2}, \ldots\ldots, a_{i_m})$$

- $H(A) = \dfrac{H_m(A)}{m+1}$

Markov Entropy

- Successive pixels are significantly interdependent even after decorrelation
- Source has memory
- Can be modeled as a Markov source

$$H(a_{i_0} / a_{i_1}, a_{i_2}, \ldots\ldots, a_{i_m}) = -\sum_{A^m} p(a_{i_0}, a_{i_1}, a_{i_2}, \ldots\ldots, a_{i_m}) \times \log_2 p(a_{i_0}, a_{i_1}, a_{i_2}, \ldots\ldots, a_{i_m})$$

- $H(a_{i_0} / a_{i_1}, a_{i_2}, \ldots\ldots, a_{i_m}) \leq H(A)$

Estimation of true source entropy

- Order of the model and conditional pdfs are unknown.
- Higher the order of the conditional probability -> Lower resulting entropy -> Closer to the true source entropy.
- Estimate conditional probabilities for an m^{th}-order Markov source model with 2^K intensity levels and N data samples
- Estimation error $\epsilon = \frac{2^{mK} - 1}{2N \ln 2}$
- For a given ε, derive a higher order parameter by reducing K - splitting the data bits.

Quick Recap

- Piano-Hilbert Curve
- Image Compression Standards
  - JBIG
  - JPEG
    - Baseline Encoding
    - Rate-Distortion Curve
- Segmentation based adaptive scanning
- Lower-limit of data compression
- Estimation of true source entropy

Thank You

Any Questions..?? *

* If there are no questions today, then be prepared to answer some very difficult questions next week..!!