Image compression

- Redundancy: character distribution, character repetition, high usage pattern
- Trade-off in lossless: coding efficiency (compression ratio), coding complexity (memory, operation), coding delay
  - Algorithm: Lzw, Run Length Coding, Huffman
- Entropy coding: entropy is lower bound for rate in lossless coding of digital image
  - Short keyword => high probability

Run Length Coding (RLC)

- Only use horizontal correlation

"000000000001100000111100011111101111110001111000001100000000000"

"11, 2, 5, 4, 3, 6, 1, 8, 1, 6, 3, 4, 5, 2, 11"

ENTROPY ENCODER

Huffman

- Order by probability
- Contraction process with 2 smallest prob symbols form new composite symbol
- Other variance : Shannon Fano (split from big to smaller group)

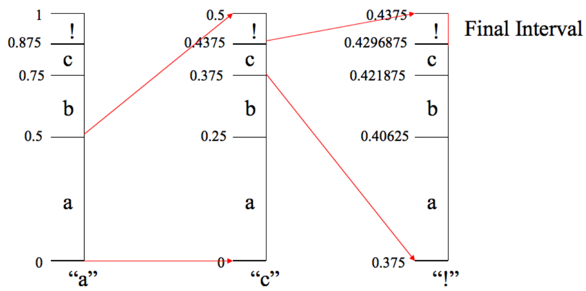
Universal code

- Predefined codes
- Need order of probability value

Arithmetic coding

- More efficient than Huffman coding
- Not require integer number of bit. Just map to a float

A={a,b,c,!}; p(a)=0.5, p(b)=0.25, p(c)=0.125, p(!)=0.125; M="ac!"



Adaptive and non-adaptive

- Non adaptive: probability of sysbols is fixed at the beginning
  - Static 1-pass (p known)
  - Static 2-pass: read all data to compute Huffman code -> re-read use code to compress
- Adaptive: the probability of symbol depend upon the symbols decoded in that ime
  - Encoder and decoder have known p
  - Agree on procedure

LZW

- Create table for coding
  - Read next symbol K
  - If table contain wK => w=wK
  - Else output code w => add wK into table => w = K
- LZ77

			b	a	b	c	a	b	a	c	b	c	a	b	a	b	a	b	a

STEP	N-F symbols already encoded							F symbols to encode				Codeword		
	7	6	5	4	3	2	1					i	j	s
1	0	0	0	0	0	0	0	b	a	b	c	0	0	b
2	0	0	0	0	0	0	b	a	b	c	a	0	0	a
3	0	0	0	0	0	b	a	b	c	a	b	2	1	c
4	0	0	0	b	a	b	c	a	b	a	c	3	2	a
5	b	a	b	c	a	b	a	c	b	c	a	4	1	b
6	b	c	a	b	a	c	b	c	a	b	a	6	4	-
7	a	c	b	c	a	b	a	b	a	b	a	2	4	-

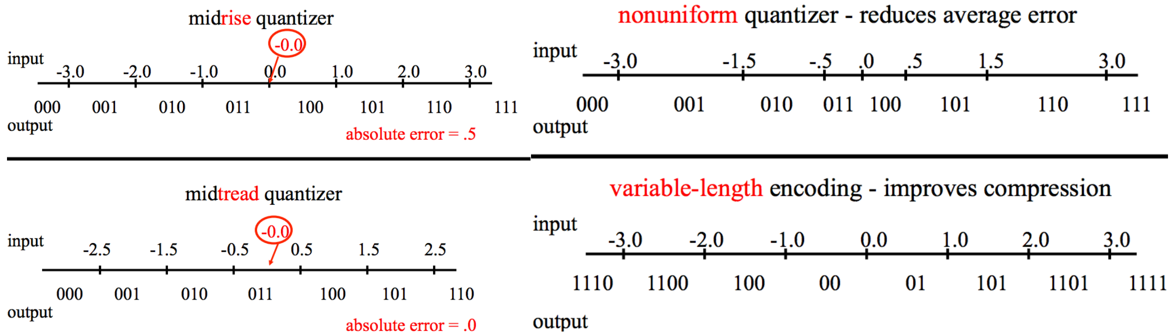
JPEG encoding

- Input component's sample are grouped into 8x8 blocks (image have many 8x8 blocks)
- Each block transform into set 64 values (corresponding to DCT coefficients) (1DC +63 AC)
- Each of 64 coefficient then **quantized (**depend on position of coefficient)
- The sequence of DC coefficient is ecoded by **DPCM**
- 63 AC quantized -> 1 dimension by zig-zag -> RLC

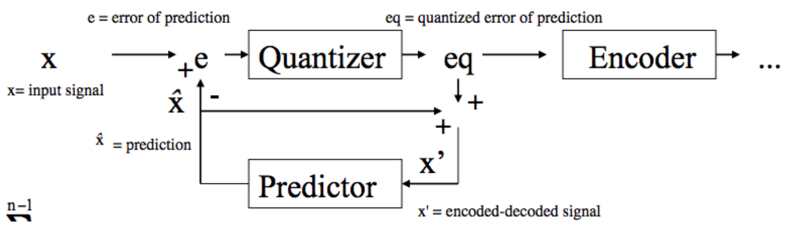
DCT

- linear combination 64 element blocks can express any image block (8x8)

Scalar quantization



DPCM – Adaptive Pulse Code Mudulation



- Effected by Slope overload (function fluctuate greatly but error coding (slope) cannot be greater than threshold) and Granular Noise (output signal always increase or decrease after quantized)
- ADPCM use

Distortion

- Compression: REDUNANCY (reversible) + IRRELEVANCY (irreversible, lossy)
- Mean square error
- PSNR, SNR, wPSNR. SNR = $10\log_{10}\frac{k^2}{MSE}$ (db)
    - wPSNR will be higher for image have complex texture (fur of animal vs the sky)
- $\mathrm{wPSNR(I,J)} = 10\log_{10}\frac{k^2}{\sum_{i,j} w(i,j)error^2 * \frac{1}{NM}}$ $with\ w(i,j) = \frac{1}{1+K\sigma_b^2}\ \sigma_b stardard\ variation\ in\ a\ block\ (size\ b)$
- BETTER RESULT WHEN PSNR > 38

Modes of operation

- Sequential DCT-base: send sequentially all inf each block (8x8)
- Progressive (successive): send basic inf of all blocks then detail inf later
- Hierarchical:
    - Downsampling -> encode reduce size -> de-docde and upsample (interpolate)
    - Compute image different and encode it

- Continue with next scale

Color Images

- Transform into YUV, YCrCb, RGB
- Non-uniform Quantization: eye is sensitive with low frequency

Interlaced GIF

- Image is displayed increasingly in several pass
- The scan line is store in unusual order

JPEG 2000 vs JPEG

- Region of interest
- Better robust against error
- More flexibilities
- Lossy and lossless modes
- Better performance
- Can manage computer-generated images

Encoding

- Original data -> preprocessing -> discrete wavelet transform -> uniform quantizer with deadzone -> apdaptive binary arithmetic coder -> bit stream organization -> compressed image data

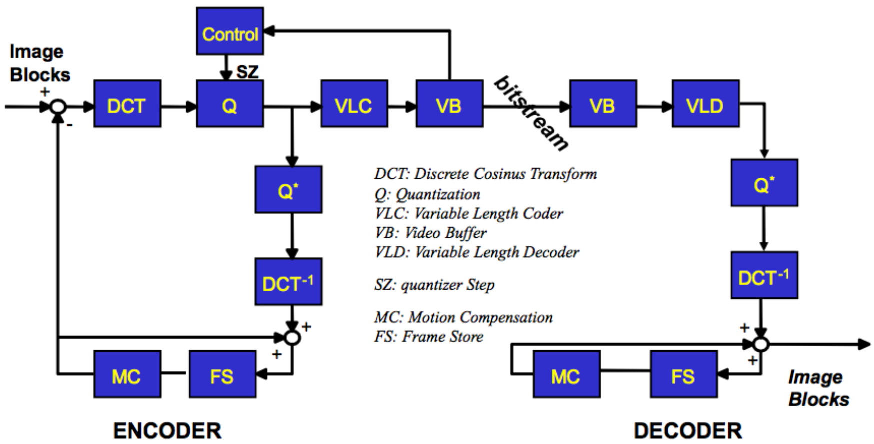
FOURIER	WAVELET
Break up a signal into sin wave of various frequency	Into shifted and scale version of origin wavelet
From time-based domain to frequency-based domain	From time-based domain to time-scale-based domain
Loses time information	Retains time information
	Provides good compression and de-noising Performs local analysis

- Component Transform. Reversible Component Transform (lossless) and YCbCr transform (lossy)
- Wavelet transform (5x3 filter lower complexity and lossless, 9x7 highest compression
- Quantization: tradeoff rate and distortion (by division or (lossy) by truncation (lossless)

Video coding

H.261 H.263 H.264 Visioconference	MPEG-x (1,2,4,7,21) Moving Picture Expert Group
HEVC (High Efficiency Video Coding)	

- MPEG(1,2) Pixel-based -> MPEG 4 Object-based -> MPEG7 Sematic-based
- Compression efficiency gain 50% every 5 years
- Resolution (number pixels in regions) – Definition (range of value in that pixel)
- Video sequence -> group of picture (GoP) -> Frame -> macroblock (8x8pixel 4 Illumination (Y) and Chromatic (Cr,Cb)



- Video buffer ensure constant target bit-rate output is produced by encoder
- FS: store motion-compensation pixel from previous frame (I- P- picture)

Motion estimation compensation (block-matching BM)

- For each block B_t current picture t => find B_t-1 is similar to B_t
  - Search limit in a area
  - Displacement is represented by vector
- Cost function, Mean-absolute different, Cross-correlation function (cos similiarity), Mean square, pixel difference
- Optimization version
  - Try on 8 neighbour (distance = 3). Find most similar one
  - Then do it again with distance 2 and 1 => the last similar one is optimum

Group of Picture

- Intra picture contains ìnormation of whole image
- Predicted picture (coded using motion-compensation from previous I or P)
- Bidirectional (Bidirectional coded from both past and future I and P)
- N distance between I, M distance between P
  - N=1 => MJPEG (send fully sequence of image)
  - M=1 => MPEG1 or H.261
  - Practice M=3 N=12 (EU) or M=3 N=15 (USA) (because of electric frequency)

Extension

H.263 vs 261

- Sub-pixel precision (Motion Compensation)
- Options (Unrestricted Motion Vector, Advanced Prediction, Syntax-based Arithmetic coding, PB)
- Support video format (SQCIF, 4CIF, 16CIF)

H.264

- Video is coded as one or more slide, contain macroblocks (16x16 luna, 8x8 chroma)
- Slice: skip run + macroblock (mb_type,mb_predict, residual)
  - Skip run: skip some macroblocks, they can be calculated by Motion compensation from neighbour -> fill to decoded frame
  - Mb_type: intra or inter

Intra block prediction

- Spatial prediction: from neighbour sample using mode (vertical, horizontal, DC,…)
- Residual: dif from predicted block and original block

Inter block prediction

- Temporal prediction: from one or more previously encoded frame
- Macroblock partition (16x16) -> sub-macroblock => each partition is predict from same area in reference picture

Deblocking filter

- Apply into Macroblock to reduce blocking distortion
- Filter strength based on intra coded, MB boundary using different reference frame or different motion vector

MPEG-2

- Levels and profiles: stipulate conformance of algorithm between levels
- Scalable encoding: SNR (quality), spatial and temporal

Profile

- Simple: YUV 4:2:0, Non-scalable coding supporting functionality (NSC) for Random Access
- Main: YUV 4:2:0, Same **simple** but NSC for B-picture prediction
- SNR scalable: YUV 4:2:0, same main, SNR scalable coding
- SPATIAL scalable: YUV 4:0:0 Spatial scalable coding
- High: YUV 4:2:2 same spatial scalable, 3 layers with SNR and and spatial scalable coding

Y:U:V

- Force chunks of pixel share chromatic
- Second number – number of chromatic values for top row
- Third number – number of chromatic value for bottom row
- 4:2:0 => bottom row share color with top row

MPEG-4

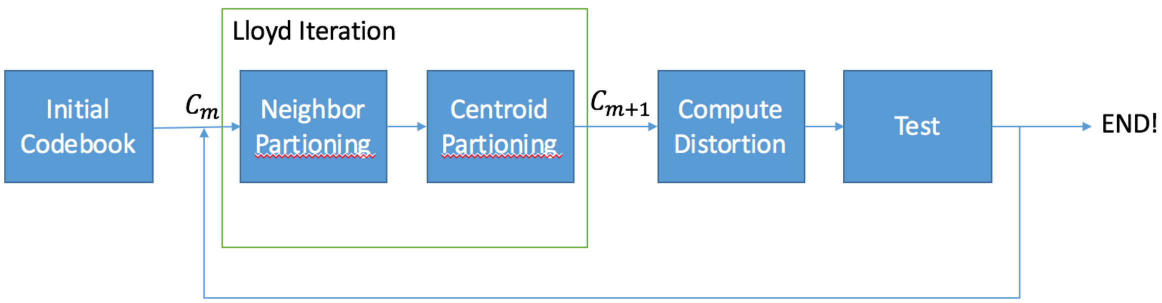
- Shape – Texture
- Video object & video object plane

Vector Quantization

- Goal: minimize global distortion $\frac{1}{n}\sqrt{\sqrt{(\sum_i^n (X_i - Q)\text{^}2}}$
- To represent your vector by vocabulary in codebook
    - Find vector in code book that “close” to your vector
    - Get index of vector in code book
- Optimal quantization (Lloyd Max) - Joint optimization
    - Given codebook find best partition=> nearest neighbour condition
    - Given the partition find best codebook -> centroid condition
- Scalar quantization – vector quantization

Generlized Loyd Algorithm (GLA)

- Begin with initial codebook C_1,
- Given code book C_m perform the Lloyd iteration to generate the improved codebook C_(m+1)
- Compute average distortion C_(m+1) if is good enough and stop



Linde, Buzo, Gray (LBG)

- Goal: mean distortion decrease, local minimum, choise of the initial cookbook
- Idea: start with code book of size 2
    - Each iteration each vector split into 2 vectors (+/- a)
    - Optimal codebook with 2n vector