Introduction to Image and Video Coding

www.vcodex.com

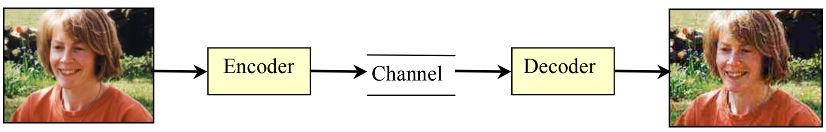
The need for compression

- Colour image, 352x288 pixels
- "Full" colour depth: 24 bits per pixel (8 bits red, green, blue)
  - 304128 bytes
- Reduced colour depth: 12 bits per pixel
  - 152064 bytes

The need for compression

- Video signal: 25 frames per second
- “VHS video” quality: 352x288 pixels per frame, 12 bits per pixel
  - 30.4 Mbits per second
- “Television” quality: 704x576 pixels per frame, 12 bits per pixel
  - 121.7 Mbits per second
- too much data for cost-effective transmission or storage
- need compression

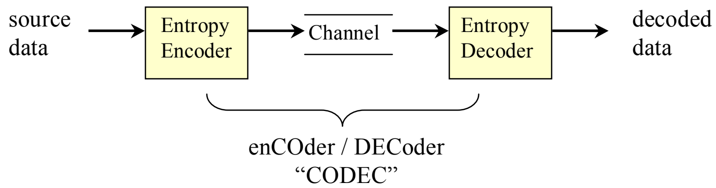
Image or Video CODEC



- Encode (compress) and decode (decompress) still images or moving video
- Key issues:
  - compression efficiency and image quality
  - computational complexity
  - frame rate

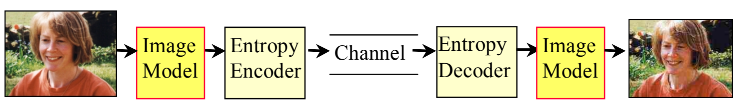
The coding model

- General-purpose compression: entropy encoding
  - remove statistical redundancy from data
  - e.g. encode common values with short codes, uncommon values with longer codes
- Good for text files, poor for images / video



The coding model

- Solution: add a model that attempts to represent the image/video signal in a form that can be easily compressed by the entropy encoder
- model exploits the subjective redundancy of images and video
- decoded image may not be identical to original image



The coding model

- Image properties that are useful for compression
  - many of the pixels of a typical photographic image contain little or no “useful” detail (e.g. “flat” areas)
  - the eye is insensitive to “high frequency” image information

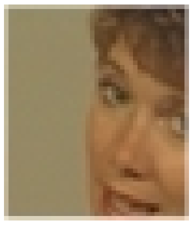
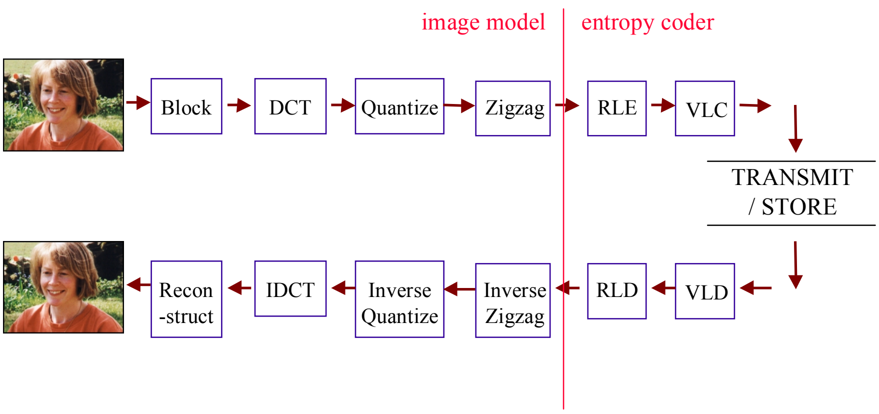
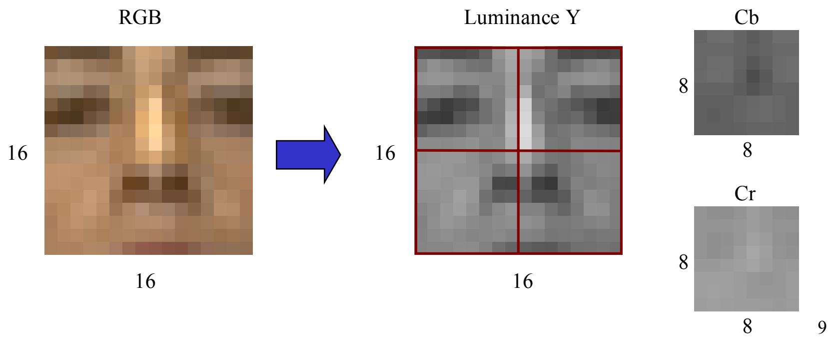


Image CODEC (e.g. JPEG)



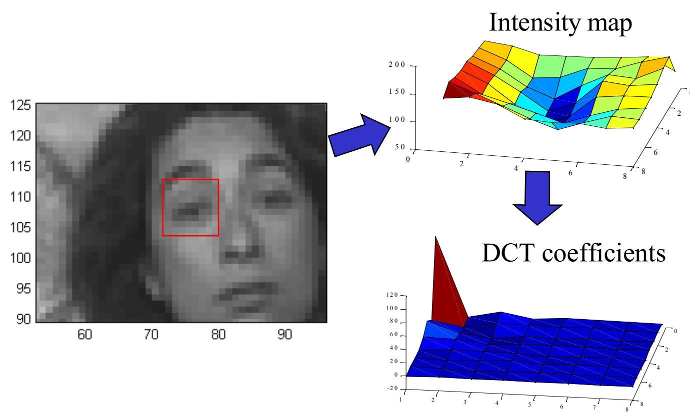
Blocks

- Process the data in blocks of 8x8 samples
- Convert Red-Green-Blue into Luminance (greyscale) and Chrominance (Blue colour difference and Red colour difference)
- Use half resolution for Chrominance (because eye is more sensitive to greyscale than to colour)



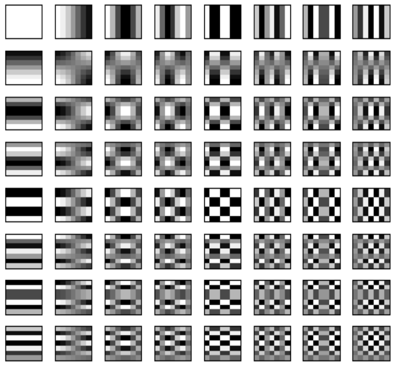
Discrete Cosine Transform

- Transform each block of 8x8 samples into a block of 8x8 spatial frequency coefficients
  - energy tends to be concentrated into a few significant coefficients
  - other coefficients are close to zero / insignificant

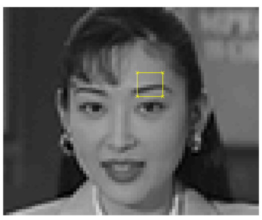


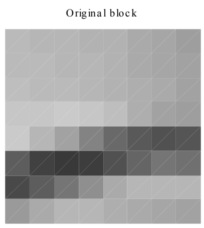
Discrete Cosine Transform

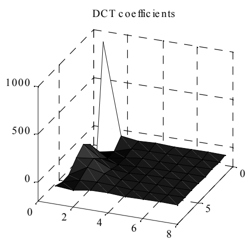
- Any 8x8 block of pixels can be represented as a sum of 64 basis patterns (black and white patterns)
- Output of the DCT is the set of weights for these basis patterns (the DCT coefficients)
  - multiply each basis pattern by its weight and add them together
  - result is the original image block

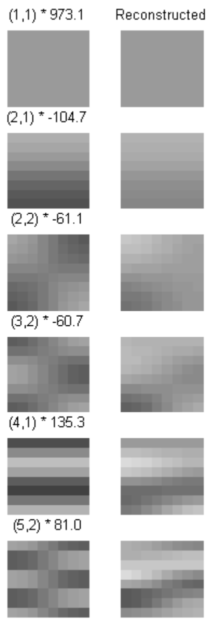


Synthesising a block from DCT coefficients









DCT

- Most image blocks only contain a few significant coefficients (usually the lowest “frequencies”)

1 Top-left coefficient per block

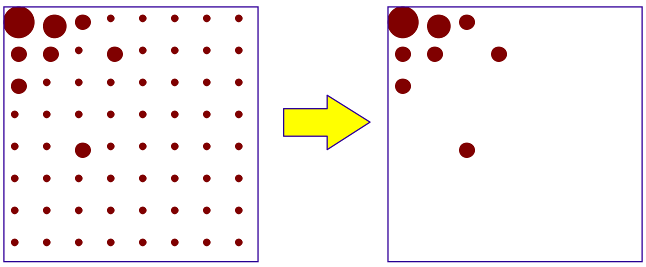
3 top-left coefficients

6 top-left coefficients

All coefficients

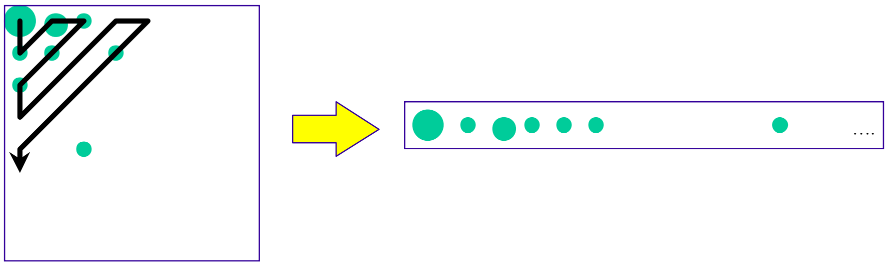
Quantize

- Divide each DCT coefficient by an integer, discard remainder
- Result: loss of precision
- Typically, a few non-zero coefficients are left



Zigzag Scanning

- "Scan" quantized coefficients in a zig-zag order
- Non-zero coefficients tend to be grouped together



Run-Level Encoding

- Encode each coefficient value as a (run,level) pair
  - run = number of zeros preceding value
  - level = non-zero value
- Usually, the block data is reduced to a short sequence of (run,level) pairs.
  - This is now easy to compress using an Entropy Encoder.

Example:

Original data	14,3,4,0,0,-3,0,0,0,0,0,14,…
(Run,level)	(0,14)(0,3)(0,4)(2,-3)(5,14)...

Variable-Length Coding

- Encode each (run,level) pair using a variable-length code
- Frequently occurring groups
  - assign a short code
- Infrequently occurring groups
  - assign a long code

- Result: compressed version of image.

Image CODEC

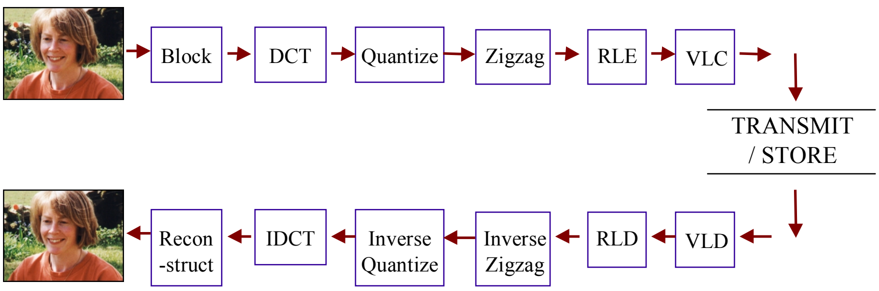


Image Decoding

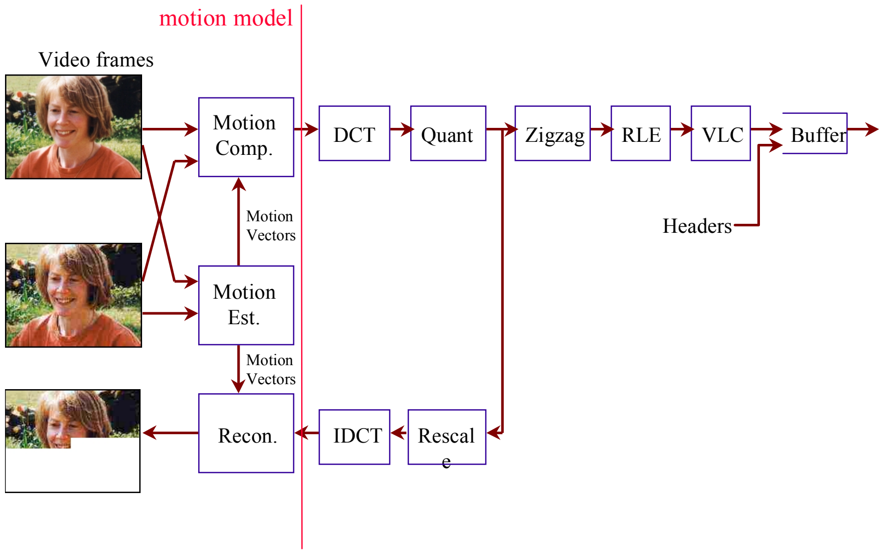
- Reverse the stages to recover the image
- Information was thrown away during Quantization
  - decoded image will not be identical to the original
- In general:
  - more compression = more quality loss
- Too much compression:
  - block edges start to show (“blockiness”)
  - high-frequency patterns start to appear (“mosquito noise”)

Video Coding

- Moving images contain significant temporal redundancy
  - successive frames are very similar
- Add an extra “motion model” at the “front end” of the image encoder.

Frames captured at 1/10 second intervals

Video Encoder



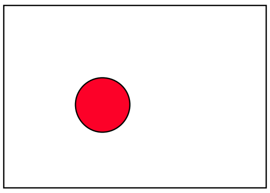
Motion Estimation and Compensation

- The amount of data to be coded can be reduced significantly if the previous frame is **subtracted** from the current frame:

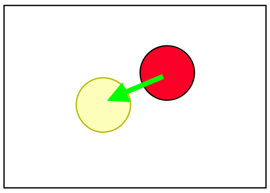
Residual Image

Motion Estimation

- Process 16x16 luminance samples at a time (“macroblock”)
- Compare with neighbouring areas in previous frame
- Find closest matching area
  - prediction reference
- Calculate offset between current macroblock and prediction reference area
  - motion vector

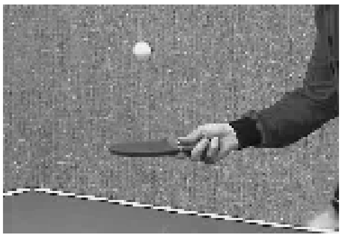


Frame 1

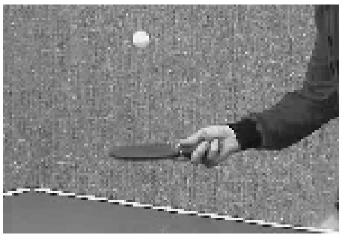


Frame 2

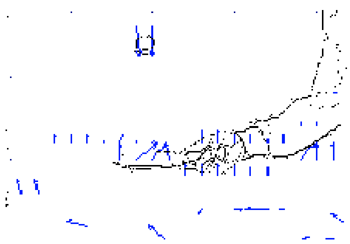
Motion Estimation



frame 1



frame 2

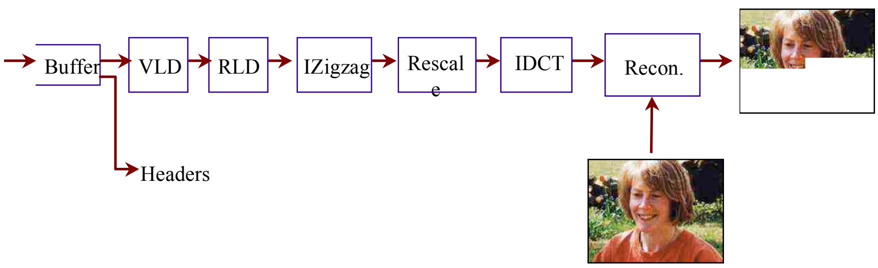


motion vectors

Motion Compensation

- Subtract the reference area from the current macroblock
  - difference macroblock
- Encode the difference macroblock with an image encoder
- If motion estimation was effective
  - little data left in difference macroblock
  - more efficient compression.

Video Decoder



Coding Standards

- JPEG
  - Joint Photographic Experts Group
  - Still image compression
- MPEG1
  - Moving Picture Experts Group
  - Video compression for CD storage / Internet
- MPEG2
  - Video compression for digital TV
- MPEG4
  - General purpose video compression
- H.261, H.263
  - Video compression for video conferencing

References

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