CS559 – Lecture 9
JPEG, Raster Algorithms

These are course notes (not used as slides)
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With some slides adapted from the notes of Stephen Chenney

Lossy Coding 2

- Suppose we can only send a fraction of the image
  - Which part?
- Send half an image:
  - Send the top half (not too good)
  - Halve the image in size (send the low frequency half)
- Idea: re-order (transform) the image so the important stuff is first

Perceptual Image Coding

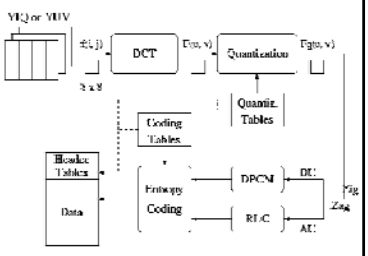
- Idea: lose stuff in images that is least important perceptually
  - Stuff least likely to notice
  - Stuff most likely to convey image
- Who knows about this stuff: The experts!
  - Joint Picture Experts Group
  - Idea of perceptual image coding

JPEG

- Key Ideas
  - Frequency Domain (small details are less important)
  - Block Transforms (works on 8x8 blocks)
    - Discrete Cosine Transform (DCT)
  - Control Quantization of frequency components
    - More quality = use more bits
    - Generally, use less bits for HF

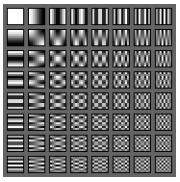
JPEG

- Multi-stage process intended to get very high compression with controllable quality degradation
- Start with YIQ color
  - Why? Recall, it's the color standard for TV



Discrete Cosine Transform

- A transformation to convert from the *spatial* to *frequency* domain – done on 8x8 blocks
- Why? Humans have varying sensitivity to different frequencies, so it is safe to throw some of them away
- Basis functions:



Quantization

- Reduce the number of bits used to store each coefficient by dividing by a given value
  - If you have an 8 bit number (0-255) and divide it by 8, you get a number between 0-31 (5 bits = 8 bits – 3 bits)
  - Different coefficients are divided by different amounts
  - Perceptual issues come in here
- Achieves the greatest compression, but also quality loss
- "Quality" knob controls how much quantization is done

Entropy Coding

- Standard lossless compression on quantized coefficients
  - Delta encode the DC components
  - Run length encode the AC components
    - Lots of zeros, so store number of zeros then next value
  - Huffman code the encodings

Lossless JPEG With Prediction

- Predict what the value of the pixel will be based on neighbors
- Record error from prediction
  - Mostly error will be near zero
- Huffman encode the error stream
- Variation works really well for fax messages

Video Compression

- Much bigger problem (many images per second)
- Could code each image seperately
  - Motion JPEG
  - DV (need to make each image a fixed size for tape)
- Need to take advantage that different images are similar
  - Encode the Changes ?

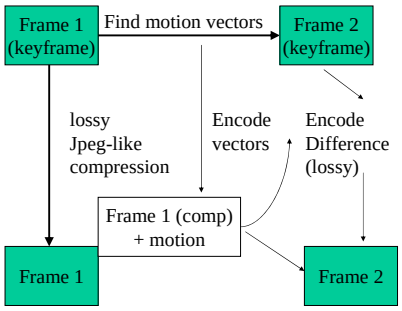
MPEG

- Motion Picture Experts Group
  - Standards organization
- MPEG-1 simple format for videos (fixed size)
- MPEG-2 general, scalable format for video
- MPEG-4 computer format (complicated, flexible)
- MPEG-7 future format
- What about MPEG-3? – it doesn't exist (?)
  - MPEG-1 Layer 3 = audio format

MPEG Concepts

- Keyframe
  - Need something to start from
  - "Reset" when differences get too far
- Difference encoding
  - Differences are smaller/easier to encode than images
- Motion
  - Some differences are groups of pixels moving around
  - Block motion
  - Object motion (models)

MPEG



Other Practical Tricks…

- Don't really know what is in image
  - Makes it hard to make changes
- Getting rid of noise
  - Low pass filters
  - Edge-preserving filtering
- "Sharpening"
  - Can we actually do it? (no – adding aliasing)
  - High-Pass attenuation
  - Unsharp mask (subtract out low frequencies)
- Feathering
  - Sharp transitions are noticeable
  - Blend/Blur around edges of changes

Geometric Graphics

- Mathematical descriptions of sets of points
  - Rather than sampled representations
- Ultimately, need sampled representations for display
- Rasterization

- Usually done by low-level
  - OS / Graphics Library / Hardware
  - Hardware implementations counter-intuitive
    - Modern hardware doesn't work anything like what you'd expect

Drawing Points

- What is a point?
  - Position – without any extent
  - Can't see it – since it has no extent, need to give it some
- Position requires co-ordinate system
  - Consider these in more depth later

- How does a point relate to a sampled world?
  - Points at samples?
  - Pick closest sample?
  - Give points finite extent and use little square model?
  - Use proper sampling

Sampling a point

- Point is a spike – need to LPF
  - Gives a circle w/roll-off
- Point sample this

- Or…
  - Samples look in circular (kernel shaped) regions around their position

- But, we can actually record a unique "splat" for any individual point

Anti-Aliasing

- Anti-Aliasing is about avoiding aliasing
  - once you've aliased, you've lost
- Draw in a way that is more precise
  - E.g. points spread out over regions

- Not always better
  - Lose contrast, might not look even if gamma is wrong, might need to go to binary display, …

Line drawing

- Was really important, now, not so important
- Let us replace expensive vector displays with cheap raster ones
- Modern hardware does it differently
  - Actually, doesn't draw lines, draws small, filled polygons
- Historically significant algorithms

Line Drawing (2)

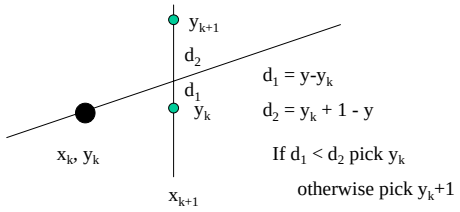
- Consider the integer version
  - (x1,y1) -> (x2,y2) are integers
  - Not anti-aliased (binary decision on pixels)
- Naïve strawman version:
  - Y = mx + b

  For x = x1 to x2
  y = mx + b
  set(x,y)
- Problems:
  - Too much math (floating point)
  - gaps

Brezenham's algorithm (and variants)

- Consider only 1 octant (get others by symmetry)
  - 0 >= m > = 1
- Loop over x pixels
  - Guaruntees 1 per column
- For each pixel, either move up 1 or not
  - If you plotted x,y then choose either x+1,y or x+1,y+1
  - Trick: how to decide which one easily
  - Same method works for circles (just need different test)
- Decision variable
  - Implicit equation for line (d=0 means on the line)

Midpoint method



Derivation

$\Delta d = d_1 - d_2$

$\Delta d = (y - y_k) - (y_k + 1 - y)$

$y = m(x_k + 1) + b$

$\Delta d = 2(m(x_k + 1) + b) - 2y_k - 1$

$m = \Delta y / \Delta x$

Multiply both sides by Δx (since we know its positive)

$\Delta d \Delta x = 2\Delta y\, x_k + 2\Delta y + 2b\Delta x - 2\Delta x\, y_k - \Delta x$

$P_k = \Delta d \Delta x = 2\Delta\, y\, x_k + 2\Delta x\, y_k + c$

$c = 2\Delta y + \Delta x(2b - 1)$

(all the stuff that doesn't depend on k)

Incremental Algorithm

- Suppose we know p_k – what is p_{k+1} ?
- $p_{k+1} = p_k + 2\Delta y - 2\Delta x\,(y_{k+1} - y_k)$
  - Since $x_{k+1} = x_k + 1$
- And $y_{k+1} - y_k$ is either 1 or 0, depending on p_k

Brezenham's Algorithm

- P_k = 2 \Delta y + x
- Y = y_1
- For X = x_1 to x_2
  - Set X,Y
  - If P_k < 0
  - Y += 1
  - P_k += 2 Δ y – 2 Δ x
  - Else: P_k += 2Δ y

Why is this cool?

- No division!
- No floating point!
- No gaps!
- Extends to circles
- But…
  - Jaggies
  - Lines get thinner as they approach 45 degrees
  - Can't do thick primitives