Chapter 7.2:
Layer 6: Compression

CS/ECPE 5516: Comm. Network
Prof. Abrams, Spring 2000
Based in part on material from Scott F. Midkiff
Multimedia Systems

- Interactive versus non-interactive

![Diagram showing server-client relationship for stored and live multimedia systems.](image)
Example Multimedia Applications

- Multimedia-on-demand
  - Video-on-demand
  - Audio-on-demand
- Live video
  - Meetings
  - Collaboration
  - News
- Remote sensing and imaging
Need for Video Compression

- Video characteristics
  - Demanding with respect to storage and/or data rate
  - Highly redundant -- duplicated information
    - Compression ratios of 200:1 or even 2000:1 are possible

\[(640 \times 480 \text{ pixels/f})(24 \text{ b/pixel})(30 \text{ f/s}) = 221 \text{ Mbps}\]

- Compression is needed to enable
  - Storage
  - Transmission
Compression Example (JPEG)

Quality: 100%  
Size: 57459

Quality: 90%  
Size: 20525

Quality: 60%  
Size: 8293

Quality: 25%  
Size: 4984

Quality: 10%  
Size: 3338

Quality: 5%  
Size: 2551

JPEG = Joint Picture Experts Group
Compression Techniques

• Information may be lost (but not missed)
  - **Lossy** compression -- information is lost
  - **Lossless** compression -- no loss

• Lossy techniques: drop info not important to human perception.

  *Examples:*
  - Images: changes in high frequency brightness changes as you move across image
  - Audio: low frequency sounds in woman’s voice
Lossless Compression Algorithms (1)

- Run Length Encoding
  
  “AAABB” $\Rightarrow$ “3A2B”

  Can actually increase file size

  Can be applied to images by comparing adjacent pixels

- Differential Pulse Code Modulation
  
  “AAABBC” $\Rightarrow$ “A00112” since B is 1 away from A, …

- Delta encoding
  
  “AAABBC” $\Rightarrow$ “A00101” since C is 1 away from B, …
Lossless Compression Algorithms (2)

• Dictionary-based methods
  - Build table of variable length strings
    “to be or not to be is Shakespeare’s line – is it not?”
    Dictionary:
    0=“to be”
    1=“not”
    2=“is”
    ⇒ “0 or 1 0 2 Shakespeare’s line – 2 it 1?”
  - Cost: must send dictionary before file
  - Examples: Lempel-Ziv (Unix compress)
Lossy Compression – Images (1)

- GIF
  - Given 24-bit pixels, pick the 256 most used colors. Map each 24-bit pixel into 1-of-256.
  - Achieves 3x compression.
  - Then run Lempel-Ziv, maybe achieving 10x compression.
Lossy Compression – Images (2)

- JPEG
  - DCT Phase:
    - Divide image into 8x8 pixel blocks.
    - If you move across x-axis, you see pixels vary with some frequency.
    - Compute something like Fourier transform, called \textit{Discrete Cosine Transform} (\textit{DCT}) – maps intensity to frequency domain with 64 intensities.
JPEG

- DCT Phase
- Quantization Phase
  - Use table of coefficients; divide step 1 values by coefficients. Maps many frequencies to zero.
- Encoding phase
  - Huffman code: use few bits for most popular numbers
  - Use delta encoding for subsequent array values
- Color: repeat 3 times (RGB)

```
3  7  11  15
7 11  15  21
11 15  21  27
15 21  27  33
```
Video Compression Techniques

- Scope of compression
  - **Intraframe** -- eliminate or reduce redundancy within a single frame
  - **Interframe** -- eliminate or reduce redundancy between consecutive frames
  - Prediction, interpolation – predict frame based on previous/subsequent values
  - Sample to take advantage of human perception
MPEG Overview (1)

• Features
  ■ Can achieve compression ratios of 200:1
    ■ Would reduce data rate to around 1.2 Mbps for a 640x480 image
  ■ MPEG-1 compresses 320x240 images and requires at least 1.5 Mbps
  ■ Also includes audio compression with compression ratios of 5:1 to 10:1
MPEG Overview (2)

• Compression techniques
  ■ Uses DCT for intraframe compression
  ■ Uses interframe compression by storing differences between successive frames

• There are three frame types
  ■ Intraframes (I frames) are encoded using intraframe compression
  ■ Predicted frames (P frames) are predicted from previous I frames
  ■ Bidirectional frames (B frames) are interpolated from previous and future frames
MPEG Overview (3)

- Repeated pattern of frames (pictures) is a group of pictures (GOP)
  - Example: IBBBPBBBB
MPEG Overview (3)

- Repeated pattern of frames (pictures) is a group of pictures (GOP)
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Exemplary sequence: IBBBBPBBBB

Diagram:
- I 1
- B 2
- B 3
- B 4
- P 5
- B 6
- B 7
- B 8
- I 9

Legend:
- **I**: Intra-coded frame
- **P**: Predicted frame
- **B**: Bidirectionally predicted frame

Direction:
- **time**
MPEG Overview (3)

- Repeated pattern of frames (pictures) is a group of pictures (GOP)

  ■ Example: IBBBBBBB

  \[ \text{forward prediction} \]

  \[ \text{bidirectional prediction} \]

\[
\begin{array}{cccccccc}
I & B & B & B & P & B & B & B & I \\
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\
\end{array}
\]

\[ \text{time} \]
Transmission of MPEG

- If stored video, send IBBBPBBBB as IPBBBBBBI
- Might use Differentiated Services, with I’s and P’s as high priority
- Can change quantization matrix during video
Some Video Compression Standards

- MPEG-1, MPEG-2, MPEG-3, and MPEG-4
- ITU-T (CCITT) standards
  - H.320 (H.261) — ISDN (64 Kbps increments)
  - H.323 — LAN
  - H.324 — POTS
- MJPEG (Motion JPEG)

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