MPEG: A Video Compression Standard for Multimedia Applications

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Initial material were slides of Didier Le Gall, Worcherster Polytechnic Institute.
Introduction

• 1980’s technology made possible full-motion video over networks
  – Television and Computer Video seen moving closer
  – (Today, Sony and Microsoft are squaring off)
• Needed a standard
  – Often, triggers needed volume production
    • Ala *facsimile* (fax)
  – Avoid *de facto* standard by industry
• 1988, Established the Motion Picture Experts Group (MPEG)
  – Worked towards MPEG-1
  – Primarily video but includes audio (MP3)
The Need for Video Compression

• High-Definition Television (HDTV)
  – 1920x1080
  – 30 frames per second (full motion)
  – 8 bits for each three primary colors (RGB)
  \( \Rightarrow \) Total 1.5 Gb/sec!

• Cable TV: each cable channel is 6 MHz
  – Max data rate of 19.2 Mb/sec
  – Reduced to 18 Mb/sec w/audio + control …
  \( \Rightarrow \) Compression rate must be \( \sim \) 80:1!
Compatibility Goals

• 1990: CD-ROM and DAT key storage devices
  – 1-2 Mbits/sec for 1x CD-ROM

• Two types of application videos:
  – Asymmetric (encoded once, decoded many times)
    • Video games, Video on Demand
  – Symmetric (encoded once, decoded once)
    • Video phone, video mail …

• (How do you think the two types might influence design?)

• Video at about 1.5 Mbits/sec

• Audio at about 64-192 kbits/channel
Requirements

• Random Access, Reverse, Fast Forward, Search
  – At any point in the stream (within \( \frac{1}{2} \) second)
  – Can reduce quality somewhat during this task, if needed

• Audio/Video Synchronization

• Robustness to errors
  – Not catastrophic if some bits are lost
  – Lends itself to Internet streaming

• Coding/Decoding delay under 150 ms
  – For interactive applications

• Ability to Edit
  – Modify/Replace frames
Relevant Standards

• Joint picture Experts Group (JPEG)
  – Compress still images only
• Expert Group on Visual Telephony (H.261)
  – Compress sequence of images
  – Over ISDN (64 kbits/sec)
  – Low-delay
• Other high-bandwidth “H” standards:
  • H21 (34 Mbits/sec)
  • H22 (45 Mbits/sec)
MPEG Compression

• Compression through
  – Spatial
  – Temporal
Spatial Redundancy

- Take advantage of similarity among most neighboring pixels
Spatial Redundancy Reduction

• RGB to YUV
  – less information required for YUV (humans less sensitive to chrominance)

• Macro Blocks
  – Take groups of pixels (16x16)

• Discrete Cosine Transformation (DCT)
  – Based on Fourier analysis where represent signal as sum of sine's and cosine’s
  – Concentrates on higher-frequency values
  – Represent pixels in blocks with fewer numbers

• Quantization
  – Reduce data required for co-efficients

• Entropy coding
  – Compress
Spatial Redundancy Reduction

- Zig-Zag Scan
- Run-length coding
- Quantization

- major reduction
- controls 'quality'

“Intra-Frame Encoded”
Question

• When may spatial redundancy reduction be ineffective?

• What kinds of images/movies?
Answer

• *When may spatial redundancy elimination be ineffective?*
  – High-resolution images and displays
    • May appear ‘coarse’
  • What kinds of images/movies?
    – A varied image or ‘busy’ scene
      • Many colors, few adjacent
Loss of Resolution

- Original (63 kb)
- Low (7kb)
- Very Low (4 kb)
Temporal Redundancy

• Take advantage of similarity between successive frames
Temporal Activity

“Talking Head”
Temporal Redundancy Reduction

- Macro blocks
- Search Area
- Centre of Search Area
- Current Macroblock
- Best Match Position
- Current Macroblock
Temporal Redundancy Reduction

Frame N

Search Area

Macro Block 16X16 Pixels

Frame N+1

Motion Vector
Temporal Redundancy Reduction

- **I** frames are independently encoded
- **P** frames are based on previous I, P frames
  - Can send motion vector plus changes
- **B** frames are based on previous and following I and P frames
  - In case something is uncovered

![Diagram showing I, B, and P frames with connections]

- I frames
- B frames
- P frames
Group of Pictures (GOP)

• Starts with an I-frame
• Ends with frame right before next I-frame
• “Open” ends in B-frame, “Closed” in P-frame
  – (What is the difference?)
• MPEG Encoding a parameter, but ‘typical’:
  – I B B P B B P B B I
  – I B B P B B P B B P B B I
• Why not have all P and B frames after initial I?
Question

• When may temporal redundancy reduction be ineffective?
Answer

• *When may temporal redundancy reduction be ineffective?*
  – Many scene changes
  – High motion
Non-Temporal Redundancy

- Many scene changes vs. few scene changes
Non-Temporal Redundancy

• Sometimes high motion
# Typical MPEG Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image resolution</td>
<td>384x288</td>
</tr>
<tr>
<td>Quantization factor</td>
<td>8</td>
</tr>
<tr>
<td>Frames between I pictures</td>
<td>5</td>
</tr>
<tr>
<td>Frames between P pictures</td>
<td>2</td>
</tr>
<tr>
<td>Frames sequence as to be displayed</td>
<td>...IBBPBBI...</td>
</tr>
<tr>
<td>Rate control</td>
<td>None</td>
</tr>
</tbody>
</table>
## Typical Compress. Performance

<table>
<thead>
<tr>
<th>Type</th>
<th>Size</th>
<th>Compression</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>18 KB</td>
<td>7:1</td>
</tr>
<tr>
<td>P</td>
<td>6 KB</td>
<td>20:1</td>
</tr>
<tr>
<td>B</td>
<td>2.5 KB</td>
<td>50:1</td>
</tr>
<tr>
<td>Avg</td>
<td>4.8 KB</td>
<td>27:1</td>
</tr>
</tbody>
</table>

Note, results are Variable Bit Rate, even if frame rate is constant
MPEG Today

- MPEG video compression widely used
  - digital television set-top boxes
- HDTV decoders
  - DVD players
  - video conferencing
  - Internet video
  - ...

MPEG Today

• MPEG-2
  – Super-set of MPEG-1
  – Rates up to 10 Mbps (720x486)
  – Can do HDTV (no MPEG-3)

• MPEG-4
  – Around *Objects*, not *Frames*
  – Lower bandwidth
  – Has some built-in repair (header redundancy)

• MPEG-7
  – New standard
  – Allows content-description (ease of searching)

• MP3, for audio
  – MPEG Layer-3
MPEG Tools

• MPEG tools at:

• MPEG streaming at:
  – http://www.comp.lancs.ac.uk/

• FFMPEG