MPEG: A Video Compression Standard for Multimedia Applications

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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)
  →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 ...
  →Compression rate must be ~ 80:1!

Outline

• Introduction (done)
• MPEG Goals
• MPEG Details
• Performance and Such
• Summary

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)
    • Video games, Video on Demand
  – Symmetric (encoded once, decoded once)
    • Video phone, video mail ...
• (Q: 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 ½ 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 150ms
  – 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)

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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

• “Intra-Frame Encoded”
Groupwork

- When may spatial redundancy reduction be ineffective? What kinds of images/movies?

Loss of Resolution

- Original (63 kb)
- Low (7 kb)
- 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
- Time
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

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 B B P B B P B B B
• Why not have all P and B frames after initial I?

Groupwork

• When may temporal redundancy reduction be ineffective?

Non-Temporal Redundancy

• Many scene changes vs. Few scene changes
  
  “Standard” Movies
  Akiyo
  Coast guard
  Hall

Groupwork

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

- Sometimes high motion

“Standard” Movies
Foreman

Possible MPEG Parameters

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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<tbody>
<tr>
<td>Frame rate</td>
<td>30fps</td>
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<tr>
<td>Quantization factor</td>
<td>8</td>
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<tr>
<td>Frame size</td>
<td>384x288</td>
</tr>
<tr>
<td>Frame reference picture count</td>
<td>2</td>
</tr>
<tr>
<td>Frame sequence to be displayed</td>
<td>JPEGEBB</td>
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<tr>
<td>Rate control</td>
<td>None</td>
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</tbody>
</table>

Possible Compression Performance (YMMV)

<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 (VBR), even if frame rate is constant

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
  - Allows content-description (ease of searching)
- MP3
  - For audio
  - MPEG Layer-3

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

- Principles are basis for other compression algorithms
  - e.g. H.264