MPEG: A Video Compression Standard for Multimedia Applications

Didier Le Gall

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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)

Dance of the 2 elephants

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:
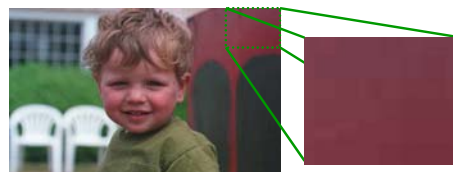 - H21 (34 Mbits/sec)
  - H22 (45 Mbits/sec)

Outline

- Introduction   (done)
- MPEG Goals   (done)
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MPEG Compression

- Compression through
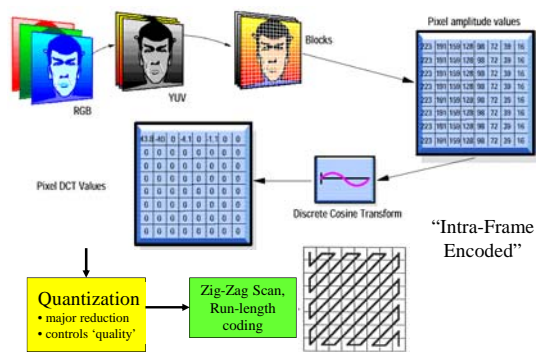 - Spatial
  - Temporal

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

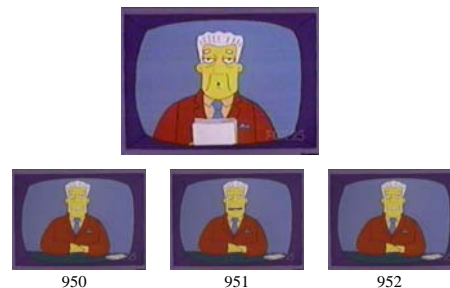- When may spatial redundancy reduction be ineffective? What kinds of images/movies?

Groupwork

- *When may spatial redundancy reduction be ineffective?*
  - High-resolution images and displays
    - May appear 'coarse'
  - A varied image or 'busy' scene
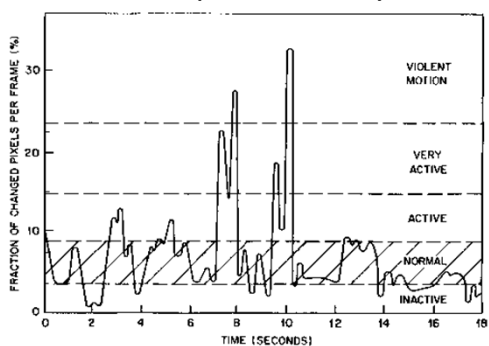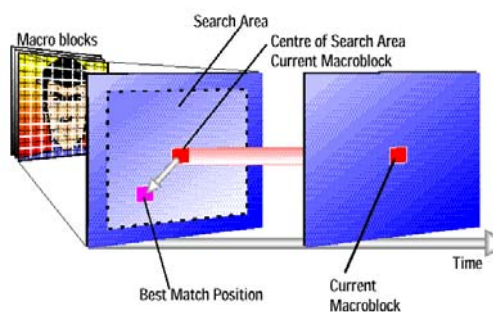   - Many colors, few adjacent

Loss of Resolution

Original (63 kb)

Low (7kb)

Very Low (4 kb)
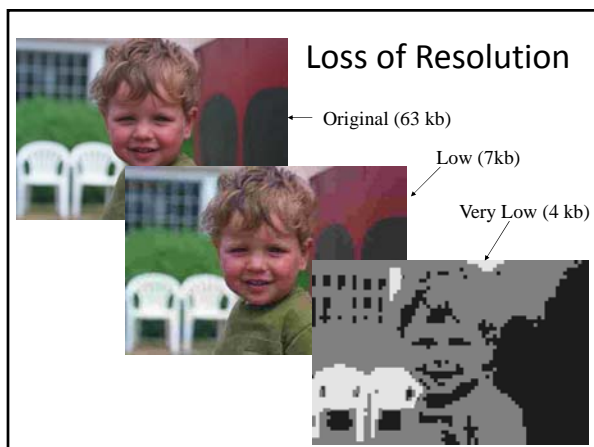
Temporal Redundancy

- Take advantage of similarity between successive frames

950 951 952

Temporal Activity

"Talking Head"

Temporal Redundancy Reduction

Temporal Redundancy Reduction

Temporal Redundancy Reduction

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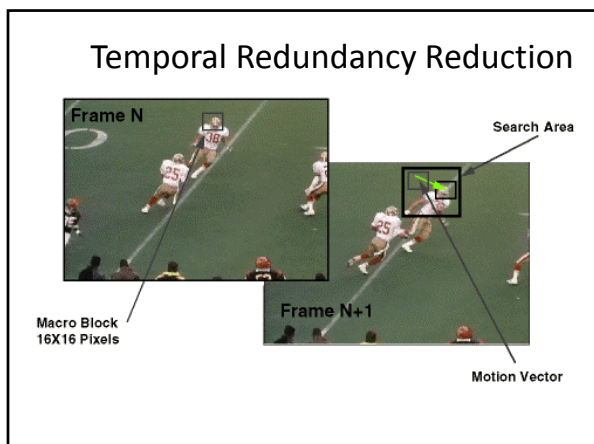- *B* frames are based on previous and following I and P frames
  - In case something is uncovered
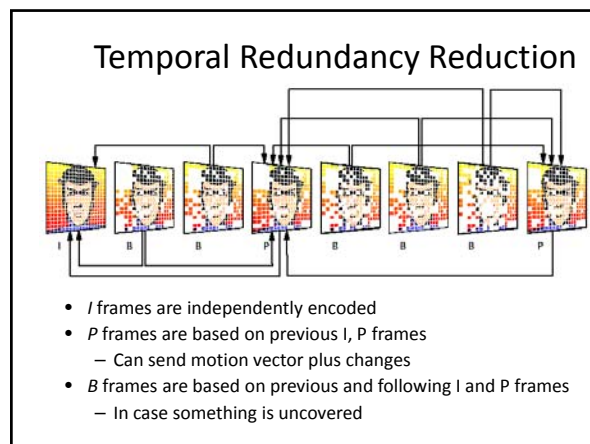
Group of Pictures (GOP)

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

Groupwork

- When may temporal redundancy reduction be ineffective?

Groupwork

- *When may temporal redundancy reduction be ineffective?*
  - Many scene changes
  - High motion

Non-Temporal Redundancy

- Many scene changes vs. Few scene changes

"Standard" Movies
Akiyo
Coast guard
Hall

Non-Temporal Redundancy

• Sometimes high motion

"Standard" Movies
Foreman

Possible MPEG Parameters

Parameters	Value
Image resolution	384x288
Quantization factor	8
Frames between I pictures	5
Frames between P pictures	2
Frames sequence as to be displayed	...IBBPBBI...
Rate control	None

Possible Compression Performance (YMMV)

```
Type Size Compression
---------------------
  I    18 KB     7:1
  P     6 KB    20:1
  B   2.5 KB    50:1
Avg   4.8 KB    27:1
---------------------
```

• Note, results are variable bit Rate (VBR), 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
  – ...
• Principles are basis for other compression algorithms
  – e.g. H.264

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