The Video Data Type
Coding & Compression Basics

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The Video Data Type
Outline

◆ What is video?
  » Video components
  » Representations of video signals
  » Color spaces

◆ Digital Video
  » Coding

◆ Compression basics
  » Simple compression
  » Interpolation-based techniques
  » Predictive techniques
  » Transforms
  » Statistical techniques
Video Basics
The components of video

- Video deals with *absorbed* and *projected* light
  - Cameras absorb light and monitors project light

- The primary colors in this domain are:
  - red, green, and blue

Video Basics
The components of video transmission

- Video is a multi-dimensional signal

\[
\begin{align*}
\text{R-component} & \quad \text{G-component} & \quad \text{B-component} \\
\begin{array}{c}
\text{x - axis} \\
\text{y - axis} \\
\text{time}
\end{array}
\end{align*}
\]
Video Basics

Video as a 1-dimensional signal

- Representation of a 2-dimensional image


- Representation of motion (3-dimensional images)

Frame \(i\)

Frame \(i+1\)

33 ms NTSC (30 fps)

40 ms PAL (25 fps)

Video Basics

Resolution

- Television broadcast standards
  - NTSC — 525 lines
  - PAL — 625 lines

- Computer graphics standards
  - VGA — 640x480
  - SVGA — 1024x768

- Multimedia standards
  - CIF — 352x288
  - QCIF — 176x144

- Digital video standards
  - CCIR 601 — 720x480
  - HDTV — 1440x1152

Image sizes
(in picture elements)
**Video Basics**

**Color spaces**

- **RGB** is not widely used for transmitting a signal between capture and display devices
  - It’s difficult to manage 3 separate inputs & outputs (and requires too much bandwidth)

- **Composite formats are used instead**
  - Luminance ("Y") — the brightness of the monochrome signal
  - Chrominance — the coloring information
  - Chrominance is typically represented by two “color difference” signals:
    - “U” and “V” ("hue and tint") or
    - “I” and “Q” ("saturation" and “color”)

---

**Video Basics**

**Color spaces**

- **NTSC video**
  - \( Y = 0.30R + 0.59G + 0.11B \)
  - \( I = 0.60R - 0.28G - 0.32B \)
  - \( Q = 0.21R - 0.52G + 0.31B \)

- **PAL video/Digital recorders**
  - \( Y = 0.3R + 0.6G + 0.1B \)
  - \( U = (B - Y) \times 0.493 \)
  - \( V = (R - Y) \times 0.877 \)
Video Basics

Digital video

- Sample an analog representation of video (RGB or YUV) & quantize
  - Two dimensions of video are already discretized
  - Sample in the horizontal direction according to the resolution of the media

- 8-bits per component per sample is common
  - 24 bits per picture element (pixel)

- Storage/transmission requirements
  - NTSC — 440 x 480 x 30 x 24 = 152x10^6 bits/sec
    (19 MB/s or 24 bits/pixel (bpp))

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  - Coding

- Compression basics
  - Simple compression
  - Interpolation-based techniques
  - Predictive techniques
  - Transforms
  - Statistical techniques
Do we really need every “bit” of a video stream?
» Not if redundancy exists
» Not if we can’t perceive the effect of eliminating the bit

Eliminating redundancy
» Spatial redundancy
» Temporal redundancy

Eliminating imperceptible detail
» Coding
» Domain transformation

Digital Video
Compression Techniques

Adapted from Buford p.147
Video Compression

Issues

◆ Bandwidth requirements of resulting stream
  » Bits per pixel (bpp)
◆ Image quality
◆ Compression/decompression speed
  » Latency
  » Cost
  » Symmetry
◆ Robustness
  » Tolerance of errors and loss
◆ Application requirements
  » Live video
  » Stored video

Simple Image Compression

Truncation

◆ Reducing the number of bits per pixel
  » Throw away the least significant bits of each sample value

◆ Example
  » Go from RGB at 8 bits/component sample (8:8:8) to 5 bits (5:5:5)
    ❖ Go from 24 bpp to 15 bpp
    ❖ This gives “acceptable results”
  » Go from YUV at 8 bits/component sample 6:5:5 (16 bpp)

◆ Advantage — simple!
Simple Compression Schemes

Color-table lookup (CLUT)

- Quantize coarser in the color domain
  - Pixel values represent indices into a color table
  - Tables can be optimized for individual images

- Entries in color table stored at “full resolution” (e.g., 24 bits)

- Example:
  - 8-bit indices (256 colors) gives
    \[(440 \times 480) \times 8 + (24 \times 256) = 1.7 \times 10^6 \text{ bits/sec}\]

Simple Compression Schemes

Run-length encoding

- Replace sequences of pixel components with identical values with a pair \((value, count)\)

- Works well for computer-generated images, cartoons. works less well for natural video

- Also works well with CLUT encoded images
  
  \((i.e., \text{multiple techniques may be effectively combined})\)
Interpolative Compression Schemes

Color sub-sampling

- Do not acquire chrominance component values at all sampling points
  - Humans have poor acuity for color changes
  - $UV$ and $IQ$ components were defined with this in mind

- Example: Color representation in digital tape recorders
  - Subsampling by a factor of 4 horizontally is performed

\[
\begin{align*}
\text{Y component} & \quad \text{U component} & \quad \text{V component} \\
\end{align*}
\]

Interpolative Compression Schemes

Color sub-sampling

- Subsampling by a factor of 4 horizontally & vertically

\[
\begin{align*}
\text{Y component} & \quad \text{U component} & \quad \text{V component} \\
\end{align*}
\]

- Interpolating between samples provides “excellent” results
  - Chrominance still sampled at 8 bpp
Interpolative Compression Schemes
Color sub-sampling

- Intermediate pixels either take on the value of nearest sampling point or their value is computed by interpolation

- Bi-linear interpolation:

\[
U(1, 1) = U(0,0) \times 0.75 + U(1,0) \times 0.25 + U(0,1) \times 0.75 + U(1,1) \times 0.25
\]

Sub-sampled \( U \) or \( V \) component

Interpolative Compression Schemes
Color sub-sampling

- Storage/transmission requirements reduction:
  - Within a 4x4 pixel block:
    \[
    \text{bpp} = \frac{(8 \text{ bpp luminance}) \times 16 \text{ samples} + (8 \text{ bpp chrominance}) \times 2}{16}
    = 9
    \]
  - A 62.5% reduction overall
Predictive Compression Schemes
Exploiting spatial & temporal redundancy

- Adjacent pixels are frequently similar
  - Do pixel-by-pixel DPCM compression
    - Leads to smearing of high-contrast edges
  - ADPCM — a little better, a little worse
    - Introduces “edge quantization” noise

- Motion Estimation — If the future is the similar to the past, encode only the difference between frames
  - This assumes we can store a previous frame to compare with a future one

Transform-Based Compression
Exploiting redundancy in other domains

- A simple linear transformation
  - 2 x 2 array of pixels
    - A B
    - C D
  - 1-D array of differences
    - A B–A C–A D–A
  - Encode differences with less precision

- Storage savings
  - Original array: 4 pixels x 8 bpp = 32 bits
  - Transformed array: 8 bits + (3 pixels x 4 bpp) = 20 bits
A transformation into the frequency domain

Example: 8 adjacent pixel values (e.g., luminance)

What is the most compact way to represent this signal?

Transform-Based Compression
The Discrete Cosine Transform (DCT)

Represent the signal in terms of a set of cosine basis functions
The basis functions derive from sampling cosine functions of increasing frequency
» From 0-3.5 Hz
» Basis functions sampled at 8 discrete points

The Discrete Cosine Transform
Represent input as a sum of scaled basis functions
Transform-Based Compression
The Discrete Cosine Transform (DCT)

- The 1-dimensional transform:

\[
F(\mu) = \frac{C(\mu)}{2} \sum_{x=1}^{7} f(x) \cos \left(\frac{(2x+1)\mu\pi}{16}\right)
\]

- \( F(\mu) \) is the DCT coefficient for \( \mu = 0..7 \)
- \( f(x) \) is the \( x \)th input sample for \( x = 0..7 \)
- \( C(\mu) \) is a constant (equal to \( 2^{-0.5} \) if \( \mu = 0 \) and 1 otherwise)

- The 2-dimensional (spatial) transform:

\[
F(\mu,\nu) = \frac{C(\mu)C(\nu)}{2} \sum_{x=1}^{7} \sum_{y=1}^{7} f(x,y) \cos \left(\frac{(2x+1)\mu\pi}{16}\right) \cos \left(\frac{(2y+1)\nu\pi}{16}\right)
\]

Transform-Based Compression
The Discrete Cosine Transform (DCT)

- DCT coefficients encode the spatial frequency of the input signal
  - DC coefficient — zero spatial frequency (the “average” sample value)
  - AC coefficients — higher spatial frequencies

- Claim: Higher frequency coefficients will be zero and can be ignored
Transform-Based Compression

The two-dimensional DCT

- Apply the DCT in \( x \) and \( y \) dimensions simultaneously to 8x8 pixel blocks
  - Code coefficients individually with fewer bits

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Video Frame

DCT Coefficients

Statistical Compression

Huffman coding

- Exploit the fact that not all sample values are equally likely
  - Samples values are non-uniformly distributed
  - Encode “common” values with fewer bits and less common values with more bits

- Process each image to determine the statistical distribution of sample values
  - Generate a codebook — a table used by the decoder to interpret variable length codes
  - Codebook becomes part of the compressed image
Order all possible sample values in a binary tree by combining the least likely samples into a sub-tree.

Label the branches of the tree with 1’s and 0’s.

» Huffman code is the sequence of 1’s and 0’s on the path from the root to the leaf node for the symbol.
Video Compression Standards

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The Video Data Type
Compression Standards

- Basic compression techniques
  - Truncation, CLUT, run-length coding
  - sub-sampling & interpolation
  - DPCM
  - DCT
  - Huffman coding

- Common algorithms
  - JPEG/MJPEG
  - H.261/H.263
  - MPEG-1-2
Compression Algorithms

JPEG

- A still image ("continuous tone") compression standard
  » DCT-based

- 4 Modes of compression
  » sequential — image components coded in order scanned
    ♦ Baseline — "default compression"
  » progressive — image coded in multiple passes so partial images can be displayed during decoding
  » lossless — guaranteed no loss
  » hierarchical — image encoded at multiple resolutions

- Typical results
  » 24:1 compression (1 bpp)

JPEG Compression
Encoder architecture — sequential mode

- Inputs are 8 or 12-bit samples
  » baseline = 8-bit samples
- Image components are compressed separately
  » DCT operates on 8x8 pixel blocks

Digitized still image (or video frame)
JPEG Compression
Quantization

- DCT coefficient quantization is the key to compression
  » Quantize according to the visual important of each coefficient
- The application specifies a quantization table
  » A table of step-sizes from 1-255
  » Default tables specified for the baseline coder

Step-size table can be scaled to control degree of compression
  » Scaling factor called the “q-factor”
JPEG Compression
Coding coefficients

- DC coefficients difference-coded
  - DC coefficients from adjacent 8x8 blocks strongly correlated

- AC coefficients run-length and Huffman coded

JPEG Compression
Coding DC coefficients

- DC coefficients DPCM coded and recoded using a variable length entropy (Huffman) code
JPEG Compression
Coding AC coefficients

◆ “Zig-zag” order the AC coefficients to increase effectiveness of run-length coding
   » DC,
      \( AC_{01}, AC_{10}, \)
      \( AC_{02}, AC_{11}, AC_{20}, \)
      \( AC_{03}, AC_{12}, AC_{21}, AC_{30}, \)
      ...

◆ Run-length code the stream
   » Each non-zero coefficient encoded as a pair:
      \((\text{run-length of preceding zero coefficients}, \text{ amplitude of non-zero coefficient})\)

JPEG Compression
Coding AC coefficients

◆ Each coefficient encoded as a variable length “pair”
   » \([\text{run length}, \text{ size}], \text{ amplitude}\)"

◆ First element coded using a variable-length Huffman code
   » A coding table (“code book”) must be provided
      ❖ Can be generated on-the-fly with an additional pass over the coefficients
      ❖ Up to four code books per image may be specified
      ❖ The codebook becomes part of the coded bit-stream

◆ Second element coded as a variable length integer
   » whose length is specified in the previous “symbol”
Sequential JPEG Compression Summary

Complete compression pipeline

Compression comes from:
» Chrominance subsampling
» DCT coefficient quantization
» Difference coding DC coefficients
» Statistical & run-length coding of AC coefficients

Qualitative results:
» 0.25 - 0.5 bpp — ok for some applications
» 0.5 - 0.75 bpp — ok for many
» 0.75 - 1.5 bpp — excellent
» 1.5 - 2.0 — indistinguishable

JPEG Compression
Examples of quality v. bpp
JPEG Compression
Examples of quality v. bpp

4.4 bpp

0.7 bpp

0.7 bpp

0.5 bpp
JPEG Compression
Other modes of operation

- **Lossy compression modes**
  - *sequential* — image components coded in order scanned
    - Default mode
  - *progressive* — image coded in multiple passes so partial images can be displayed during decoding
    - Useful for transmission of images over slow communications links
  - *hierarchical* — image encoded at multiple resolutions
    - Useful for images that will be displayed on heterogeneous displays

- **Lossless mode**
  - Guaranteed lossless
  - Uses DPCM encoding rather than DCT

JPEG Compression Modes
Loseless mode operation

- Uses prediction instead of the DCT
  - Each pixel’s value is expressed as a function of neighboring pixels
  - A code word identifies the predictor being used
JPEG Compression Modes

Loseless mode operation

- Predicted samples are DPCM encoded
- Differences are entropy coded as before
- Achieves approximately 2:1 compression

JPEG Compression Modes

Progressive mode operation

- Encode the image in scans to enable the display of a series of progressively refined images
  - Requires an image-sized coefficient buffer between quantizer & entropy coder
  - Scans of image components are also interleaved in bit-stream
JPEG Compression Modes

Progressive mode operation

- Scan the coefficient buffer in multiple passes
  - Transmit portions of each coefficient

Sequential Encoding

“Successive approximation”

JPEG Compression Modes

Progressive mode operation

- Scan the coefficient buffer in multiple passes
  - Transmit portions of each coefficient

Sequential Encoding

“Spectral selection”
JPEG Compression Mode
Hierarchical mode operation

- Encode the image at multiple resolutions
  » Each image differs from the previous by a factor of 2 in either the vertical or horizontal dimension
  » Images created by filtering and subsampling

- Each resolution encoded by either the sequential or progressive algorithm

JPEG Compression Mode
Hierarchical mode operation

- Start with the lowest desired resolution & iteratively encode until the full image resolution has been coded
  » Each iteration encodes an image with a factor of 2 higher resolution in one dimension
Motion JPEG
Applying JPEG to moving images

- Video can be (trivially) encoded as a sequence of stills
  - This practice is routine in the digital video editing world

- The issue is how to encode and transmit “side information”
  - Quantization tables, Huffman code-book may/may not change between frames

The Video Data Type
Compression Standards

- Basic compression techniques
  - Truncation, CLUT, run-length coding
  - Sub-sampling & interpolation
  - DPCM
  - DCT
  - Huffman coding

- Common algorithms
  - JPEG/MJPEG
  - H.261/H.263
  - MPEG-1,-2
Compression Algorithms

H.261 \( (p \times 64) \)

- A telecommunications (ITU) standard for audio & video transmission over digital phone lines (ISDN)

- H.261 primarily intended for interactive video applications
  - Design of the standard driven by a 150 ms maximum encoding/decoding delay goal

- A scalable coding architecture capable of generating bit streams from 64 kbps (“1x64”) to 1,920 kbps (“30x64”) in 64 kbps increments
  - \( p = 1, 2 \) produces a low res “videophone” (Common use is for ISDN BRI — 112 kbps video, 16 kbps audio)
  - \( p \geq 6 \) produces an acceptable videoconference and allows multipoint communication

H.261
Video formats

- **Inputs**
  - 525 or 625 line composite video
  - 8 bits/sample
  - 30 frames/second

- **Color space**
  - \( Y, Cr, Cb \)

- **Outputs**
  - CIF or QCIF
  - 30, 15, 10, or 7.5 frames/second
H.261
Video frame representation

- Chrominance components are subsampled 2:1 horizontally & vertically
- Each video frame is subdivided into 16x16 *macroblocks*

![Diagram showing Y component: 4 8x8 blocks and Cr component: 1 8x8 block (same for Cb)]

H.261
Video compression pipeline

- Two compression modes, selectable on a frame-by-frame basis
  - **INTRA-frame mode** — DCT-based compression *á la* JPEG
    - video is treated as a sequence of stills
  - **INTER-frame mode** — Incorporates motion estimation & DPCM prediction
    - temporal redundancy is eliminated to further improve compression

![Diagram showing compression pipeline with INTRA-frame and INTER-frame pipelines]
**H.261 Video Compression**

**INTRA-frame mode**

- Compression is similar to JPEG
  - DCT encoding
  - linear quantization
  - entropy coding

- Quantization is uniform across all AC coefficients
  - But is adaptive and driven by the space remaining in a transmission buffer

**H.261 INTER-Frame Mode**

**Motion estimation & prediction**

- Motion estimation is performed only on luminance macroblocks
  - Compare a luminance macroblock with its neighbors in the previous frame
  - If the difference is small, do not compress the block, only record location of matching block
  - If the difference is “large” send the difference between this macroblock and a previous neighboring macroblock into the DCT compression pipeline
Finding a predictor is the process of finding the minimally different adjacent 16x16 block in the previous frame.

Construct a “motion vector” — a relative displacement $w$ for block $b$ that minimizes the mean absolute distortion (MAD):

$$\frac{1}{256} \sum_{i=0}^{15} \sum_{j=0}^{15} |frame_n[16b_x+i, 16b_y+j] - frame_{n-1}[(16b_x+w_x)+i, (16b_y+w_y)+j]|$$
H.261 INTER-frame Mode

Complete pipeline

H.261

Video frame representation

- Macroblocks combined into *groups of blocks* (GOBs)
  - An 11 by 3 array of macroblocks

<table>
<thead>
<tr>
<th>CIF Image: 12 GOBs</th>
<th>QCIF Image: 3 GOBs</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 GOBs</td>
<td>3 GOBs</td>
</tr>
<tr>
<td>176 pixels</td>
<td>176 pixels</td>
</tr>
<tr>
<td>352 pixels</td>
<td>144 pixels</td>
</tr>
<tr>
<td>288 pixels</td>
<td>144 pixels</td>
</tr>
<tr>
<td>48 pixels</td>
<td>48 pixels</td>
</tr>
<tr>
<td>5 pixels</td>
<td>5 pixels</td>
</tr>
</tbody>
</table>

= video frame buffer
= 16x16 pixel block
= 8x8 pixel block
= control data
H.261 Data Transmission

Bit-stream format

- Picture data is hierarchically transmitted

<table>
<thead>
<tr>
<th>Picture Layer</th>
<th>GOB1 data</th>
<th>GOB12 data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group of Blocks Layer</td>
<td>GOB header</td>
<td>MB1 data</td>
</tr>
<tr>
<td>Macroblock Layer</td>
<td>MB header</td>
<td>block1 data</td>
</tr>
<tr>
<td>Block Layer</td>
<td>DCT coeff</td>
<td>...</td>
</tr>
</tbody>
</table>

ITU H.320 Teleconferencing Standards

Teleconferencing over ISDN

- H.261 — Video communications at \( p \times 64 \) kbps
- H.221 — Syntax for multiplexing audio and video packets
- H.230 — Protocol for call setup and negotiation of end-system (“terminal”) capabilities
- H.242 — Conference control protocol
- G.711 — ISDN audio coding standard at 64 kbps
- G.722 — High-quality audio at 64 kbps
- G.728 — Reduced quality speech at 16 kbps
H.263 Video Compression
Low-bitrate video compression for data networks

- Based on H.261 (& MPEG-1, -2)
- Includes new image formats:

<table>
<thead>
<tr>
<th>Format</th>
<th>Image Size</th>
<th>Maximum Number of coded bits/picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>sub-QCIF</td>
<td>128 x 96</td>
<td>64</td>
</tr>
<tr>
<td>QCIF</td>
<td>176 x 144</td>
<td>64</td>
</tr>
<tr>
<td>CIF</td>
<td>352 x 288</td>
<td>256</td>
</tr>
<tr>
<td>4CIF</td>
<td>704 x 576</td>
<td>512</td>
</tr>
<tr>
<td>16CIF</td>
<td>1,408 x 1,152</td>
<td>1024</td>
</tr>
</tbody>
</table>

- Added coding efficiency from:
  » Unrestricted motion vectors
  » Bi-directional motion estimation/prediction
  » Arithmetic coding of AC coefficients

H.263 Video Compression
Companion standards

- H.263 — “Low bit-rate” video coding
- H.324 — Terminal systems
- H.245 — Conference control
- H.223 — Audio/video multiplexing
- G.723 — Audio coding 5.3 and 6.3 kbps

- For Internet conferencing there is also the related T.120 Document Conferencing standards family
The Video Data Type
Compression Standards

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  - sub-sampling & interpolation
  - DPCM
  - DCT
  - Huffman coding

- Common algorithms
  - JPEG/MJPEG
  - H.261/H.263
  - MPEG-1,-2

Compression Algorithms
MPEG

- A family of audio/video coding schemes
  - MPEG-1 — A video coding standard for digital storage/retrieval devices
    - “VHS quality” video coded at approximately 1.5 Mbps
  - MPEG-2 — Video coding for digital television
    - SIF/CIF to HDTV resolutions at data rates up to 100 Mbps
  - MPEG-4 — Coding of audio/visual “objects” for multimedia applications
    - Coding of natural & synthetic images
    - Object-based encoding for content access & manipulation
  - MPEG-7 — A content/meta-data representation standard for content search and retrieval
MPEG-1 Video Compression

Requirements

- MPEG intended primarily for stored video applications
  - A “generic” standard
  - But a basic assumption is that video will be coded once and played multiple times

- Support for VCR-like operations
  - Fast forward/forward scan
  - Rewind/reverse scan
  - Direct random access
  - ...

MPEG-1 Video Compression

Relation to H.261

- Similar to H.261...
  - INTER and INTRA picture types, entropy encoded, motion compensated, DCT-based compression...

- … but with more aggressive motion compensation:
  - prediction — approximately the same as in H.261
  - interpolation (bi-directional prediction)
  - DPCM encoding of motion vectors
MPEG-1 Video Compression

Relation to JPEG

- Non-uniform quantization for intra-coded pictures
  » Uniform quantization for inter-coded pictures

The predictor search space is not specified in the standard
» Implementations can perform as exhaustive a search as they desire

Find the motion vector \( w \) that minimizes some cost function \( f \):

\[
\sum_{i=0}^{15} \sum_{j=0}^{15} f(frame_n[16b_x+i, 16b_y+j] - frame_{n-1}[16b_x+w_x+i, 16b_x+w_y+j])
\]
Besides simple prediction, *interpolation* (bi-directional prediction) is used to achieve further compression.

A future frame *and* a past frame are used to predict the current frame:
- Deals effectively with scene changes and new object appearances
- Produces predictors (pairs) with better statistical properties

MPEG defines three picture (frame) types:
- **I** — intracoded pictures coded as a still image
- **P** — predicted pictures predicted from the previous I or P picture
- **B** — interpolated pictures predicted from the previous I or P picture and the next I or P picture
MPEG Motion Compensated Prediction

Bi-directional prediction

- Directional prediction implies that frames cannot be encoded or transmitted in the order they are scanned

- Encoding & transmission order:
  » I1 P5 B2 B3 B4 I9 B6 B7 B8 P13 B10 B11 B12 I17 B14 B15 B16 ...

MPEG Motion Compensated Prediction

Bi-directional prediction

- Bi-directional prediction modes are selectable on a macroblock by macroblock basis within a B picture

- Macroblocks can be predicted by:
  » themselves: \( frame'_n[i, j] = frame_n[i, j] \)
  » a previous frame: \( frame'_n[i, j] = frame_{n-y}[i+w_x, j+w_y] \)
  » a future frame: \( frame'_n[i, j] = frame_{n+x}[i+w_x, j+w_y] \)
  » a previous & future frame:
    \[
    frame'_n[i, j] = (frame_{n-y}[i+w_x, j+w_y] + frame_{n+x}[i+w'_x, j+w'_y])/2
    \]
Bi-Directional Motion Compensation

Compression rates

- Some prototypical results for 2 movies encoded at 320x240, 30 fps and constant quality

“Crocodile Dundee”

“ET”

MPEG Video Compression

Decoder architecture

- $u$

- "Crocodile Dundee"

- "ET"

- "Stream Demultiplexor"

- "Inverse Quantizer"

- "DCT Decoder"

- "Macroblock Buffer"

- "Entropy Decoder"

- "DPCM Decoder"

- "Prediction Control"

- = video frame

- = 16x16 pixel block

- = 8x8 pixel block

- = control data
MPEG Video Compression

Coded bit-stream

- MPEG has a layered bit-stream similar to H.261
- There are seven layers:
  - **Sequence Layer**
    - decoding parameters (bit-rate, buffer size, picture resolution, frame rate, ...)
  - **Group of Pictures Layer**
    - a random access point
  - **Picture Layer**
    - picture type and reference picture information
  - **Slice Layer**
    - position and state information for decoder resynchronization
  - **Macroblock Layer**
    - coded motion vectors
  - **Block Layer**
    - coded DCT coefficients, quantizer step size, etc.

MPEG-2
“New & Improved” MPEG-1

- A coding standard for the broadcast industry
  - Coding for video that originates from cameras
  - Offers little benefit for material originally recorded on film
- But included is support for:
  - Higher (chrominance) sampling rates
  - Resilience to transmission errors
  - ...
- More mature and powerful coding/compression technology is used
  - Unrestricted motion search with 1/2 pel resolution for motion vectors