

CSE 490 G
 Introduction to Data Compression
 Winter 2006
 Video Compression

Human Perception of Video

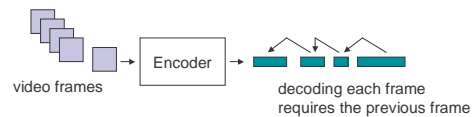
- 30 frames per second seems to allow the visual system to integrate the discrete frames into continuous perception.
- If distorted, nearby frames in the same scene should have **only** small details wrong.
 - A difference in average intensity is noticeable
- Compression choice when reducing bit rate
 - skipped frames cause stop action
 - lower fidelity frames may be better

Applications of Digital Video

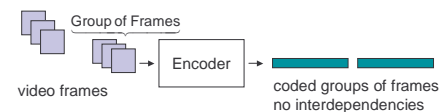
- Teleconference or video phone
 - Very low delay (1/10 second is a standard)
- Live Broadcast Video
 - Modest delay is tolerable (seconds is normal)
 - Error tolerance is needed.
- Video-in-a-can (DVD, Video-on-Demand)
 - Random access to compressed data is desired
 - Encoding can take a lot of time
- Decoding must always be at at least the frame rate.

Video Encoding

Frame-by-Frame coding



Group-of-Frames coding



Coding Techniques

- Frame-by-frame coding with prediction
 - Very low bit rates
 - low delay
 - Not error resilient
- Group-of-frames coding
 - Higher bit rates – within a group prediction is used
 - Error resilient
 - Random Access
 - Higher delay

Digital Video Data

- CCIR 601 (4,2,2 scheme)
 - 13.5 MHz sample rate for luminance channel
 - 6.75 MHz sample rate for each of two chrominance channels
 - 8 bits per sample is a bit rate of $27 \times 8 = 216$ Mb per second
 - MPEG-SIF – $\frac{1}{2}$ sample rate for luminance and $\frac{1}{4}$ for chrominance – 81 Mb per second
- CIF (Common Interchange Format)
 - 288×352 pixels per frame for luminance channel
 - 144×176 pixels per frame for each of two chrominance
 - 8 bits per pixel and 30 frames per second gives 48.7 Mb per second
 - QCIF (Quarter - CIF) is $\frac{1}{4}$ the data or 12.2 Mb per second.

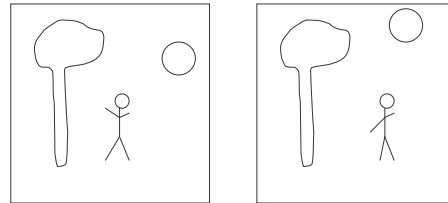
High Compression Ratios Possible

- Nearby frames are highly correlated. Use the previous frame to predict the current one.
- Need to take advantage of the fact that usually objects move very little in $1/30$ th of a second.
 - Video coders use **motion compensation** as part of prediction

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Motion Compensation



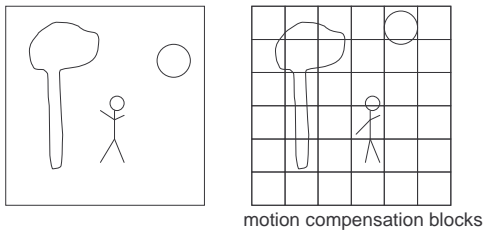
Previous Frame

Frame

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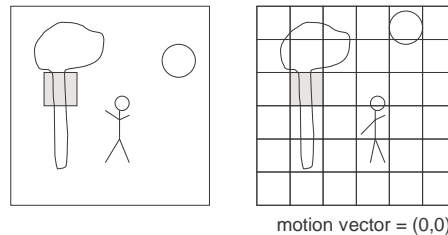
Block Based Motion Compensation



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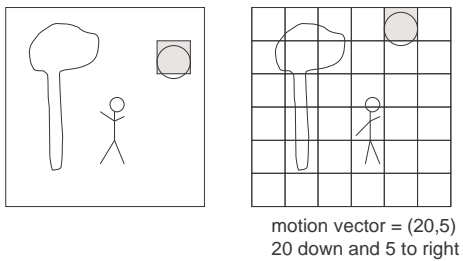
Motion Vectors



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Motion Vectors



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Motion Compensation

- For each motion compensation block
 - Find the block in the previous **decoded** frame that gives the least distortion.
 - If the distortion is too high then code the block independently. (intra block)
 - Otherwise code the difference (inter block)
- The previous decoded frame is used because both the encoder and decoder have access to it.

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Issues

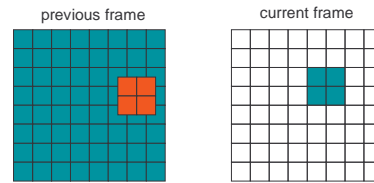
- Distortion measured in squared error or absolute error
 - Absolute error is quicker to calculate
- Block size
 - Too small then too many motion vectors
 - Too large then there may be no good match
- Searching range to find best block
 - Too large a search range is time consuming
 - Too small then may be better matches
 - Prediction can help.
- Prediction resolution
 - Full pixel, half-pixel, quarter-pixel resolution
 - Higher resolution takes longer, but better prediction results

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Fractional Motion Compensation

- Half or quarter pixel motion compensation may achieve better predictions.
- Fractional motion compensation is achieved by linear interpolation.



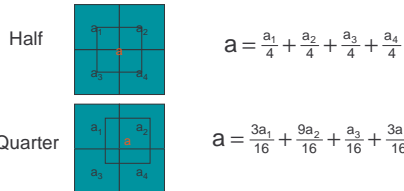
Half pixel motion compensation

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Linear Interpolation

- Calculate an interpolated pixel as the average of overlapping pixels.
- Better interpolation methods exist.



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Rate Control



- Buffer is filled at a constant rate (almost).
- Buffer is emptied at a variable rate.

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Underflow Problem

- Set up
 - Constant rate channel at C bits per second
 - Frame rate F in frames per second.
 - b_i is the number of bits in compressed frame i
 - Initial occupancy of buffer B
- B_i is the number of bits in the buffer at frame i

$$B_0 = B$$

$$B_{i+1} = B_i + C/F - b_i$$
- Buffer should never empty $B_i \geq 0$ for all i

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Rate Control

- The rate control buffer is seeded to allow for variability in number of bits per frame and variability in channel rate.
- Causes of variability in bits per frame.
 - Encoder does not predict well how many bits will be used in a frame - scalar quantization.
 - Encoder allocates more bits in frames that are hard to encode because they are not predicted well - scene changes.
- Causes of channel rate variability
 - Congestion on the internet

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Rate Control Algorithms

- On-line solution
 - Send a few frames to seed the buffer
 - Encoder simulates the buffer, should the buffer threaten to empty start sending more frames at lower fidelity or skip frames (decoder will interpolate skipped frames).
- Off-line solution
 - Attempt to allocate bits to frames to assure even fidelity.
 - Seed the buffer with enough frames to prevent underflow.

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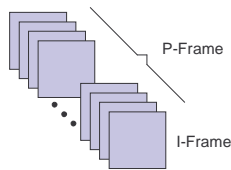
H.261

- Application – low bit rate streaming video
- Frame-by-frame encoder
- DCT based with 8x8 coding block
 - Uses JPEG style coding
- Motion compensation based on 16x16 macroblocks.
- Half pixel motion compensation

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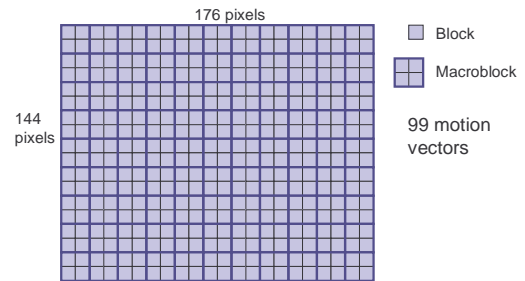
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H.261(QCIF)



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H.261

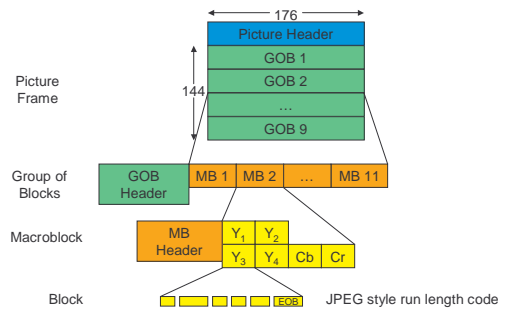
- Within a group of blocks (GOB) prediction is used with motion vectors for coding.



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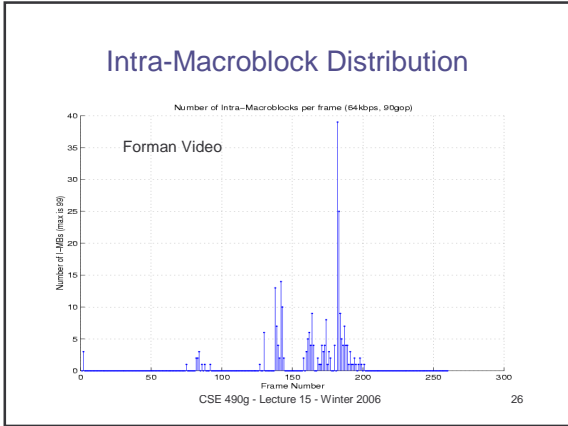
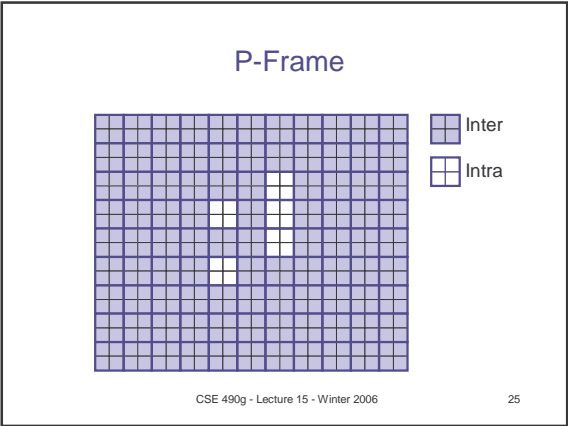
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H.261 Organization

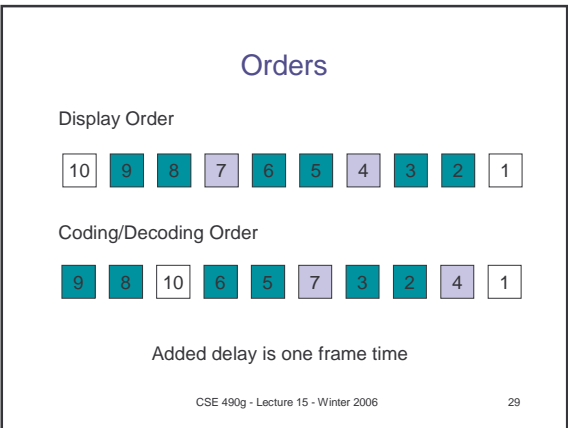
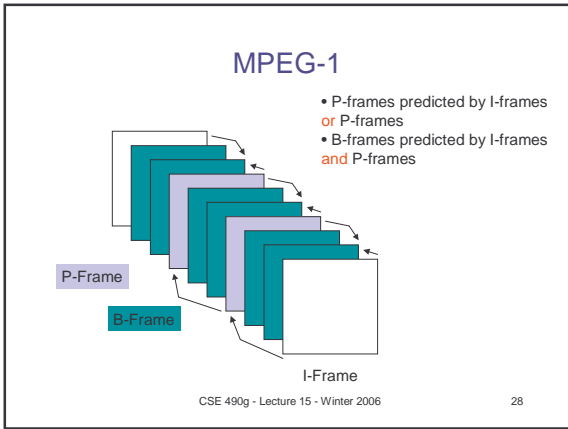


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- ### MPEG-1
- Application – Video coding for random access
 - Group-of-frames encoder
 - DCT based with 8x8 coding block
 - Uses JPEG style coding
 - Motion compensation based on 16x16 macroblocks.
 - Forward and Backward Prediction within a group of frames
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- ### MPEG-1 Notes
- Random access unit = Group-of-Frames
 - Called GOP for group-of-pictures
 - Error resilient
 - B-frames can be damaged without propagation
 - Added delay
 - Coding order different than display order
 - Encoding time consuming
 - Suitable for non-interactive applications
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Beyond MPEG-1

- MPEG-2
 - Application independent standard
- MPEG-4
 - Multimedia applications
 - Model based coding
- H.263
 - More error resilience

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Newest Trends

- H.264
 - Just out in 2003, many new features
 - Quarter pixel motion compensation
 - Variable size motion blocks
 - Multiple frame prediction
- 3-D Wavelet Coding
 - Third dimension is time
 - 3-D SPIHT has been implemented
 - Delay is large because GOP is large
- GTV
 - Group testing for video
 - Bits per frame can be controlled enabling off-line rate control to succeed.

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