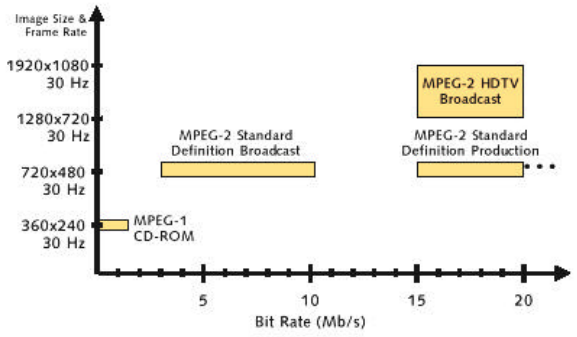
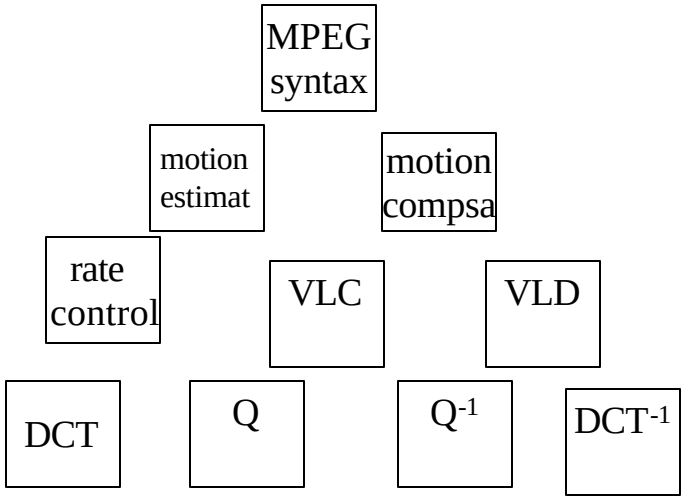
MPEG-1

MPEG-1 vs. MPEG-2 Operating Points



MPEG Building Blocks



MPEG-1

- It only specifies bitstream syntax and decoding process
- Encoding process (e.g., motion estimation, rate control and mode decisions) are open to invention and proprietary techniques
- It is asymmetric compression standard, much less computation needed for decoder.

MPEG-1

- SIF format video and its associated audio at about 1.5 Mbs
- Quality of MPEG-1 is similar or superior to VHS recorded analog video
- Spatially adaptive quantization, for Intra coding, MPEG-1 provides 30% better compression compared to JPEG.
- VLC using Huffman tables similar to H.261, completely different from JPEG.

MPEG-1 Features

- Random access
- Fast forward/reverse
- Reasonable coding/decoding delay (1 sec)
- Progressive (non-interlaced) video only
- Input video is converted to SIF (Standard Input Format): 352x240 30 fps

MPEG-1 Parameters

- Max number of pixels/line: 720
- Max number of lines/picture: 576
- Max number of pictures/sec: 30
- Max number of macroblocks/picture:396
- Max number of macroblocks/sec: 9900
- Max bitrate: 1.86 Mbps
- Max decoder buffer size: 376,832 bits

MPEG-1 LAYERS

- Block
- Macroblock
- Slice
- Picture
- GOP
- Sequence

Picture Types

- I (intra) frames (spatial DCT)
- P (predicted) frames (DCT with forward MC)
- B (bidirectional) frames (DCT with forward/backward MC)
- D (difference) frames, only contain the DC component of each block, and serve for browsing purpose at low bitrate

Picture Types

- The relative number of I, P and B frames in a GOP is application dependent.
- At least one out of 132 pictures must be an "I" picture to avoid the error propagation
  - due to mismatch of IDCT at encoder and decoder
  - 64 bit floating-point IDCT implementation (IEEE 1180-1990)
- B frames are optional

B-Pictures

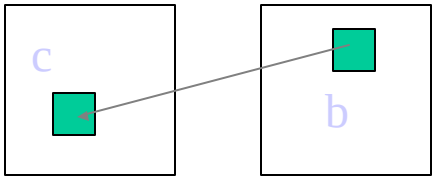
- “B” frames effectively handle the problems due to covering/uncovering of background.
- MC over two frames may provide better SNR.
- Since “B” frames are not used for predicting any future frames, they can be encoded with fewer bits.

B-Pictures

- Two frame-stores are needed at decoder and encoder.
- If too many B-pictures are used
  - the distance between two reference frames increases, resulting in lesser correlation, more bits required to encode reference frames
  - longer coding delay

Motion Prediction

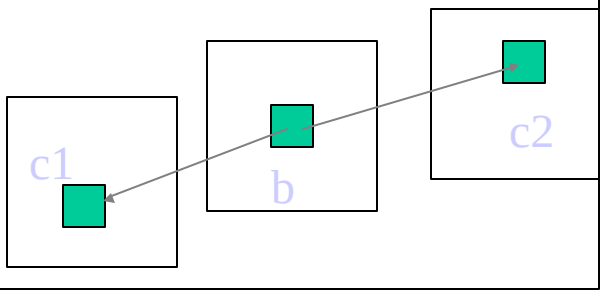
$b' = c'$



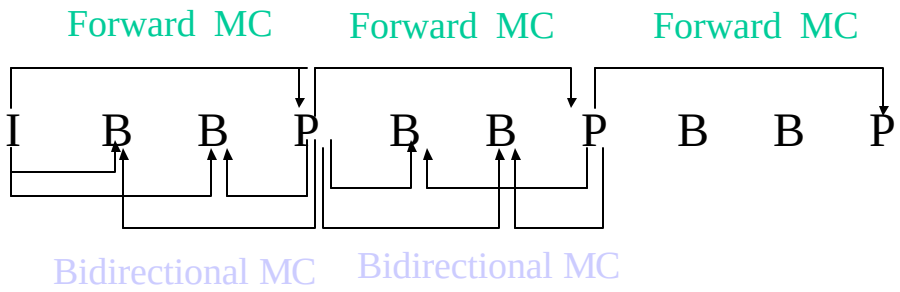
$b' = a_1 c_1' + a_2\ c_2'$

$a_1, a_2 = 0,.5,1$

$a_1 + a_2 = 1$



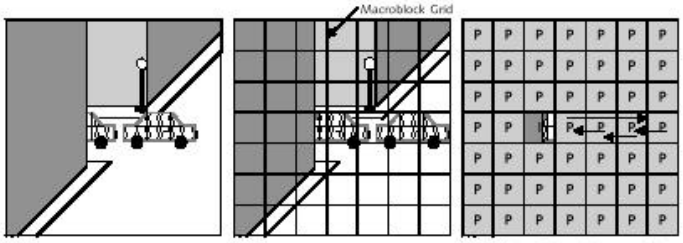
GOP



Example

Example of Forward Motion Estimation

For Best Coding Efficiency, Prediction Error should have low energy.



Previous I or P Picture

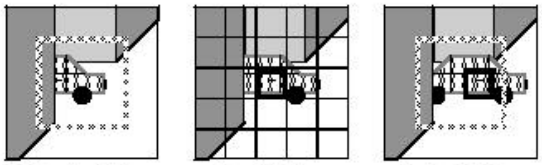
Current P Picture

Prediction Error Picture, with MB Type and Motion Vectors Superimposed.
(I = Intra, P = Inter)

Example

Example of Backward Motion Estimation

Handles uncovered objects missed by forward prediction.



Previous I or P Picture.
Searching here finds no good match because some features are partially hidden.

Current B Picture.
Current MB is shown with heavy outline.

Next I or P Picture.
Searching here finds a good match because features are now uncovered.

GOP

- "I" and "P" frames
  - anchor frames
  - stored in memory
  - used for prediction of "B" frames
- GOP Rules
  - It must contain at least one "I" frame
  - "I" frame may be followed by any number of "I" and "P" pictures

GOP Rules

- Any number of "B" pictures may occur between anchor pictures, "B" picture may precede the first I picture
- A GOP in coding order must start with "I" picture
- A GOP in display order must start with an "I" or "B" picture and must end with an "I" or "P" picture.

GOP Picture Ordering

- If B pictures are used, “Display Order” and “Coding order “may be different.
- B pictures must be reordered, so that “anchor” frames are available for prediction.
- Reordering causes delay.

GOP Ordering

I, B, B, B, P, B, B, B, P
0, 1, 2, 3, 4, 5, 6, 7, 8

Two possible coding orders:
0, 4, 1, 2, 3, 8, 5, 6, 7
0, 1,4, 2, 3, 8, 5, 6, 7

GOP Ordering

Display Order

B, B, I, B, B, P, B, B, P, B, B, P

Coding Order

I, B, B, P, B, B, P, B, B, P, B, B

Display Order

B, B, I, B, B, P, B,…..

GOPS

N=1, M=1 I I I I I I I I I I I I

N=6, M=2 B I B B P B I B P B P B I

N=12, M=3 B B I B B P B B P B B P

Irregular B B I B B B B P P B P

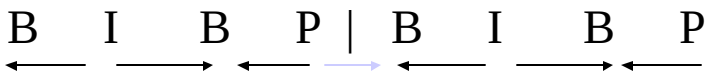
N= I picture interval, M= anchor picture interval

M-1 “B” frames between anchor frames

Open & Closed GOP

Closed GOP

Open GOP



Closed GOP can be decoded without using decoded pictures from previous GOP.

Macroblock Types

I	P	B
Intra	Intra	Intra
Intra-A	Intra-A	Intra-A
	Inter-D	Inter-F
	Inter-DA	Inter-FD
	Inter-F	Inter-FD
	Inter-FD	Inter-B
	Inter-FDA	Inter-BD
	Skipped	Inter-I
		Inter-ID
		Inter-IDA
		Skipped

Definitions

- Intra: MB coded with current quantization matrix
- Intra-A: quantization matrix is scaled by “MQUAINT”, which is transmitted in the header
- Inter: interframe coded, temporal prediction may use MC and or adaptive quantization
  - “D” indicates DCT of prediction error coded

Definitions

- “F”: forward MC is on
- “B”: bi-directional MC is on
- “A”: adaptive quantization, new MQUAINT is transmitted.
- “FD”: transmit motion vector and DCTs of prediction error
- “FDA”: a motion vector, DCTS of error, and “MQUAINT”
- “I”: Interpolated prediction with motion prediction

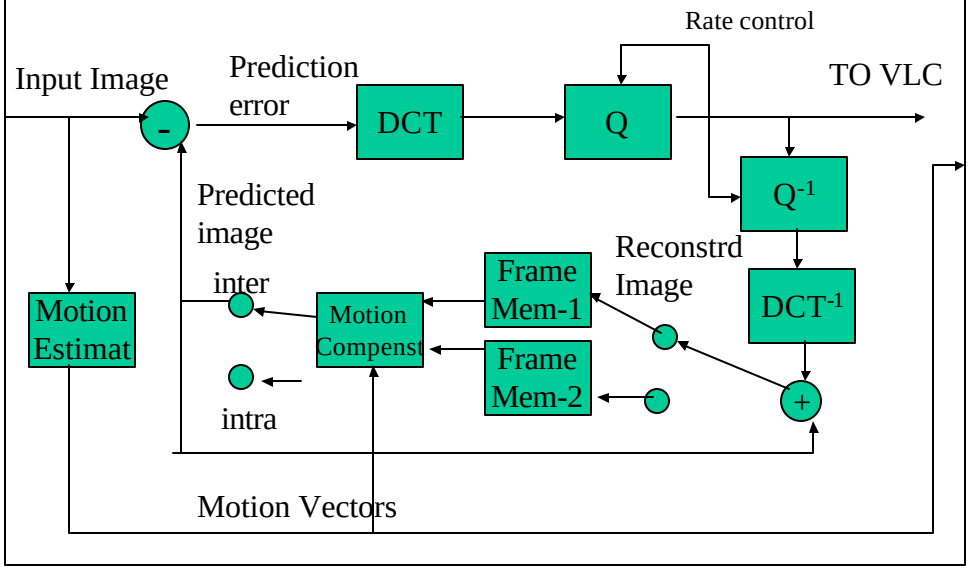
MPEG-1 Encoder

- Decide on labeling I, P, B-pictures in a GOP.
- Estimate motion vector for each MB in P- and B-pictures.
- Determine the compression mode MTYPE for each MB.
- Set the quantization scale, MQUAINT, if adaptive quantization is selected.

MPEG-1 Intra Quantization Matrix

$$\begin{bmatrix} 8 & 16 & 19 & 22 & 26 & 27 & 29 & 34 \\ 16 & 16 & 22 & 24 & 27 & 29 & 34 & 37 \\ 19 & 22 & 26 & 27 & 29 & 34 & 34 & 38 \\ 22 & 22 & 26 & 27 & 29 & 34 & 37 & 40 \\ 22 & 26 & 27 & 29 & 32 & 35 & 40 & 48 \\ 26 & 27 & 29 & 32 & 35 & 40 & 48 & 58 \\ 26 & 27 & 29 & 34 & 38 & 46 & 56 & 69 \\ 27 & 29 & 35 & 38 & 46 & 56 & 69 & 83 \end{bmatrix}$$

MPEG-1 Encoder



Comparison

- H.261
  - sequential access
  - One basic frame rate
  - CIF and QCIF images
  - I and P frames
  - MC over 1 frame
  - I pixel MV accuracy
  - uniform quantization
  - No GOP
  - GOB structure
- MPEG-1
  - random access
  - flexible frame rate
  - flexible image size
  - I, P and B frames
  - MC over 1 or more frames
  - 1/2 pixel MV accuracy
  - Quantization matrix
  - GOP structure
  - Slice structure