18-899 Special Topics in Signal Processing

Multimedia Communications:
Coding, Systems, and Networking

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Lecture 4

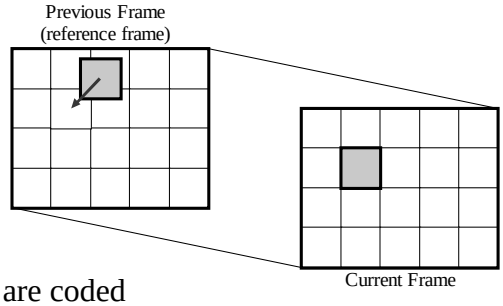
H.261

H.261

- ITU-T Study Group 15, 1984-1990
- Videophone and video conferencing
  - Low bit rates and low delay
  - Originally for m×384 kbits/s (m=1...5), changed to p×64 kbits/s (p = 1...30) in 1988. Also called **"p×64"**
  - 40 kbits/s to 2 Mbits/s
- A "hybrid" coding algorithm
  - Block-based motion-compensated DCT coding
  - Basis of most video coding standards

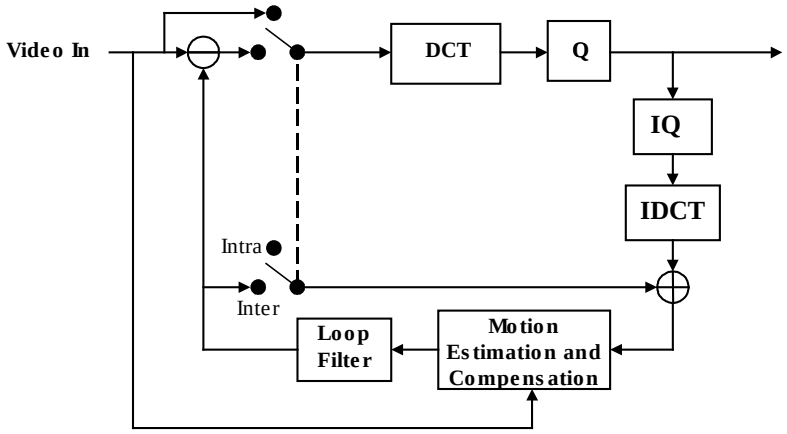
INTER and INTRA

- INTRA coding: 8×8 DCT (similar to JPEG)
- INTER coding:
  - Block matching for motion estimation (16×16)



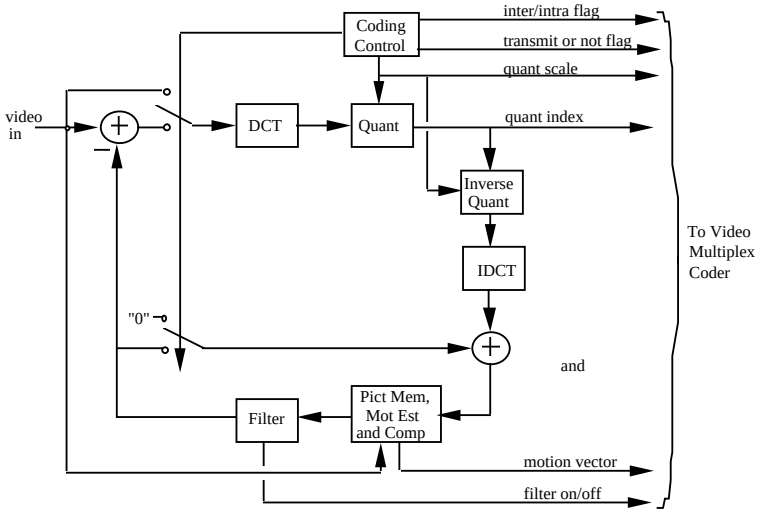
  - Motion vectors are coded
  - Residue is DCT coded (as in INTRA)

Encoder

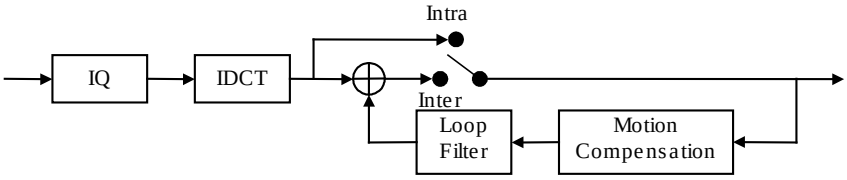


Loop Filter: Low pass filter with [1/4,1/2,1/4]

Encoder (more detail)



Decoder



Picture Formats

- Only two picture formats are allowed
  - CIF (common intermediate format) (~CGA)
  - QCIF (quarter-CIF)

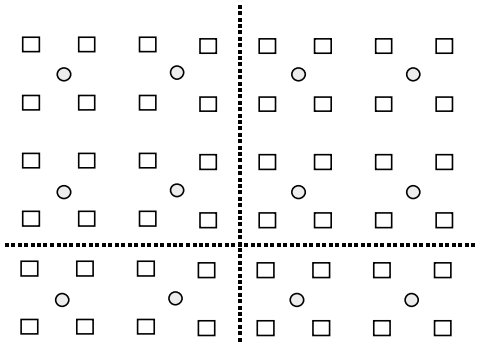
	Pels/line	Lines	Uncompressed Bit Rate
QCIF	176	144	9.12 Mbits/s
CIF	352	288	36.5 Mbits/s

- Color components
  - As in ITU-R 601 (CCIR 601)

$$\begin{matrix} 16\cdots235\rightarrow \\ 16\cdots240\rightarrow \\ 16\cdots240\rightarrow \end{matrix}\begin{bmatrix} Y \\ C_B \\ C_R \end{bmatrix} = \begin{bmatrix} 0.257 & 0.504 & 0.098 \\ -0.148 & -0.291 & 0.439 \\ 0.439 & -0.368 & -0.071 \end{bmatrix}\begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix}$$

Positions of Samples

- Luminance (Y) and chrominance (C_B, C_R)



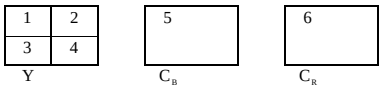
□ = Y Pels

○ = C_B and C_R Pels

..... = Block Edges

4:2:0 Format

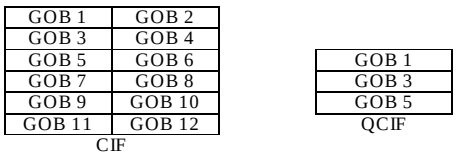
Blocks, Macroblocks and Groups of Blocks



A macroblock

1	2	3	4	5	6	7	8	9	10	11
12	13	14	15	16	17	18	19	20	21	22
23	24	25	26	27	28	29	30	31	32	33

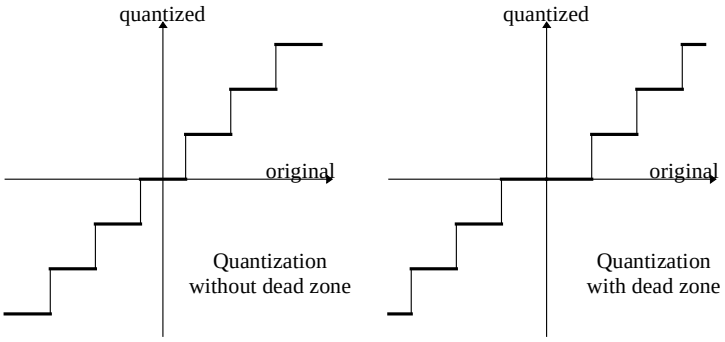
A group of blocks (GOB)



GOB strucutres in a picture

Quantization

- No quantization tables (cf. JPEG)
- Intra DC: Uniform quantization with step size 8
- All others: Uniform quantization with dead-zone
  - Noise removal



Quantization (cont.)

- Step size may change at every MB or GOB
  - Step size = QUANT × 2; QUANT=1…31
- Threshold can be used at the encoder
  - Adaptive threshold (e.g., RM8) to increase the run of zeros, e.g.,

Coefficients	50	0	0	0	33	34	0	40	33	34	10	32	…
Threshold	32	32	33	34	35	36	37	38	32	32	32	33	…
New coeff.	50	0	0	0	0	0	0	40	33	34	0	0	…

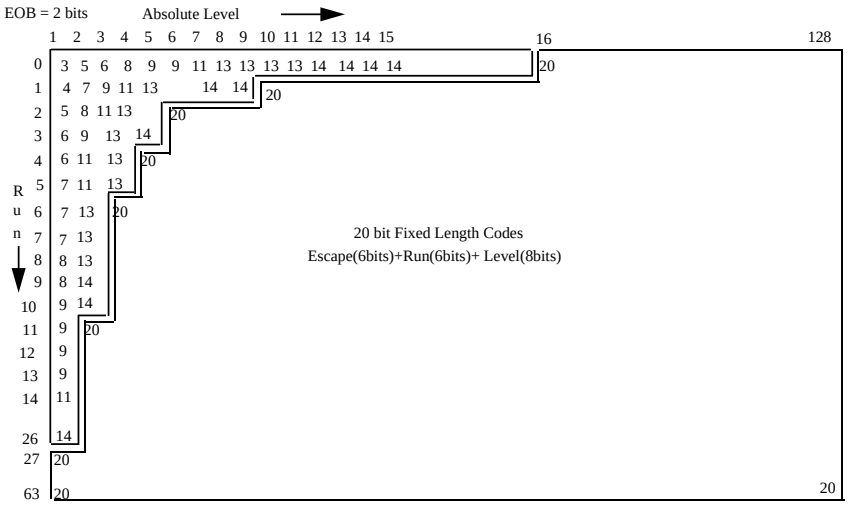
Zigzag Scan and Entropy Coding

- Zigzag scan: Same as in JPEG
- Entropy coding
  - DC: Differential coding, same as in JPEG
  - AC: Run-level coding

AC Coding

- **Run-level** symbols
  - **run**: Length of the zero run
  - **level**: Amplitude of the nonzero coefficient
- Huffman coding
  - Short codes for frequent symbols
  - 2D table of variable length codes (VLC)

Length of VLC



An Example...

Run	Level	Code
EOB		10
0	1	1s If first coefficient in block
0	1	11s Not first coefficient in block
0	2	0100 s
0	3	0010 1s
0	4	0000 110s
0	5	0010 0110 s
0	6	0010 0001 s
0	7	0000 0010 10s
0	8	0000 0001 1101 s
0	9	0000 0001 1000 s
0	10	0000 0001 0011 s
0	11	0000 0001 0000 s
0	12	0000 0000 1101 0s
0	13	0000 0000 1100 1s
0	14	0000 0000 1100 0s
0	15	0000 0000 1011 1s
1	1	011s
1	2	0001 10s
1	3	0010 0101 s
1	4	0000 0011 00s
1	5	0000 0001 1011 s
1	6	0000 0000 1011 0s
1	7	0000 0000 1010 1s
2	1	0101 s
2	2	0000 100s
2	3	0000 0010 11s
2	4	0000 0001 0100 s
2	5	0000 0000 1010 0s
3	1	0011 1s
…	…	…

0 0 0 -1 6 0 3 EOB

001111 001000010 001001010 10

Coding of Motion Vectors

- MVs have integer values in [-15,15]
- Differential coding in each direction
  - VLC for MV difference

MVD	Code
…	…
–7 & 25	0000 0111
–6 & 26	0000 1001
–5 & 27	0000 1011
–4 & 28	0000 111
–3 & 29	0001 1
–2 & 30	0011
–1	011
0	1
1	010
2 & –30	0010
3 & –29	0001 0
4 & –28	0000 110
5 & –27	0000 1010
6 & –26	0000 1000
7 & –25	0000 0110
…	…

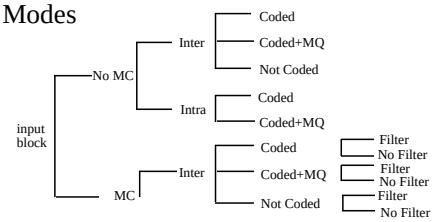
Example:

15 14 -13 12 …
-1 -27 25 ...

011 00001010 00000111...

Microblock Type (MTYPE)

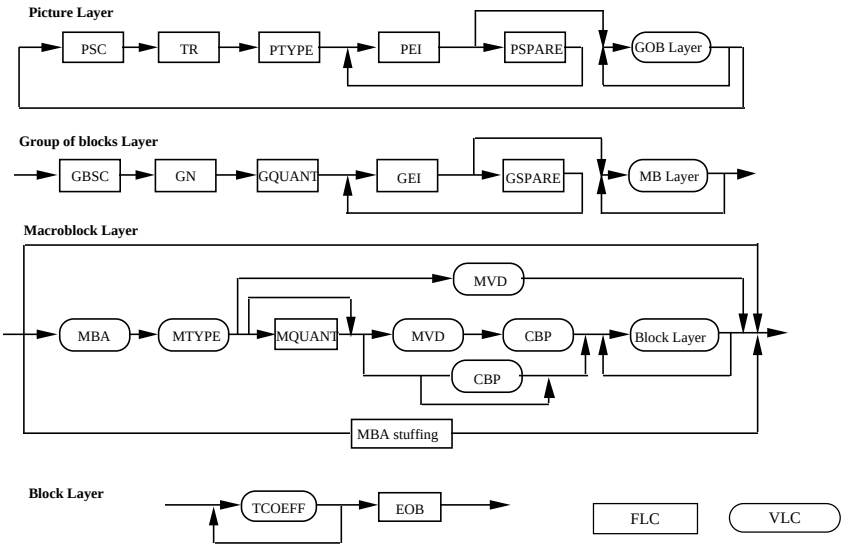
- MTYPE Modes



- VLC Table for MTYPE Modes

Prediction	MQUANT	MVD	CBP	TCOEFF	VLC
Intra				y	0001
Intra	y			y	0000 001
Inter			y	y	1
Inter	y		y	y	0000 1
Inter + MC		y			0000 0000 1
Inter + MC		y	y	y	0000 0001
Inter + MC	y	y	y	y	0000 0000 01
Inter + MC +FIL		y			001
Inter + MC +FIL		y	y	y	01
Inter + MC +FIL	y	y	y	y	0000 01

Syntax Diagram



Syntax Diagram (cont.)

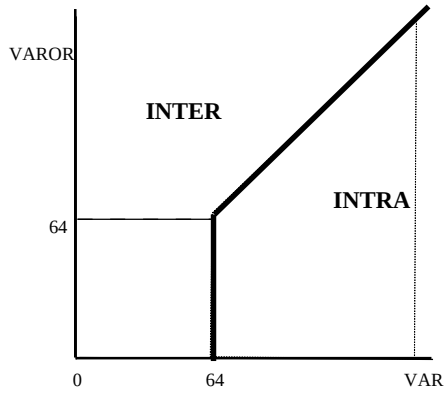
- Picture layer
  - PSC (20 bits): Picture Start Code
  - TR (5 bits): Temporal Reference
  - PTYPE (6 bits): CIF or QCIF, etc.
  - If PEI = 1, PSPARE: spare bits for future
- GOB layer
  - GBSC (16 bits): GOB Start Code
  - GN (4 bits): Group Number
  - GQUANT: Group quantizer, 1…31
  - If GEI = 1, GSPARE: spare bits
- MB layer
  - MBA: MB Address
  - MQAUNT: MB quantizer, 1…31
  - MVD: MV Data
  - CBP: Coded Block Pattern

Reference Model (RM) 8

- Encoder specification
  - Motion estimation: 3-step search
  - Quantization
  - Inter/intra decision
  - MC/No MC decision
  - Buffer and rate control
  - Loop filter on/off

Inter/Intra Decision

- Intra



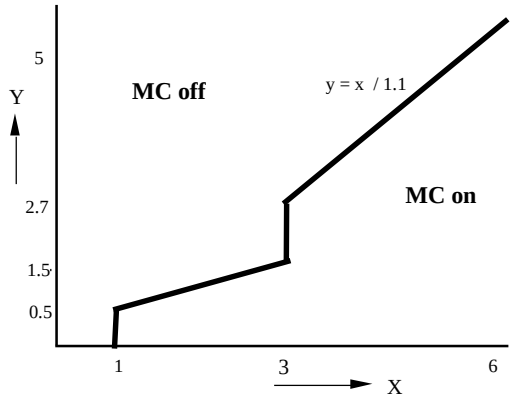
Inter $VAR = (\sum (pel - mc_pel)^2) / 256$

$VAROR = (\sum (pel - blk_avg)^2) / 256$

MC/No MC Decision

$$Y = \frac{\sum |DFD|}{256}$$

MC Frame Difference



$$X = \frac{\sum |FD|}{256}$$

Frame Difference

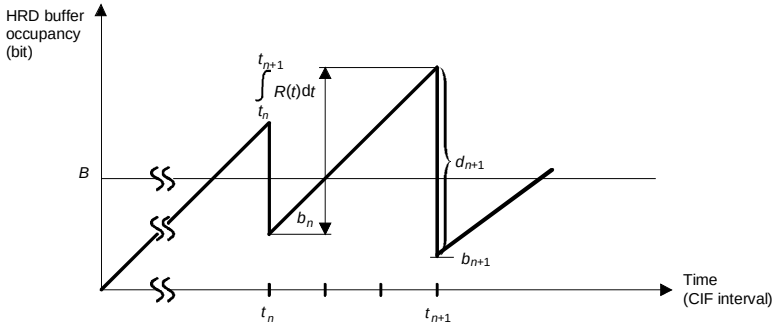
Buffer Control

- Quantization step size varies from 2 to 62 with step 2
- Buffer size of q*64 kbits, q determines video bitrate
- Bitrate=q*64 kbits/s, frame rate= 30/k Hz (k=1...4)
- Mean bits/MB for CIF is 5*k*q and for QCIF is 20*k*q
- step = 2* INT (buffer fullness / [200*q]) + 2

Buffer Fullness	Quantizer Step size
< 200*q	2
< 400*q	4
< 600*q	6
< 800*q	8
< 6000*q	60
< 6200*q	62

Hypothetical Reference Decoder

- HRD $$d_{n+1} \geq b_n + \int_{t_n}^{t_{n+1}} R(t)dt - B$$



NOTE – Time ($t_{n+1} - t_n$) is an integer number of CIF picture periods (1/29.97, 2/29.97, 3/29.97, ...).

H.261 Quality vs. Bit Rates

	CIF	QCIF
20 kbits/sec	so so	poor
64 kbits/sec	fair	fair+
112 kbits/sec	good	good+
320 kbits/sec	good	excellent

Multipoint Considerations

- Freeze picture request
  - causes decoder to freeze picture until release request or time-out
- Fast update request
  - causes encoder to encode next picture in INTRA mode
- Freeze release request
  - causes decoder to exit freeze picture mode and go in normal mode
- Used by Multipoint Control Unit (MCU)
  - Example...

References

- Ming Liou, "Overview of the p×64 kbit/s video coding standard," Comm. of the ACM, April 1991
- Arun N. Netravali, and Barry G. Haskell, Chapter 8, *Digital Pictures: Representation, Compression, and Standards*, 2nd Edition, Plenum Publishing Corp., New York, NY
- Joan L. Mitchell et al., Sec. 19.2, *MPEG Video: Compression Standard*, Chapman & Hall, New York, NY