1. Digital Video Fundamentals

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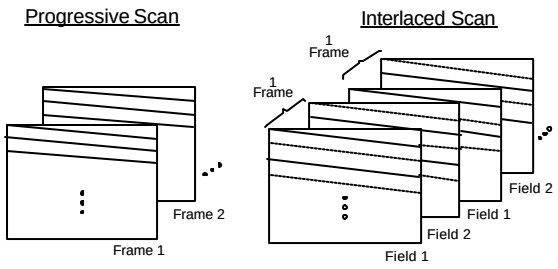
DIGITAL VIDEO APPLICATIONS

- Multimedia
- Digital TV, HDTV
- VCD (Video CD), DVD (Digital Versatile/Video Disc), Digital camcoder, Digital VCR, ...
- Video on demand
- Videophone and video conferencing
- Distance learning
- Remote collaboration
- Surveillance
- ...

Standards: M-JPEG, MPEG-1, MPEG-2, MPEG-4, H.261, H.262, H.263, H.264

VIDEO REPRESENTATION



COMPONENT VIDEO

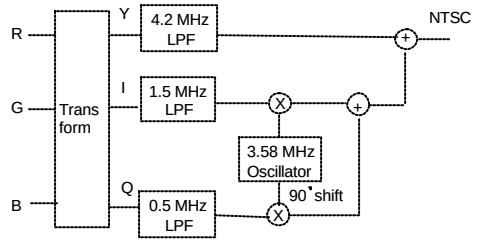
RGB - YCbCr -YUV - YIQ

$$\begin{bmatrix} Y \\ B\text{-}Y \\ R\text{-}Y \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.299 & -0.587 & 0.886 \\ 0.701 & -0.587 & -0.114 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$I = \frac{(R-Y)\cos 33^\circ}{1.14} + \frac{(B-Y)\sin 33^\circ}{2.03}$$

$$Q = \frac{(R-Y)\sin 33^\circ}{1.14} + \frac{(B-Y)\cos 33^\circ}{2.03}$$

NTSC COMPOSITE VIDEO



(LPF: Low-Pass Filter)

- NTSC signal and spectrum
- Artifact of the NTSC composite video

CCIR (ITU-R) 601 4:2:2 FORMAT

	NTSC	PAL
Luma sampling frequency	13.5 MHz	13.5 MHz
Chroma sampling frequency	6.75 MHz	6.75 MHz
Frames/sec	30	25
Luma #active samples/line	720	720
Chroma #active samples/line	360	360
Active #lines/frame	480	576
Sample resolution	8 bits	8 bits
Data rate	166 Mb/s	166 Mb/s

30x720x480x8x2 = 25x720x576x8x2 = 166 Mb/s

COMMON DIGITAL VIDEO FORMATS

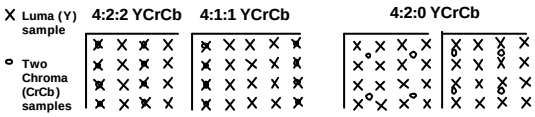


Image format	Resolution	Frame rate	YCrCb	Scan type
CCIR601 (NTSC)	720 x 480	30	4:2:2	interlaced
CCIR601 (PAL)	720 x 576	25	4:2:2	interlaced
SIF (NTSC)	352 x 240	30	4:2:0	progressive
SIF (PAL)	352 x 288	25	4:2:0	progressive
CIF	352 x 288	30	4:2:0	progressive
QCIF	176 x 144	30	4:2:0	progressive

HHR (Horizontal Half Resolution): 352 x 480 (NTSC) or 352 x 576 (PAL/SECAM). Supported by the DVD-Video specification. HHR reduces the bandwidth with a reduction in picture quality. Also called Half D1.

NEEDS FOR VIDEO COMPRESSION

- Without compression
  - Visual telephony (e.g. CIF @ 15 frames/s):
    352 (pels) x 288 (lines) x 15 (frames/s) x 1.5 bytes = 18.25 Mbit/s
  - Digital TV (CCIR601 4:2:0 @ 30 frames/s):
    720 (pels) x 480 (lines) x 30 (frames/s) x 1.5 bytes = 124.4 Mbit/s
  - HDTV (e.g. 1280x720 pels 4:2:0 @ 60 frames/s):
    1280 (pels) x 720 (lines) x 60 (frames/s) x 1.5 bytes = 663.6 Mbit/s
- Compression results in lower bitrates which enables new applications and results in lower transmission and storage cost

COMPRESSION

Remove Redundancy: statistical, spatial, temporal, human perception

Lossless (entropy, reversible): Huffman, Run-length, Arithmetic, …

Lossy:

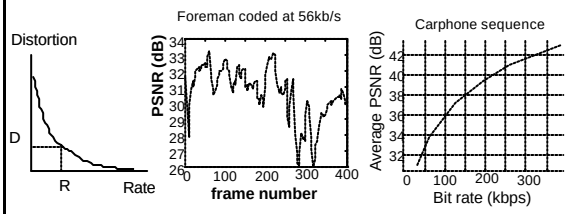
Spatial domain: DPCM (Differential Pulse Code Modulation), ...

Frequency domain: DCT (Discrete Cosine Transform) ...

Intra-frame coding: same as still image coding

Inter-frame coding (reduce temporal redundancy):
Motion-compensated predictive coding, ...

QUALITY EVALUATION



PSNR (Peak Signal-to-Noise Ratio): $PSNR = 10 \log(\frac{N 255^2}{\sum e^2})$

Objectives for coding a video sequence:
- High Average PSNR, Minimum PSNR
- Low PSNR variation

QUALITY EVALUATION

Subjective evaluation

TRADE-OFF in VIDEO CODING

- Video quality
- Bit-rate
- Complexity
- Encoding latency

VIDEO vs. IMAGE COMPRESSION

- Temporal redundancy
- Interlaced artifact
- Temporal artifact after compression/decompression
- Transmission buffer and rate-control
- Often need real-time encoding/decoding
- Latency is a concern for 2-way applications

A TYPICAL END-TO-END DIGITAL VIDEO SYSTEM