Digital Video Technology Seminar Notes

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Digital Video Technology

- **Video Formats**
  - File Formats, Codecs
- **Video Characteristics**
  - Resolution, Aspect ratio
  - Analog television formats, Frame rate, Broadcast standards
  - Color Depth, Color models, Subsampling
- **Video Compression**
  - Compression parameters: GOP
  - Data rates
- **Video Processing**
  - Desktop Video Processing, Filtering

Source Video Characteristics

- **File Format**
  - File name, Length, File Format
- **File Processing**
  - Stitch, Trim, Crop
- **Video Format**
  - Resolution, Aspect Ratio, Interlacing, Colors
  - Frame rate, Codec
- **Audio Format**
  - Channels, Sample Rate, Bits/Sample, Codec

Target Video Parameters

- **Destination**
  - File name, Location, Splitting
  - Attributes, DRM
- **Streaming**
  - Elementary, Program; Download, Progressive, Stream
- **Video Format**
  - Format, Resolution, Frame rate, Interlacing, Aspect Ratio
- **Video Compression**
  - Codec, Bitrate, Passes, CBR/VBR
  - Quality / Speed, Key Frames, GOP Structure
- **Audio Format**
  - Codec, Bitrate, Stream, Channels, Sample Rate, Bits/Sample

Basic PC Video Formats

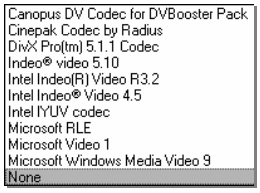
- **Consumer Electronics Digital Video**
  - "Full-quality" video for display on consumer televisions
  - DV, DVD-Video / MPEG-2
  - 720 x 480 video, 30 fps, Stereo / surround audio
- **Desktop Video**
  - Presentation video for PC playback or CD-ROM productions
  - Microsoft AVI, Apple QuickTime, MPEG-1, MPEG-2
  - Typically 640 x 480 -> 320 x 240, 30 / 24 / 15 fps
- **Streaming Video**
  - Bandwidth reduces resolution, frame rate, quality
  - Dial-up to Broadband; Handheld to High Definition
  - QuickTime, Win Media, RealNetworks, MPEG-4, Kinoma
  - Typically 320 x 240 -> 160 x 120, 15 / 10 / 5 fps

Video File Formats

- **File Formats**
  - Container: Identifies video & audio formats, compression
  - Players attempt to load required codecs
- **AVI – Audio Video Interleave – Windows**
  - Container for wide range of formats, Old to DV
- **WMV - Windows Media Video – Microsoft**
  - Next generation, desktop, streaming, digital cinema
- **MOV – QuickTime Movie – Apple**
  - Multiplatform, multimedia container
- **RM, RAM – RealMedia – Real Networks**
  - Web streaming
- **MPG – MPEG (-1 or -2), Program stream (w/ audio)**
  - M2V – MPEG-2 Elementary stream (video only)

Video Compression Formats

- **Historic – AVI / QT**
  - Raw / Uncompressed – Huge
  - Cinepak – Old
  - Indeo (Intel)
  - Sorenson Video (QuickTime)
  - Motion JPEG – Capture format for editing



- **Streaming / Portable Devices / Desktop**
  - Microsoft Windows Media
  - RealVideo
  - Macromedia Flash (SWF)
  - MPEG …

Video Compression Formats

- **Standards**
  - H.261, H.262 – Video conferencing
  - DV – Embedded in AVI, QuickTime
  - MPEG-1 – Moving Picture Experts Group, 1991
    - For CD-ROM, VHS quality, e.g., 352x240 NTSC, 1.5 Mbps
  - MPEG-2 – 1994
    - TV-quality, full-screen, full-rate, e.g., 720x480 NTSC, 4-9 Mbps
    - Profiles and levels, IPB and interlacing
    - Used for DVD, digital broadcasting, satellite, cable
  - MPEG-4 – late 1990s
    - Container: Video, audio, interactive multimedia
    - Supports networks, wireless, streaming
  - MPEG-4 part 10 H.264 / AVC - 2003
  - DixX – MPEG-4 in AVI wrapper

Video Resolution

- **Resolution**
  - Pixels – width x height
  - Video – dots x lines
  - PC – Display Properties
- **Perceived Resolution**
  - Display size
  - Pixel size/structure
  - Viewing distance

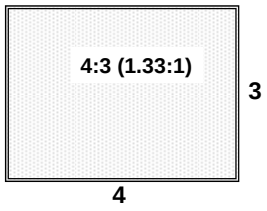
Handheld / phone		160 320
Video phone / Interchange Formats	QSIF QCIF SIF CIF	160 x 120 (NTSC) 176 x 144 352 x 240 (NTSC) 352 x 288 x 29.97
TV / DVD	NTSC PAL	720 x 480 720 x 576
High Def	720p 1080i	1280 x 720 1440 x 1080
PC Display	VGA SVGA XGA - SXGA WXGA - UXGA	640 x 480 800 x 600 1024 x 768 / 800 1280 x 800 1280 x 1024 1366 x 768 1400 x 1050 1600 x 1200

Aspect Ratio

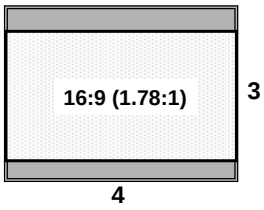
- **Aspect Ratio**
  - Standard (television) – 4:3 (1.33:1)
  - Widescreen (film) – 16:9 (1.78:1) …
- **Conversions**
  - Letterbox – Widescreen on standard display (Black strips)
  - Anamorphic – Widescreen stored in standard frame
    - Edit widescreen, squeeze to store, stretch to display (DVD, Film)
  - Pan and scan – Crop to standard aspect, Pan in full frame
- **Workflow Issues**
  - Shoot – Store – Process – Display
  - Computer vs. Screen displays – Square & Rectangular pixels
  - Associate attributes with frame data

Aspect Ratio Viewing

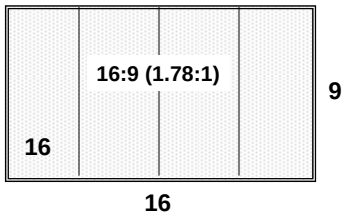
Standard Aspect Ratio



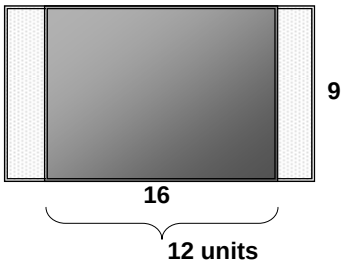
Letterboxed display



Widescreen Aspect Ratio

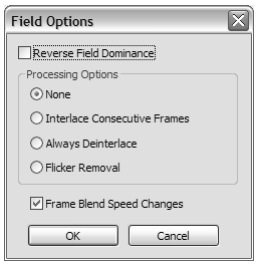


Pan and scan display



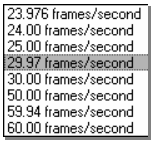
Frame Rate: Television Formats

- **Frames per second**
  - Smooth motion ~ 10 fps
  - Film – 24 fps (double-shuttered)
- **Interlaced vs. Progressive**
  - Two alternating fields (odd/even) per frame
  - Separate in time – Motion artifacts in still
- **Issues**
  - TV Overscan – Safe Area; NTSC safe colors
  - Film – 2-3 / 3-2 pulldown / Inverse telecine
    - Convert between film and interlaced NTSC rates
    - 24 to 30 fps, duplicating fields



Broadcast Standards

- **NTSC – National Television Standards Committee**
  - 525 lines at ~ 60 fields/sec, 30 frames/sec
  - Actually ~ 29.97 – (30,000 / 1001)
  - U.S., Canada, Japan, Korea, Mexico



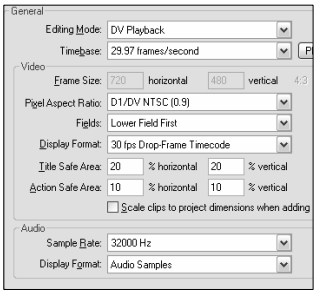
- **PAL – Phase Alternation Line**
  - 625 lines at 50 fields/sec, 25 frames/sec (exact)
  - South America, most of Europe, Australia, China
- **SECAM – Sequential Color with Memory**
  - 625 lines at 50 fields/sec, 25 frames/sec (exact)
  - France, Middle East, much of Africa

Analog Video Formats

- **RF – Radio Frequency**
  - Composite signal, modulated with audio (F connector, ch 3,4)
- **Composite / Baseband**
  - Single signal, luma and chroma
  - Not modulated (RCA / phono connector)
- **S-Video / Y/C**
  - Single cable, separate luma and chroma
- **Component video**
  - Three separate signals (RGB; Y + color)

DV Tape Formats

- **Consumer Standard**
  - Compression for tape - single fixed data rate, symmetric
  - High Quality: 500 lines (S-Video & Hi-8 425, VHS & 8mm 300)
  - 25 Mbps video rate (DV-25) – 4.5 min. = 1 GB disk space
- **DV (Mini-DV)**
  - 1 hour, 1/4" tape
  - Half the size (and thinner) than 8mm
- **Sony Digital 8**
  - Compatible with 8mm, 2X speed
- **HDV**
  - 720p (1280 h), ~ 19 Mbps at 60,30,50,25p
  - 1080i (1440 h), ~ 25 Mbps at 60i, 50i
- **Professional**
  - Sony DVCAM, Panasonic DVCPRO (DV-50)

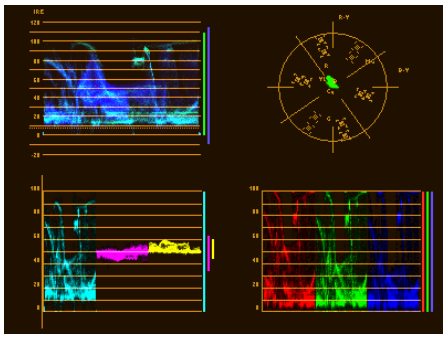


Professional Video Formats

- **Analog**
  - VHS – JVC 1976 – 1/2 in.
  - U-Matic – JVC / Sony … 1970 – 3/4 in.
- **Digital Professional**
  - D1 – Sony – 3/4 in.
  - D5 - Matsushita/ Panasonic – 1/2 in. – Uncompressed
  - Digital Betacam – Sony – 1/2 in. – D1 quality
  - D-VHS – JVC – 1/2 in. - 7, 14, 28 Mbps, 1394
- **Digital 1/4 in.**
  - DV – 25 Mbps
  - DV-50 – 50 Mbps
  - DVCAM – Sony
  - DVCPRO (D-7) – Panasonic
  - DVCPRO-50 – Panasonic – 50 Mbps, 4:2:2 color
  - DVCPRO HD – Panasonic

Color Models

- **Display – Phosphors – Red, Green, Blue**
- **Transmit / Process – Intensity + Color**
  - Luminance – Y – Intensity / brightness
  - Chrominance – Color, two color difference signals
    - YUV / YCbCr
      Y Pr Pb / Y, Y-R, Y-B
- **Color calibration**
  - Scanner / Camera
  - Monitor – Printer



Color Depth

- **Color channels**
  - Pixels packed or planar (separate)
  - Color can be subsampled at lower resolution
- **Bits per color**
  - Grayscale – 8 bits – 256 levels
  - Indexed color – 8-bit, 256 colors - Animations
  - 8-bit – Typical, 24-bit pixel (32-bit with alpha)
  - 10-bit – Higher-quality, HD (not visible banding)
  - 16-bit – Very high quality

Bits	Format	Total Colors
8	Indexed	256
16	4-bit ea.	64 K / Thousands
24	8-bit ea.	16 M / Millions
32	10-bit ea.	4 B / Billions

Color Subsampling

- **Subsampled Color**
  - Eye less sensitive to color detail
  - Used in broadcast, professional, HD
  - Reduce horizontal and/or vertical color resolution
  - Issue after multiple conversions

Name	Bits Per Pixel	Color Horiz	Color Vert	Color Block	Used For	Ratio	Reduce
4:2:2 1/2 H	16-bit	1/2	x	2:1 (2x1)	D1, D5, BetaSX, DigiBeta, Digital-S, DVCPRO-50, M-JPEG	1.5:1	66%
4:1:1 1/4 H	12-bit	1/4	x	4:1 (4x1)	DV-NTSC, DVCAM, DVCPRO	2:1	50%
4:2:0 1/2 HV	YUV-12	1/2	1/2	4:1 (2x2)	DV-PAL, MPEG, HDV, YUV12	2:1	50%
n/a	YUV-9	1/4	1/4	16:1 (4x4)	Indeo YUV9	2.6:1	37%

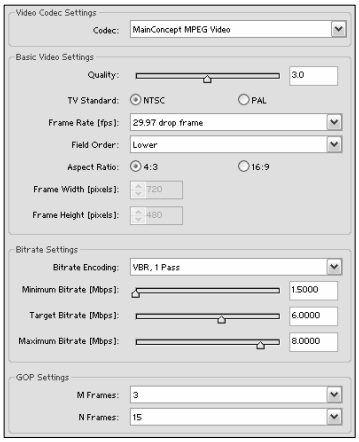
Video Compression

- **Compression Properties**
  - Perceptual: Intensity, color, motion
  - Reduce size – Resolution, Frame rate, Color res/depth
  - Real-time vs. Non-real-time – Asymmetric
    - Real-time play and capture - 30 fps
  - Lossless vs. Lossy
  - Intra-frame (spatial) vs. Inter-frame (temporal)
  - Bit rate: Video + audio
    - CBR / VBR – Constant Bit Rate / Variable Bit Rate
    - Target rate, Min / Max
- **Compression Issues**
  - Transcode – Convert formats
  - Native editing – Edit compressed frames

Compression Technology

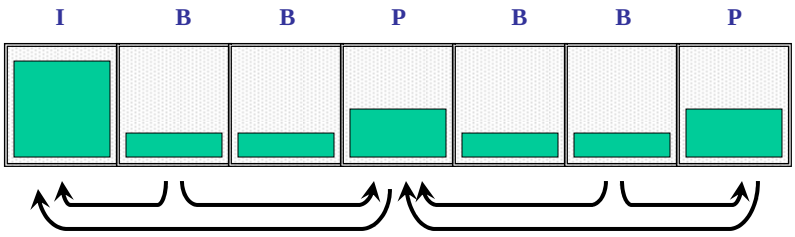
- **Intra-Frame – Spatial Compression - Transform Coding**
  - Discrete cosine transform (DCT), 8 x 8 blocks
  - Quantization, frequency coefficients, quantization matrix
  - Run-length encoding, of zeros

- **Inter-Frame – Temporal Compression**
  - Predictive coding – Temporal redundancy
  - MPEG – Group of Pictures
    - Pattern of I,P,B frames
    - I-frame only ~ Motion JPEG
    - Need index, Random access to I frames Decode GOP
  - Motion compensation
    - Motion estimation
    - Motion vectors for macroblocks
    - Fix up differences (errors)



MPEG – Group of Pictures (GOP)

- References within same GOP – Open / Closed (DVD)
  - i.e., 15 frames, IPPP … / IBPBPBP … / IBBPBBP …
- I Frames – Intra Pictures
  - Intra-frame - Transform coding, typically 2 bits per pixel
- P Frames – Predicted Pictures
  - Forwarded prediction to nearest previous I- or P-picture.
- B Frames – Bidirectional Pictures
  - Predicted from both past and future I or P frames



MPEG Standards

- **Moving Picture Experts Group**
  - Profiles (tools) @ Levels (complexity)
- **MPEG-1 - 1991 - CD**
  - Designed for CD-ROM rates, quarter-screen TV
  - 352 x 240 (SIF), 30 frames/sec (NTSC), 1.5 Mbps

- **MPEG-2 - 1994 - Broadcast / DVD -> HD**
  - Designed for digital TV broadcasting, scalability, 4 - 9 Mbps
  - NTSC to 15 Mbps / HDTV to 80 Mbps

- **MPEG-4 - 1999 - Interactive Media**
  - Designed for interactive multimedia across networks
  - Video, plus audio, interactivity, objects, error resilience
  - Clear improvement for medium rates (384 to 768 Kbps)
- **MPEG-4 H.264 / AVC - 2003**
  - Joint Video Team (JVT)
  - ITU H.264 / MPEG-4 part 10 - Advanced Video Coding (AVC)
  - Substantially higher video quality – 20% improvement
- **MPEG-7 - Metadata**
- **MPEG-21 – Digital rights management**

MPEG-1 and MPEG-2

- **MPEG-1 - 1991**
  - Designed for CD-ROM rates, quarter-screen TV
  - 352 x 240 (SIF), 30 frames/sec (NTSC)
  - Bit rate optimized around 1.5 Mbps

- **MPEG-2 - 1994**
  - Designed for digital TV broadcasting, scalability
  - Target bit-rate between 4 and 9 Mbps
  - Main Profile, Main Level (MP@ML) 720 x 480 at bit rates up to 15 Mbps for NTSC video
  - HDTV resolution of 1920 x 1080 pixels at 30 frame/sec at bit rates of up to 80 Mbps

Video Data Rates

- **Full Rate Video is Too Much**
  - 720 x 480 x 3 — 240 Mbps — (2 GB/min, 100+ GB/hour)
- **Need Video Compression**
  - DV — 25 Mbps — (10x: 187 MB/min, 11 GB/hour)
  - MPEG — ~ 4 - 6 Mbps — (+3x: 45 MB/min, 2.6 GB/hour)
- **PC Interfaces Can Handle**
  - USB 1 / 2 — 12 / 480 Mbps — Keyboard / Disks, Video capture
  - FireWire / 899 — 400 / 800 Mbps — Camcorders, disk drives
- **Video over Networks**
  - Modem — 28 - 56 Kbps — -> Half-screen
  - DSL / Cable — 200 - 650 Kbps — -> Near-VHS,-DVD
  - T1 / Broadband — 1 - 2 Mbps — -> SD DVD
  - Ethernet 10/100 — 10 / 100 Mbps — -> HD at 5 Mbps

Video Resolutions

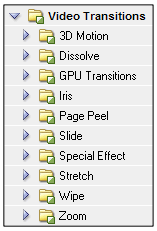
- **Computer**
  - VGA — 640 x 480, SVGA 800 x 600
  - XGA — 1024 x 768 / 1152 x 864 / 1280 x 800
  - SXGA — 1280 x 1024
  - WXGA — 1366 x 768 / 1400 x 1050; UXGA 1600 x 1200
- **Standard Definition (SD)**
  - DV, MPEG-2 (DVD)
  - 720 x 480 (interlaced) …
- **High Definition (HD)**
  - Cameras, Files, Displays
  - 720p – 1280 x 720 – Progressive (p60) – 720 lines in 1/60 sec.
  - 1080p – 1920 x 1080 – Interlaced (i30) – 540 lines in 1/60 sec.
  - 1080p ~ 1440 x 1080 (reduced data rate)

Video Formats and Rates

Video Format	Horiz	Vert	Mbps	MB/sec	MB/Min	GB/Hr
HD - 1080 4:2:2 Raw	1920	1080	712	89	5339	320
HD - 720 4:2:2 Raw	1280	720	316	40	2373	142
HD-SDI 4:2:2 10b Raw	1920	1080	1500	30	1780	107
HD-D5 1080p/24	1920	1080	270	30	1780	107
SD - NTSC - Raw	720	480	237	30	1780	107
SD - NTSC - 4:2:2	720	480	158	20	1187	71
SD - NTSC - 4:2:0	720	480	119	15	890	53
DVCPRO HD (DV-HD)	1280	720	100	13	750	45
DV-50 4:2:2	720	480	50	6	375	23
DV-25 4:1:1 (HDV 1080)	720	480	25	3	188	11
HDV - 720 - 4:2:0	1280	720	19	2	143	9
MPEG - High	720	480	8	1	60	4
MPEG - Med - 4:2:0	720	480	6	0.8	45	3
MPEG - Low	720	480	4	0.5	30	2

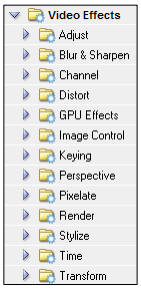
Video Processing

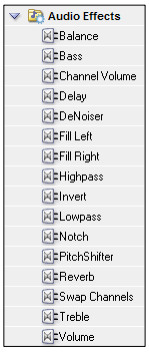
- **Capture**
  - Analog and digital, DV / FireWire
  - Transcode: Edit format (DV, raw, light compression)
    - Quality vs. Storage and Performance
- **Process – Editing**
  - Assemble – Timeline – Tracks – Clips
  - Transitions, Effects, Titles
  - Compositing – Motion / Overlays, Keying
  - Audio – Mixing, Effects
  - Native (compressed) or raw (uncompressed) frames
- **Deliver – Export**
  - Filtering
  - PC files, Web streaming
  - Tape: Analog, DV
  - Handheld / PDA, DVD



Video Filtering

- **Filtering for Compression**
  - Pre, Within Compression; Decompression fix-up
- **Video Reformat**
  - NTSC / PAL conversion
  - Adaptive De-Interlace; Aspect ratio conversion
  - Frame rate interpolation; 3:2 Pulldown
- **Video Enhancement**
  - Black/White, Color Correction, Color Safe
  - Gamma Correction; Blur, Sharpen, Median
  - Temporal Noise Reduction
  - Fade In/Out; Keyed Overlay / Watermark
- **Audio Filters**
  - Volume, Lowpass, Normalize, Fade In/Out
  - Noise Reduction, Compressor, Parametric EQ





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The Manifest Technology site by Douglas Dixon contains over 150 articles and technical references on multimedia technology, especially digital video editing and DVD authoring.