Zur Organisation

- Zeit: DO 11:05 - 12:35, 13:00-13.45
- Unterlagen (in *Englisch*)
  Kopien der Vorlesungsunterlagen: Anfang November
  Folien: TISS –
- schriftliche Prüfung: 23. 1. 2014

Contents

References

1. *Multimedia Programming. Objects, Environments and Frameworks*, S.Gibbs, D.C. Tsichritzis, Addison-Wesley, ACM Press, 1995.
2. *Multimedia: Computing, Communications and Applications,* R.Steinmetz, K.Nahrstedt, 2nd edition, Prentice Hall, 1999.
3. *Video and Image Processing in Multimedia Systems,* B. Furht, S.W. Smoliar, H. Zhang, Kluwer Academic Publishers, 1995.
4. *Image and Video Compression Standards. Algorithms and Architectures,* V. Bhaskaran, K. Konstantinides, 2nd edition, Kluwer Academic Publishers, 1997.

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5. *Schall&Klang: Wie und was wir hören.* Georg Eska, Basel; Boston; Berlin; Birkhäuserverlag 1997.
6. *Physikalische und psychoakustische Grundlagen der Musik.* Juan G. Roederer, 3. Auflage, Springer 2000
7. *Fundamentals of Multimedia*. Ze-Nian Li and Mark S. Drew, Prentice Hall, 2004.
8. *The Science of Digital Media*. Jennifer Burg, Pearson Education, 2009.

Prologue: Multimedia—Definitions

- Multimedia—General Definition
- Media Classification
- *Multimedia Systems Definition*

Multimedia—General Definition

- *Multi-* [lat.: much] many; much; multiple
- *Medium* [lat.: middle]
  - an intervening substance through which something is transmitted or carried on; a means for distribution and presentation of information; e.g., atmosphere, water, text, ..
  - a means of mass communication; e.g., newspaper, magazine, television, ...

Media Classification

- *Perception media* help humans to perceive their environment. *How do humans perceive information in a computer environment?*
- *Representation media* are characterized by internal computer representations of information. *How is the computer information coded?*
- *Presentation media* refer to the tools and devices for i/o of information. *Through which medium is information delivered by the computer, or introduced into the computer?*

Media Classification

- *Storage media* refer to a data carrier which enables storage of information. *Where will the information be stored?*
- The *transmission medium* characterizes different information carriers, that enable *continuous* data transmission (storage media excluded!). *Over what will the information be transmitted?*
- The *information exchange medium* includes all information carriers for transmission, i.e., all storage and transmission media. *Which information carrier will be used for information exchange between different places?*

Representation—Space and Dimension

- *representation spaces* are part of the presentation media for information output; e.g., movie screen, stereo space
- each representation space consist of one or more *representation dimensions*; e.g. computer screen (2), stereophony (3)
- time may occur inside each representation space as additional dimension; *central* to multimedia systems;
  media are divided into 2 types with respect to time in their information space: *time-independent* and *time-dependent*

Representation

- time-independent (discrete) media—information consists exclusively of a sequence of elements or a continuum without any time reference; e.g., text, graphics, ...
- time-dependent (continuous) media—information consists of timed sequences, i.e., element values plus time of occurrence; e.g., audio, video, sensor signals, ...

  processing of these media is *time-critical*

Properties of a MM System

- not every *combination of media* justifies the term *multimedia*; e.g., a text processing program with incorporated images
- the *level of independence* of different media is important; a computer-controlled VCR vs. a text presentation with synchronized audio
- *computer-supported integration*—Computer controlled-data of independent media can be processed and integrated by a programmer or multimedia author.

Multimedia System—Definition

A multimedia system is characterized by computer-controlled, integrated production, manipulation, presentation, storage and communication of independent information, which is encoded at least through a continuous (time-dependent) and a discrete (time-independent) medium. (Steinmetz/Nahrstedt)

- MM is often used as an attribute of systems, products, etc., without satisfying the characteristics above. Thus, 2 notions of mm can be distinguished:
  - mm, strictly speaking (above)
  - mm, in the general sense
    used to describe the processing of individual images and text, although no continuous medium is present.

Part I Media Types

Representation, formats and operations of media types

- ❑ Text
- ❑ Graphics (Images)
- ❑ Audio
- ❑ Video

I.1. Media Type Text

Text Representations

- ❑ ASCII / ISO character sets
- ❑ marked-up text — e.g. SGML, HTML, XML, etc.
- ❑ hypertext — e.g. HyperCard, World Wide Web

Text Operations

- ❑ character and string operations
- ❑ editing
- ❑ formatting — interactive, non-interactive, page description languages
- ❑ pattern matching and searching — indexes, signatures
- ❑ sorting
- ❑ compression — Huffman, Lempel-Ziv
- ❑ encryption
- ❑ language specific operations — spelling checking, parsing, statistical analysis of writing style

I.2. Media Type Graphics (Images)

- ❑ Achromatic and Colored Light
- ❑ Intensities
- ❑ Color Models
- ❑ Image Representations
- ❑ Image Formats
- ❑ Image Operations

Light

- chromatic: of color
- achromatic: without color (i.e. B&W)
- color of an object depends upon:
  - object surface: reflectivity, physical properties, composition
  - light source(s) illuminating it
  - color of surrounding environment
  - visual system (eyes, brain, photoelectric cell, ...) of perceiving entity

Achromatic Light

- black, white, usually greys (rare to see pure black or pure white)
- quantity or energy of light is only measurement used for achromatic light
  - intensity, luminance, brightness
  - scale: 0 = black, 1 = white, greys in between
- eye is sensitive to ratios of intensity changes, not the changes in intensity values themselves
- small changes of low intensity seem to have the same effect as larger changes of high intensity
- dynamic range: ratio between min. and max. intensities

Selecting Intensities

- to find 256 intensities starting with the lowest attainable intensity I_0 and going to a maximum intensity 1.0, with each intensity r-times higher, we use:

  $I_1 = rI_0$, $I_2 = rI_1 = r^2 I_0$, $I_{255} = rI_{254} = r^{255} I_0 = 1$ therefore,

  $r = (1/I_0)^{1/255}$, $I_j = r^j I_0 = r(1/I_0)^{j/255} I_0$
- example: n=3, I_0= 1/8 gives r=2 and intensity values of 1/8, 1/4, 1/2 and 1
- minimum attainable intensity I_0 for a CRT is between 1/200 and 1/40

Selecting Intensities

- how many intensities are enough?
- answer: r is 1.01 or less, therefore

  $n = \log_{1.01}(1/I_0)$
- table on next page shows theoretical values

Dynamic Range

display media	typical dynamic range	number of intensities
CRT	50 - 200	400 - 530
photographic prints	100	465
photographic slides	1000	700
coated paper printed in b/w	100	465
coated paper printed in color	50	400
newsprint printed in b/w	10	234

Different Intensity Levels

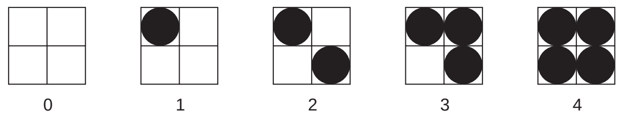
intensity levels

2 4 16

Halftone Approximation

- ❑ dithering (or half-toning): approximating intensities using dot patterns
  - ❑ human eye generalizes patterns into shades
  - ❑ similar effect with colour: approximate colours using multi-coloured pixel patterns: 8-bit colour graphics does this to "simulate" 24-bit colours (with varying success)
- ❑ simple approach: N device pixels per image point/pixel
  - ❑ create an N by N dither matrix: defines N*N + 1 intensities
  - ❑ to display intensity K, turn on pixels having values < K

Halftone Approximation



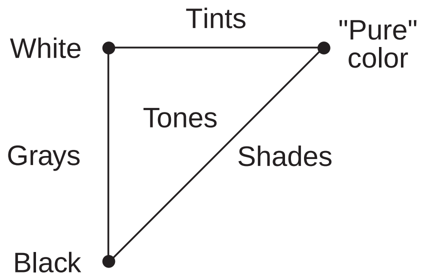
- ❑ cluster dithering: dither intensity centered on middle of matrix
  - ❑ avoid line patterns or other artifacts
  - ❑ patterns should grow - minimizes "contouring" effects
  - ❑ patterns should emanate from centre: effect of increasing dot sizes
- ❑ cluster dithering with diagonal periodicity

Color

- various models of colour used:
  - printing & graphics industry: colour sample books and codes
  - artists: tint (adding white to pure pigment), shade (adding black), tone (adding both)
  - CRT's: use hardware models, eg. RGB
  - physicists: use optical models (wavelengths, energy measures)
- human perception of colour depends on how brain reacts to whole visual environment, as well as brain & eyebiological factors

Color

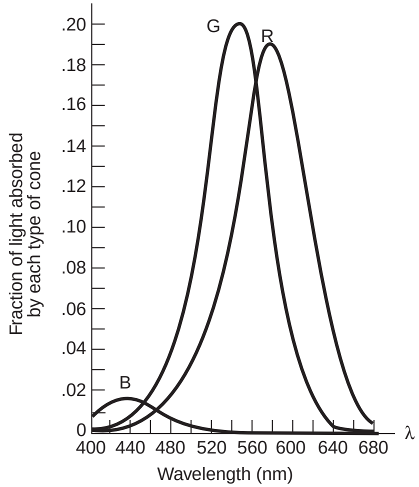
- colour is how we perceive beams of electromagnetic energy that fall on our retina
- we see light between 400 and 700 nanometers in wavelength (10^{-9} meters)

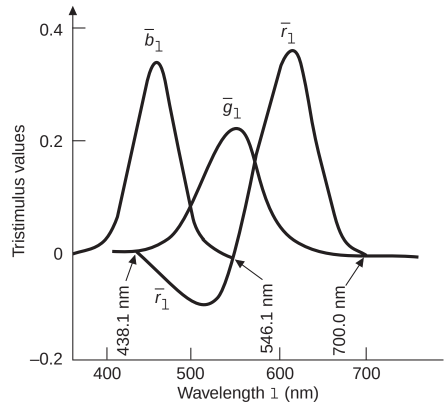


Tristimulus Theory

- the retina contains cones that sense either red, green, or blue light
- 6-7 million cones per eye, concentrated in central area called "fovea"
- rods: sensors that surround fovea, and perceive weak "night" images
- hence, use indirect vision at night to see low-light images
- tristimulus theory isn't totally accurate, because many colors we see are not exact combinations of red, green, blue wavelengths

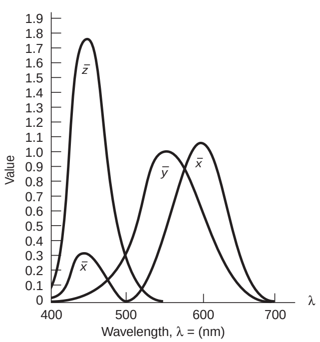
Tristimulus Theory

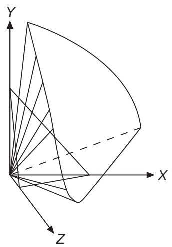


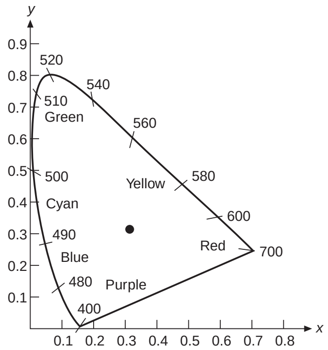


CIE Color Space

- ❑ many combinations of dominant wavelength, luminance, saturation appear the same to us
- ❑ CIE color space (Commission Internationale de l'Eclairage) used to calibrate other color models; 1931 CIE XYZ



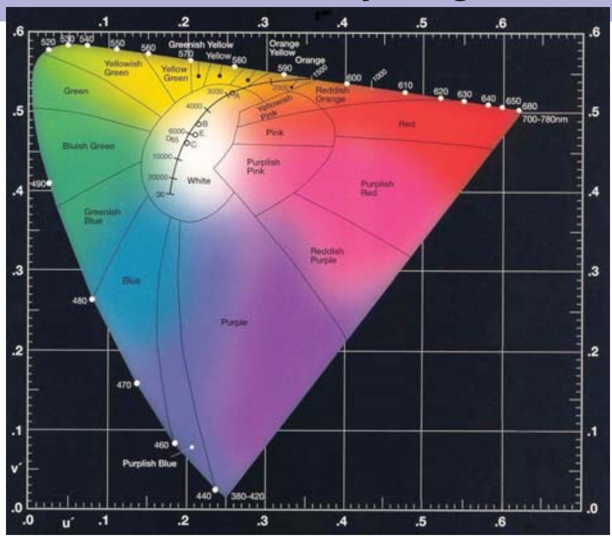




CIE Color Space

- ❑ 100% spectrally pure colors on outer curve edge; pure white near centre (at C)
- ❑ if color at A, then B is dominant wavelength: you mix B with C to get A
- ❑ F's dominant wavelength defined as the complement of A's ones
- ❑ complementary colors: mix together to get white (e.g.. E and D, or F and A)
- ❑ can therefore use CIE to:
  - ❑ identify and analyze colors
  - ❑ measure CRT performance: how much of CIE color space does a particular CRT cover?

CIE Chromaticity Diagram

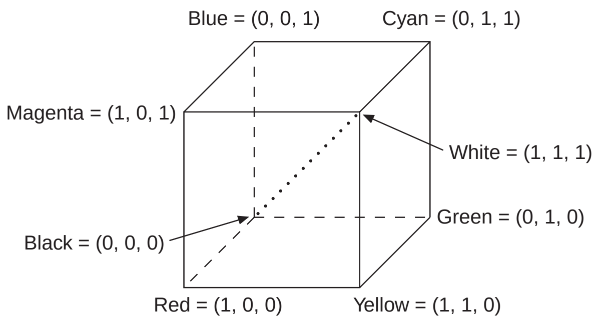


Color Models for Raster Graphics

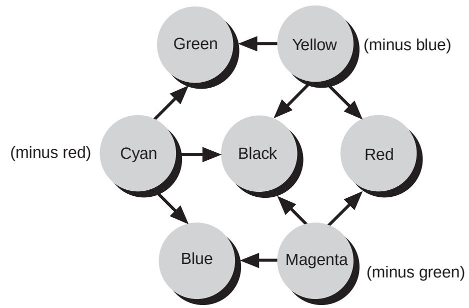
1. The RGB color model

- ❑ hardware-oriented model that turns on red, green, and blue pixels at varying intensities
- ❑ additive: add red, green, blue together to get overall color
- ❑ not all colors are exactly duplicable, and gamut (color range) covered by a CRT depends on performance of its phosphor technology

The RGB Color Model



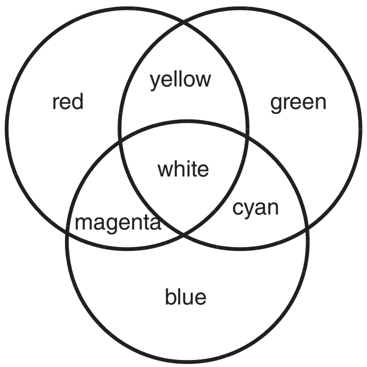
2. The CMY Color Model



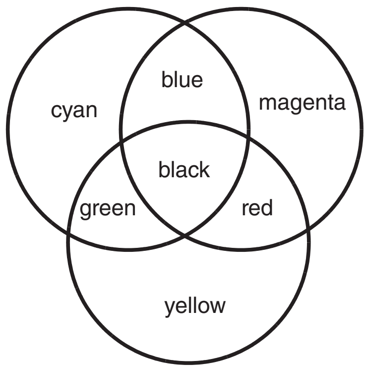
$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} C \\ M \\ Y \end{bmatrix}$$

- another related model, CMYK, uses black as 4th color:
  K = min (C,M,Y), C = C - K, M = M - K, Y = Y - K

Direct and Reflected Light



direct light

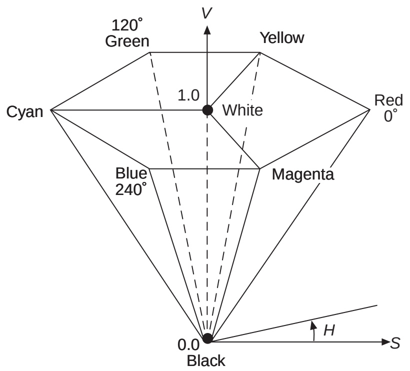


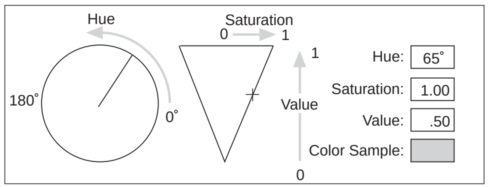
reflected light

The HSV Color Model

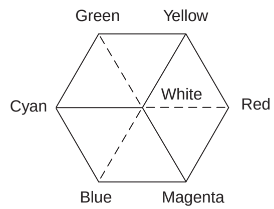
- HSV: “hue saturation value”; based on tint, shade, tone model; defines a hexcone geometry
- V=1: top of cone, bright pure color; V=0: bottom of cone, Black
- H: angle around vertical axis; red = 0 deg, green = 120 deg, ...; complementary colors are 180 degrees from one another
- S = 0: centre line (V axis), S =1 side of cone
- can convert between RGB and HSV using formulae
  - subcubes of RGB fit down the cone
  - tools (xv, Photoshop, Fractal Painter) give both sets of controls to define color

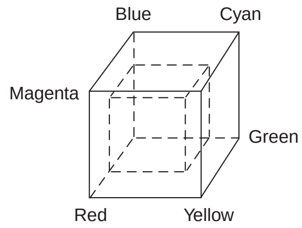
The HSV Color Model





The HSV Color Model





Color Models (Spaces) Overview

- CIE color space (Commission Internationale de l'Eclairage) used to calibrate other color models
  1931 CIE XYZ, *tristimulus* theory
- RGB — for video display drivers
- HSB — hue (dominant color), saturation (amount of gray), brightness (intensity)
- CMYK — cyan, magenta, yellow, black, *(subtractive primaries*)
- YUV — used in television industry, Y (luminance), UV (color difference signals)

Media Type Image—Example

image descriptor = {

image width = 640
image height = 480
image depth = 24
color model = RGB
encoding = YUV 8:2:2, JPEG}

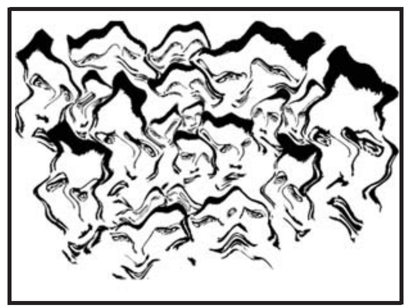
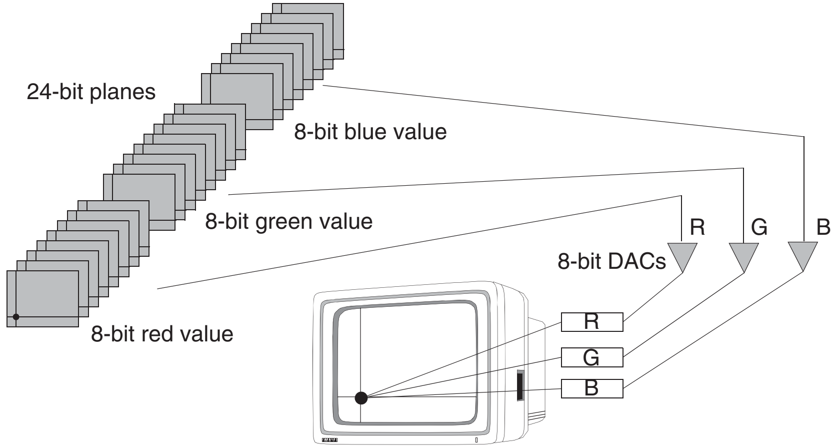


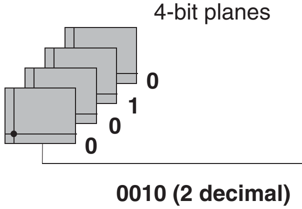
Image Representations

- ❑ number of channels — dim. of color model plus alpha channels
- ❑ channel depth — number of bits-per-pixel
- ❑ alpha — controls transparency; masks and blends
- ❑ pixel aspect ratio
- ❑ interlacing
- ❑ compression — lossless vs. lossy
- ❑ indexing — colors are represented by index in *color maps* or *color lookup tables* [CLUT]; map predefined or part of image

Color Display

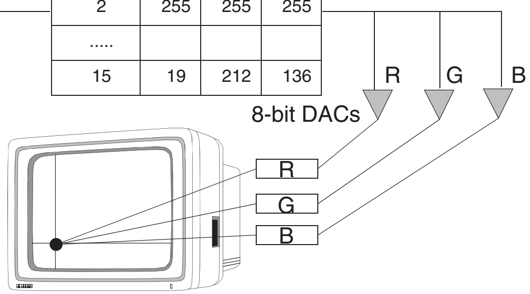


Color Mapping



Color Look-up Table

register	R	G	B
0	0	0	0
1	127	123	72
2	255	255	255
.....			
15	19	212	136



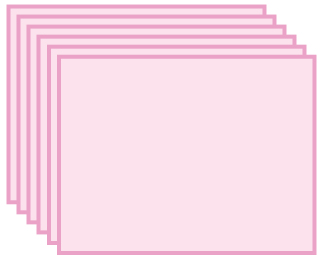
Some Image Formats

- ❑ EPS — Encapsulated PostScript
- ❑ GIF — Graphics Interchange Format
  CompuServe Information Service, originally for dialup lines
- ❑ Group 3 and Group 4 Facsimile
- ❑ PICT — may contain geometric data (lines, polygons, etc.)
- ❑ JPEG — Joint Photographic Experts Group, lossy

Image Operations

- editing — “paintbrush operations”, selection
- point operations — e.g. thresholding, color correction
- filtering — also values of neighboring pixels used
- compositing — alpha channels frequently used
- geometric transformations — e.g. scaling, warping
- conversions — e.g. format conversion, color separation

I.2 Media Type Video



Video is a

sequence of

FRAMES

Broadcasting History

1893 Telephone Audio Broadcasting (Puskas)

1895 Wireless Communication (Marconi, Popov)

1819 Radio Broadcasting (The Netherlands, Canada)

1935 TV Broadcasting (Germany, Britain)

1941 US b&w TV

1953 US color TV (NTSC)

1963 geostationary satellites

mid ’70s fiber optic transmission

1989 HDTV broadcasting (Japan)

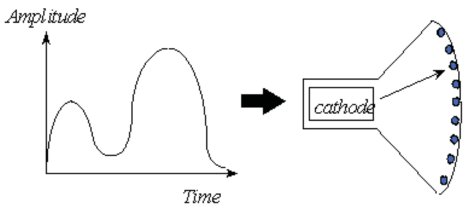
1996 ATSC - digital TV standard

Standards Groups

- ITU - International Telecommunication Union (formerly CCITT)
- SMPTE - Society of Motion Picture and Television Engineers
- MPEG - Motion Picture Experts Group
- ATSC - Advanced Television Systems Committee
- CCIR - Consultative Committee for International Radio
- ......

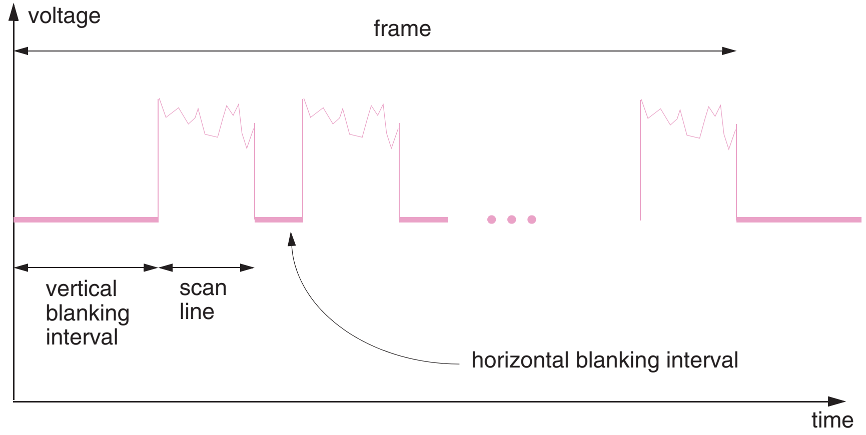
Video Display Scanning

- analog video is a continuous signal that drives a CRT

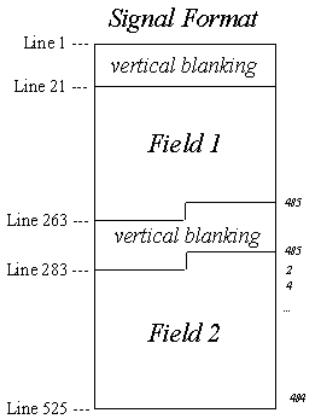


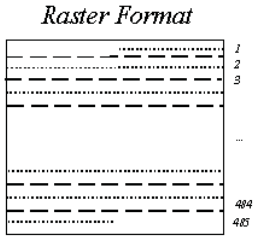
- video composed of luminance and chroma signals

Analog Video Signals



Interlaced Fields





Characteristics of Analog Video

- frame rate (25, ~30)
- scan lines (525, 625, >1000)
- aspect ratio (4:3, 16:9)
- interlacing (2:1, non-interlaced = progressive)
- signal quality (consumer, professional, broadcast)

Characteristics of Analog Video

- composite versus component
- stability (editing degradation)
- audio tracks
- tape size

Video Representations

- component video
  each primary is sent as a separate signal - RGB or a luma/chroma transformation (YUV, YIQ, YC_RC_B, ...)
  requires more bandwidth and good synchronization
- composite video
  signals are mixed into a single carrier wave; interference
- S-video (separated video)
  a compromise between component and composite analog video, 2 lines, one for chroma and one for luma

Analog Video Signal Formats

- NTSC (National Television Systems Committee): North America, Central America and Japan, and some parts of the South Pacific and South Africa.
- PAL (Phase Alternation Line): western Europe , India, China, Australia, and parts of Asia and South America.
- SECAM (Séquentiel Couleur avec Mémoire): France, Eastern Europe, Russia, and parts of Africa and the Middle East.
- RGB: A component video signal format, used for computer displays. No single RGB standard.
- HDTV (High Definition Television): The earliest HDTV system, Japan´s Hi-Vision, is used for daily broadcasts in Japan (also known as MUSE)

Analog Video Signal Format Comparison

Signal format	Comp.	Frame rate (Hz)	Scan lines	Aspect ratio	Interlacing
NTSC	1	29.97	525	4:3	2:1
YUV 525/60	3	29.97	525	4:3	2:1
PAL	1	25	625	4:3	2:1
SECAM	1	25	625	4:3	2:1
YUV 625/50	3	25	625	4:3	2:1
RGB	3	ca. 25-75	ca. 200-1000	Varies	Usually 2:1
1125/60 (Hi-Vision, MUSE)	3	30	1125	16:9	2:1
1250/50 (HD-MAC)	3	25	1250	16:9	2:1

PAL

Phase Alternating Line

- 625 scan lines repeated 25 times per second (40msec / frame)
- interlaced scan lines divide frame into 2 fields each 312.5 lines
- aproximately 20% more lines than NTSC
- YUV color model
- lines reserved for control information at the beginning of each field, only 575 lines of visible data
- each line lasts 64 *u*sec (12 *u*sec blanked)

NTSC

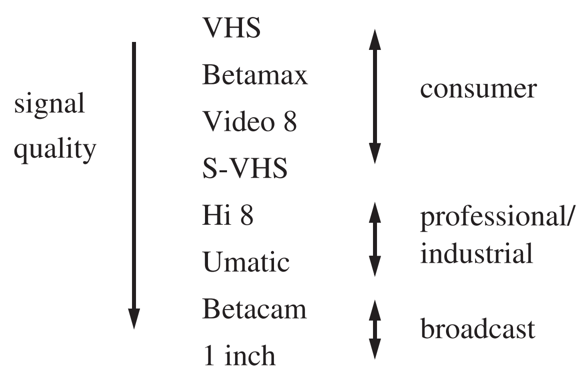
National Television Systems Committee

- 525 scan lines per frame, 30 frames per second (actually 29.97)
- interlaced scan lines divide frame into 2 fields each 262.5 lines
- YIQ color model
- lines reserved for control information at the beginning of each field, only 485 lines of visible data
- each line lasts 63.5 *u*sec (10.5 *u*sec blanked)

Video Representations

- PAL (Phase Alternation Line)
  Y = 0.299R + 0.587G + 0.114B
  U = 0.492(B-Y)
  V = 0.877(R-Y)
- NTSC (National Television Systems Committee)
  Y = 0.299R + 0.587G + 0.114B
  I = 0.596R - 0.275G - 0.321B
  Q = 0.212R - 0.523G + 0.311B
- new ATSC (Advanced Television Systems Committee)
  1920x1080 progressive 16:9
  1280x720 progressive 16:9

Analog Video Tape Formats



Composite vs. Component Video

composite video

single electrical signal
+ easy to broadcast
+ simple cabling
- poor quality

component video

multiple electrical signal
- difficult to broadcast
- cabling more difficult
+ good quality

examples:
RGB, YUV, Y/C

Video Equipment

- routing switcher (matrix switch) - nxn cross bar circuit switch; analog or digital; can switch several signals; one input can be routed to multiple outputs
- distribution amplifier - split 1 input signal to 2 or more outputs
- timebase correctors (TBCs) - reconstructs signal to remove timing errors introduced by VTR/VCR
- sync generator - master clock to provide sync pulse for all equipment
- frame (delay) buffer - to synchronize external sources
- video production switcher

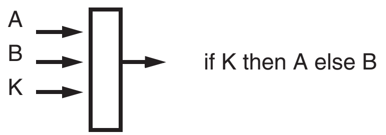
Video Production Switcher

- to produce high quality visual images - n input streams and 1 output stream (live events and post-production)
- special effects - titles, transitions, picture-in-picture, chroma-key, compositing
- implementation
  - conventional solutions use custom-designed hardware
  - modern approaches use more and more software

Video Production Switcher

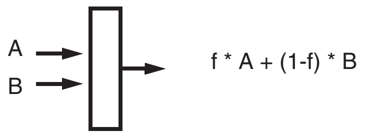
mixing

keying



blending

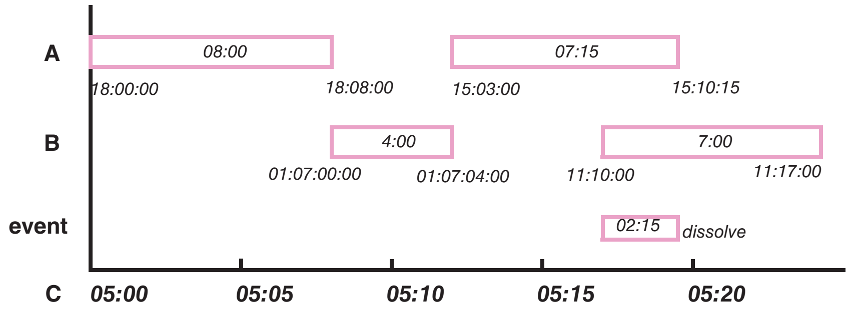
wipes



DVEs

key framing

Video Editing / EDL

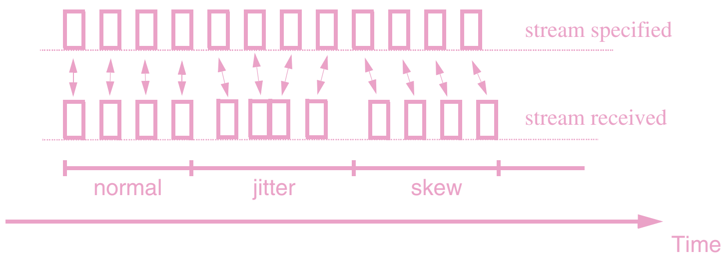


Video Time Codes

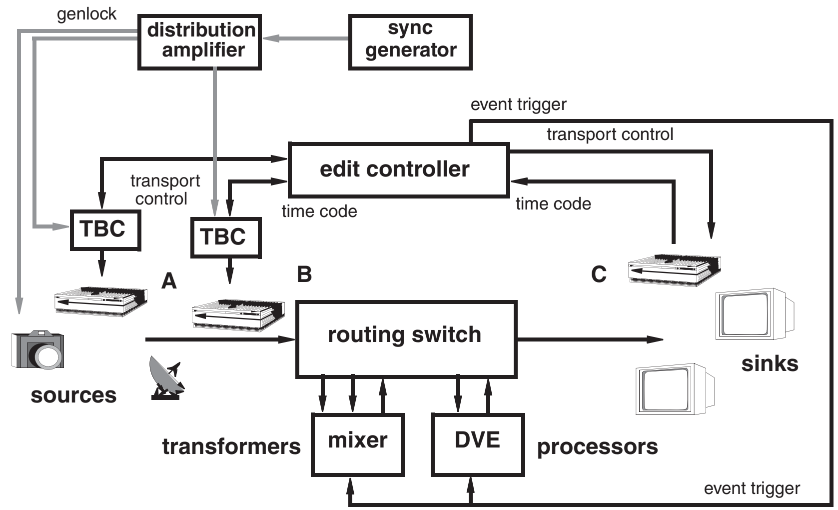
- SMPTE time code (HH:MM:SS:FF)
  - non-drop frame time code - FF in [0, 29]
  - drop frame time code - FF in [2, 29], except every tenth minute [0, 29]
- time code recorded on tape
  - LTC - longitudinal time code, recorded in audio track
  - VITC - vertical interval TC, recorded in vertical blanking
  - RCTC - rewritable consumer time code, Sony Video-8 ad Hi-8

Video Synchronization

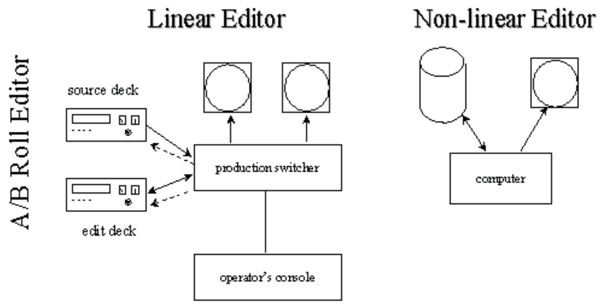
- intra-flow synchronization (skew, jitter)



Video Studio



Video Editing Comparison



Digital Video

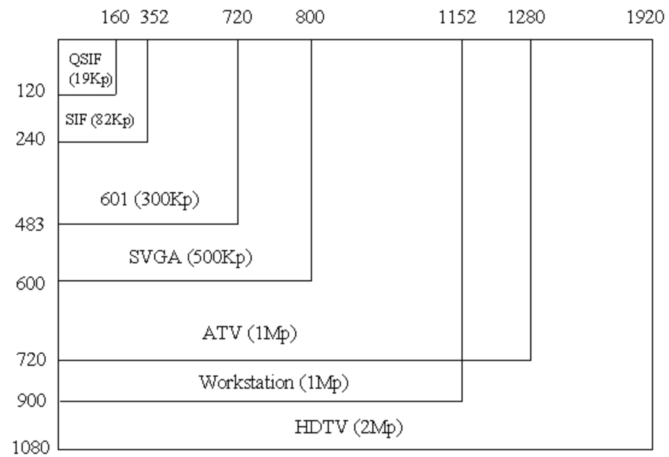
Digital video "sizes":

- "raw" digital video:
  - 20 Mbyte/sec
  - 70 Gbyte/hr
  - 1 Gbyte = 50 seconds
- "low data rate" digital video
  - 200 kbit/sec – 5 Mbit/sec
  - 1 Gbyte = 30 min – 10 hr

Digital Video

- analog video is a continuous signal
- digital video uses discrete numeric values
- signal is sampled
- small, discrete regions are digitized
- frame is represented by pixel array

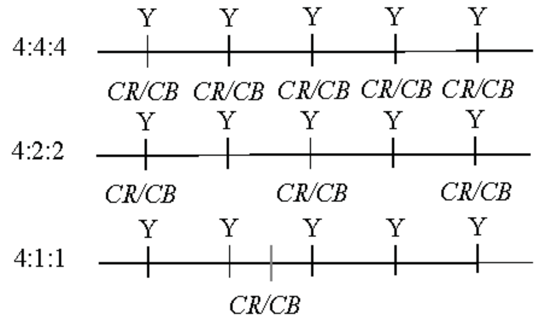
Pixel Arrays



CCIR 601

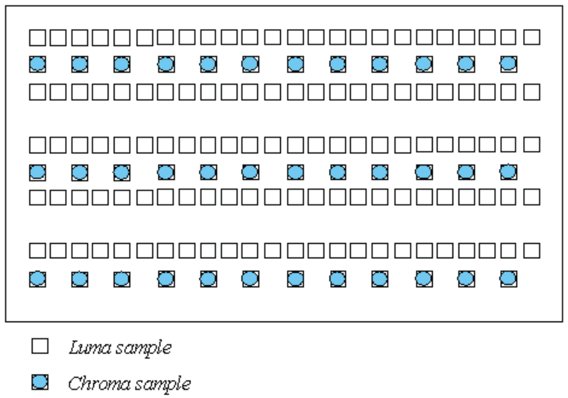
- digital component video - CCIR Recommendation 601
- format is obtained by sampling a component video signal
- base sampling rate 3.375 MHz
- particular member of 601 m:n:l (multipliers of sampling base rate)
- multiplier values: 1, 2, 3 or 4

Line Sampling



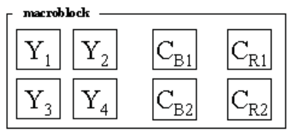
- 4:2:2 - broadcast quality; 4:1:1 - VHS quality
- 4:2:0 - 2:1 subsampling in horizontal and vertical direction
- 4:1:1 and 4:2:2 mostly used in MPEG and JPEG

4:2:0 Sampling

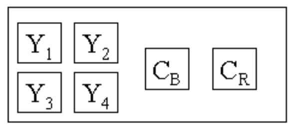


Video Block Structure

- 4:2:2 YC_RC_B
  16x16 macroblock
  8x8 pixel blocks
  8 bits/sample = 16 bits/pixel = 4Kbits/macroblock



- 4:1:1 YC_RC_B
  3Kbits/macroblock
  12 bits/pixel



Digital Video Representations

- Digital Composite Video (D2/D3, SMPTE 244M)
  - 14.3 MB/s data rate
  - subsampled color signals 4:2:2
- Digital Component Video (D1/D5, SMPTE RP125)
  - separate signals for luminance and color
  - 27 MB/s data rate
  - subsampled color signals 4:2:2

Video Data Rate

- D1 Digital
  - 720x483 = 347,760 pixels/frame
  - 4:2:2 sampling gives 695,520 bytes/frame
  - 21 MB/sec (168 Mbs)
- ATV
  - ATV
  - 4:2:0 sampling gives 1,382,400 bytes/frame
  - 41 MB/sec (328 Mbs)

Video Formats

- Digital Betacam - 720x480; 4:2:2; CCIR 601
- Sony DV Format - 500 lines; 4:1:1; DCT-based compression
- Panasonic/JVC DV Format (DVCPro) - similar to Sony DV but 4:2:2
- Sony Betacam SX - MPEG coding (IBBI patterns)

- DVI (Intel) PLV + RTV
- QuickTime (Apple)
- px64 / H.261 (CCITT)

Digital Video Formats

Video Format	Analog formats sampled	Sampling rate (Mhz)	Sample size	Appr. video data rate (Mbyte/sec)	Frame resolution
Digital Component (CCIR 601)	525/60 YUV 625/50 YUV	13.5	8/10	30.9, 20.6, 15.4	720 X 500 720 X 600
Digital composite	Compos. NTSC Compos. PAL	14.3 17.7	8	11.2 13.7	768 X 510 948 X 608
CIF QCIF	Various	Various	8	4.5 1.1	360 X 288 180 X 144
Digital HDTV	NA	NA	NA	ca. 125	ca. 1600 X 900

Compression

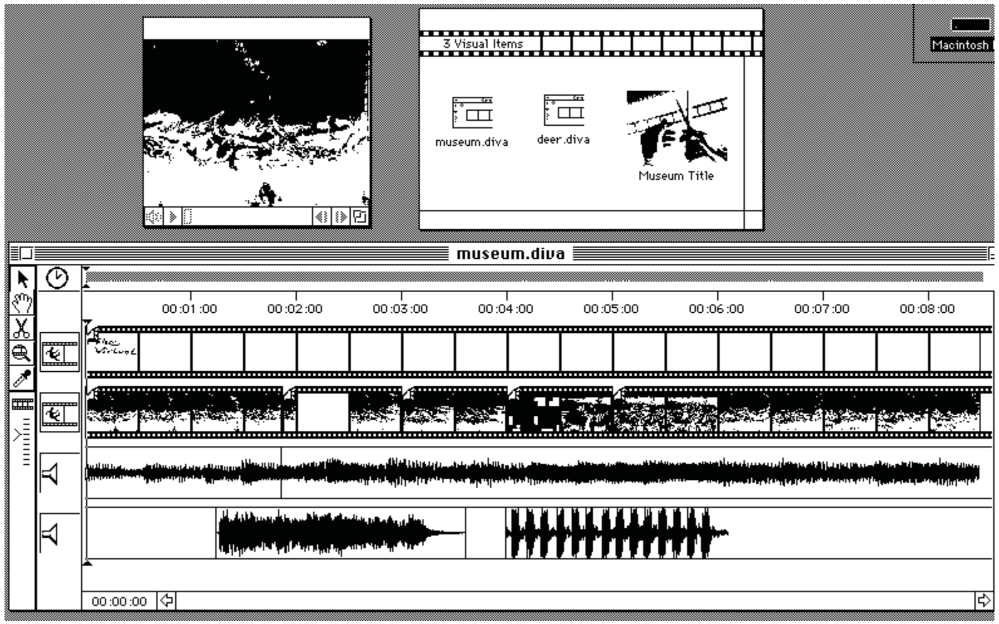
- ❑ lossy versus lossless
- ❑ real-time (symmetric)
- ❑ spatial versus temporal
- ❑ scalable
- ❑ type of source material

Factors Influencing Video Quality

- ❑ frame size and depth
- ❑ frame rate, key frame rate
- ❑ source material ⇒ algorithm
- ❑ algorithm parameters, decode time
- ❑ compressed data rate
- ❑ compressed file size

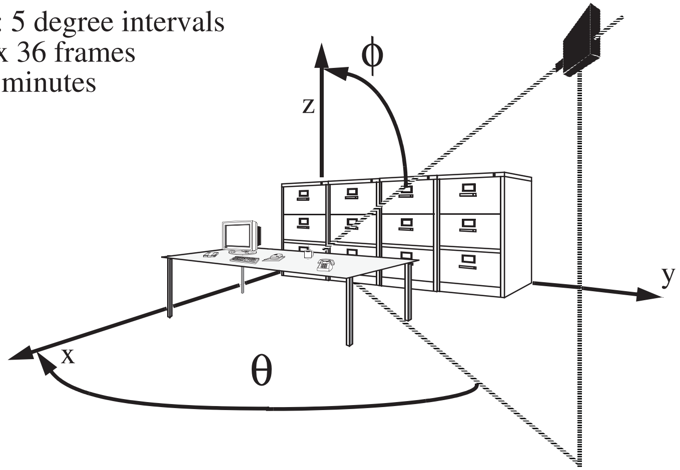
Operations on Digital Video

- ❑ storage and retrieval (HD, CD-ROM, RAID, DVTR)
- ❑ editing (“non-linear”)
- ❑ digital video effects (transitions, keying, compositing*..)
- ❑ conversion (e.g. NTSC ⇒ digital ⇒ PAL)
- ❑ compression, decompression

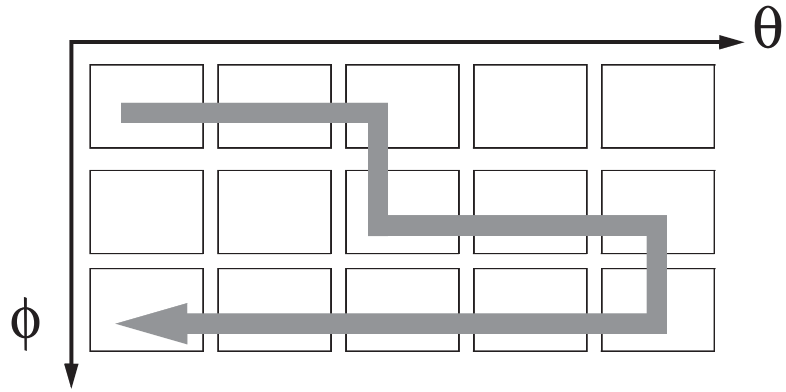


Example: "Navigable Video"

θ ϕ: 5 degree intervals
72 x 36 frames
1.5 minutes



Access Function



$\theta,\phi \Rightarrow \text{frame}(\theta,\phi)$