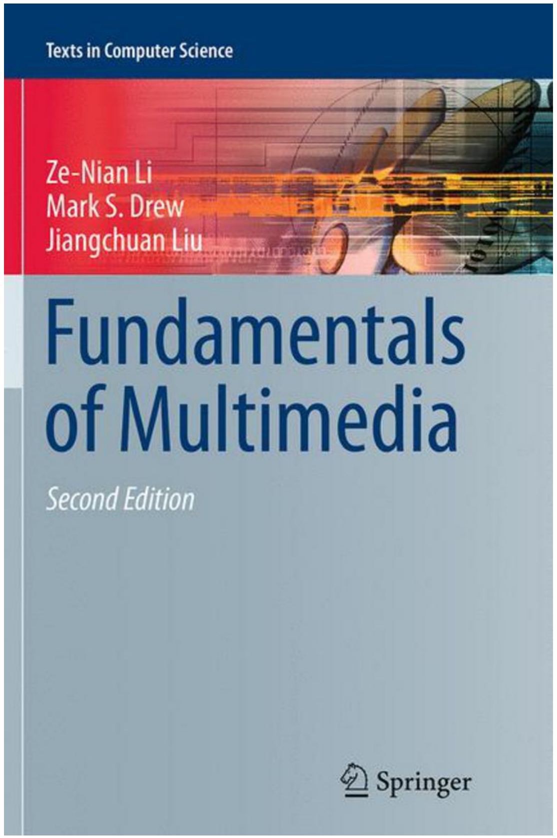
Background Photo:
Opera Garnier Ceiling

MULTIMEDIA

Dr Siba HAIDAR • INFO430 • 2019-2020

Textbook: Fundamentals of Multimedia • Z.-N. Li et al.

Course Outline



1. Introduction to multimedia
2. Digital representation of graphics and images
3. Colors in images and video
4. Fundamental Concepts in Video
5. Lossless compression algorithms
6. Lossy compression algorithms (JPEG)
7. Video Coding (MPEG)
8. Introduction to Image Processing

Background Photo:
The Starry Night

FUNDAMENTAL CONCEPTS IN VIDEO

Chapter Outline

- Fundamental Concepts in Video
- chapter 5 in textbook

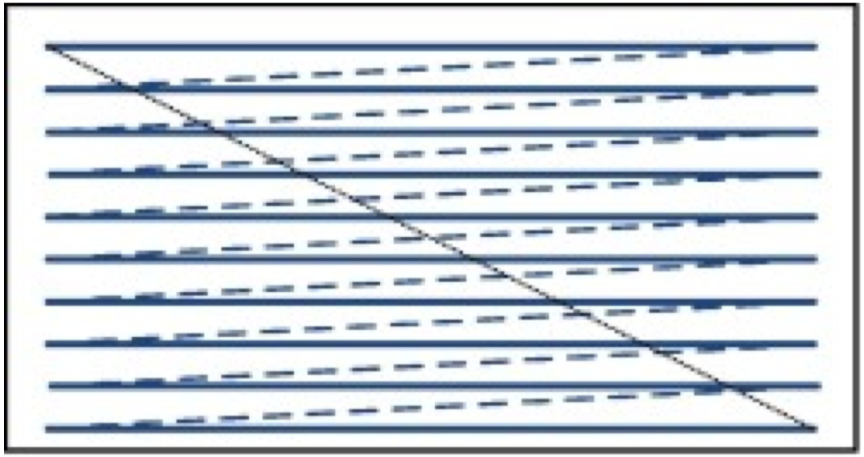
1. Analog Video
2. Digital Video
3. Video Display Interfaces
4. ~~3D Video and TV~~

Background Photo:
The Milk Maid

Analog Video

Analog Video

- up until last decade
  - most TV programs were sent and received as an analog signal
- once the electrical signal is received
  - we may assume that brightness is at least a monotonic function of voltage, if not necessarily linear, because of gamma correction
- progressive
  - an analog signal f(t) samples a time-varying image
  - progressive scanning traces
  - through a complete picture (a frame)
  - row-wise for each time interval

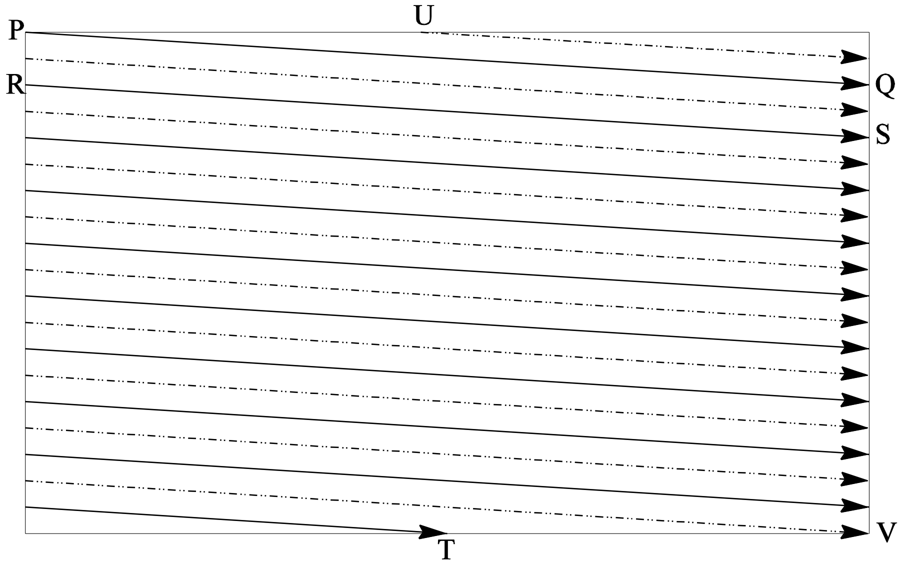


Progressive scan

Interlacing

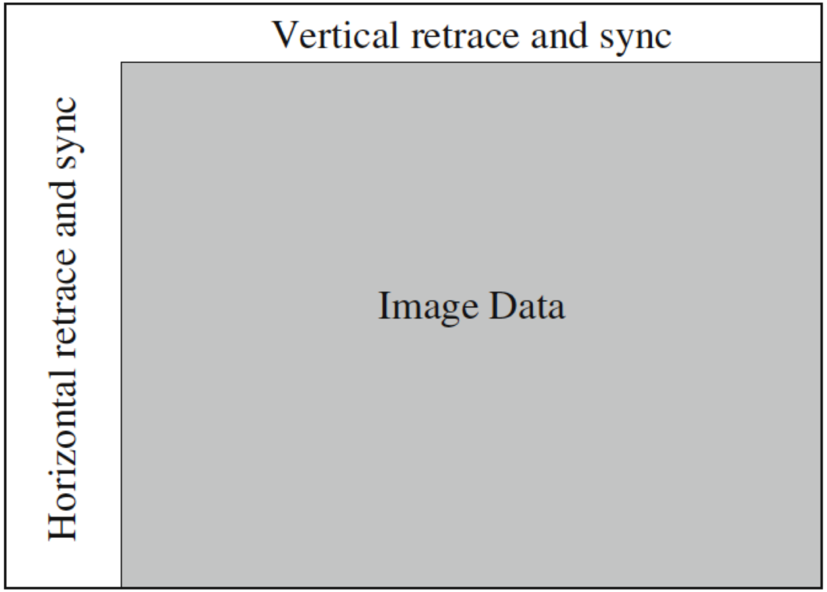
- trace lines all odd then all even
- 1 frame →2 fields: odd & even
- tracing
  - P → Q
  - R → S, etc., ending at T;
    - then
  - U → … → V
- horizontal retrace
  - jump from Q to R, etc
  - electronic beam in CRT: blanked
- vertical retrace
  - jump from T to U
  - or from V to P

- Interlaced raster scan



Video raster including retrace and sync data

- vertical retrace and sync ideas are similar to horizontal one, except that they happen only once per field



Why Interlace?

- interlacing was invented because
  - when standards were being defined
  - it was difficult to transmit the amount of information in a full frame quickly enough to avoid flicker
- the double number of fields presented to the eye reduces perceived flicker

Aliasing

- because of interlacing
  - odd and even lines are displaced in time from each other
  - — generally not noticeable except when very fast action is taking place on screen
  - blurring may occur
- example
  - moving helicopter is blurred more than still background

- (a) The video frame,
- (b) Field 1, (c) Field 2, (d) Difference of Fields

(a)

(b)

(c)

(d)

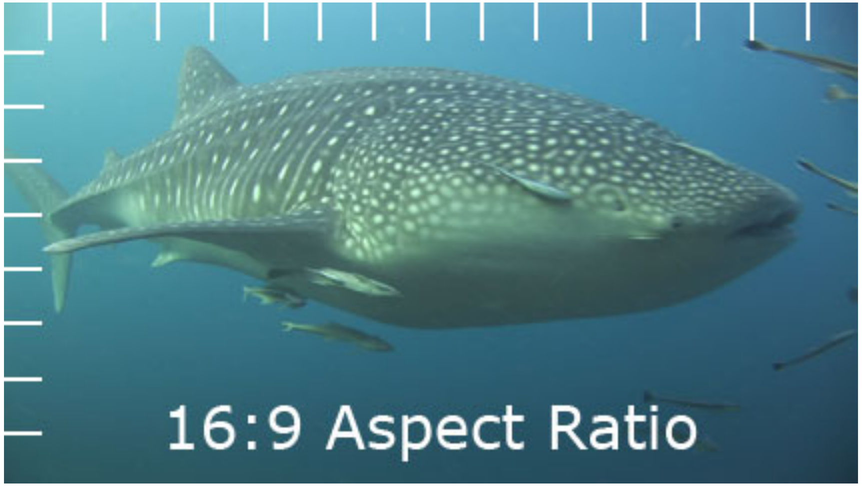
Textbook: Fundamentals of Multimedia • Z.-N. Li et al.

De-Interlacing

- de-interlace
  - sometimes necessary to change the frame rate, resize, or even produce stills from an interlaced source video
- simplest de-interlacing method
  - discarding one field and duplicating the scan lines of the other field
  - information in one field lost completely
- other more complicated methods possible

What is Aspect Ratio?

- the ratio of the width to the height of an image or screen



NTSC Video

- National Television System Committee
- TV standard mostly used in North America and Japan
  - 4:3 aspect ratio
  - 525 scan lines per frame
  - 30 frames per second (fps)
    - in fact 29.97 fps = 33.37ms per frame
- interlaced scanning system
  - each frame divided into 2 fields
  - 262.5 lines/field
  - horizontal sweep frequency $525 \times 29.97 \approx 15734$ lines /sec
  - each line swept out in $\frac{1}{15.734} \times 10^6 \approx 63.6 \mu sec$
  - horizontal retrace $10.9\ \mu sec$
  - $63.6 - 10.9 = 52.7 \mu sec$ → active line signal during which image data is displayed

- analog signal with no fixed horizontal resolution
- different video formats provide different numbers of samples per line
- samples per line for various video formats

Format	Samples per line
VHS	240
S-VHS	400-425
Betamax	500
Standard 8 m	300
Hi-8 mm	425

Exercise 1

- NTSC video has 525 lines per frame and 63.6μs per line, with 20 lines per field of vertical retrace and 10.9μs horizontal retrace.
  - (a) Where does the 63.6μs come from?
  - (b) Which takes more time, horizontal retrace or vertical retrace? How much more time?

PAL Video

- Phase Alternating Line
- TV standard widely used in Western Europe, China, India, and many other parts of the world
- 625 scan lines per frame
- 25 fps
- 4:3 aspect ratio
- interlaced fields
- YUV color model
- 8 MHz channel
- allocates a bandwidth of
  - 5.5 MHz to Y
  - 1.8 MHz each to U and V
    - why less? chroma subsampling
- chroma signals have <u>alternate</u> signs (+U –U) in successive scan lines
- facilitates use of a (line rate) comb filter at receiver
  - signals in consecutive lines averaged
  - cancel opposite chroma signals
  - for separating Y & C → high quality Y signals

SECAM Video

- Système Electronique Couleur Avec Mémoire
- 3rd major broadcast TV standard
- 625 scan lines per frame
- 25 fps
- 4:3 aspect ratio
- interlaced fields

- SECAM & PAL very similar
  - differ in color coding scheme
  - SECAM
    - → U and V signals are modulated using separate color subcarriers at 4.25 MHz and 4.41 MHz respectively
  - sent in alternate lines
  - only one of U or V signals will be sent on each scan line

Comparison of Analog Broadcast TV Systems

TV System	Frame Rate (fps)	# of Scan Lines	Total Channel Width (MHz)	Bandwidth Allocation (MHz)		
				Y	I or U	Q or V
NTSC	29.97	525	6.0	4.2	1.6	0.6
PAL	25	625	8.0	5.5	1.8	1.8
SECAM	25	625	8.0	6.0	2.0	2.0

Background Photo:
The Milk Maid

Digital Video

Digital Video

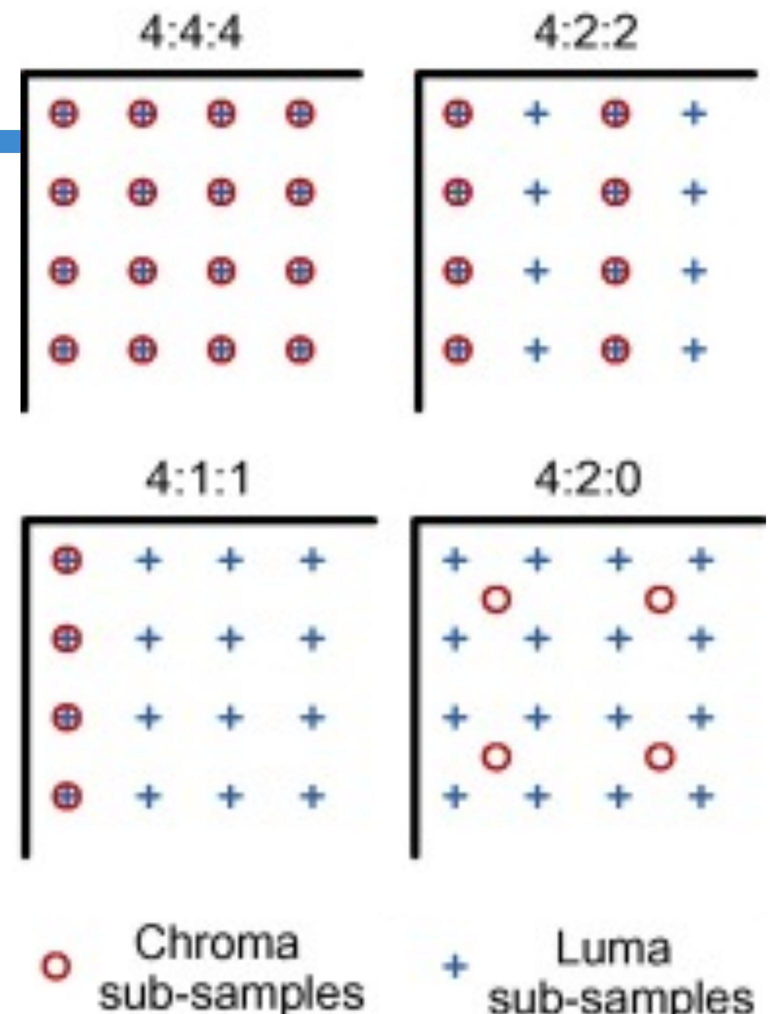
- advantages of digital representation:
  - video can be stored on digital devices or in memory, ready to be processed (noise removal, cut and paste, etc.), and integrated to various multimedia applications
  - direct access is possible, which makes nonlinear video editing achievable as a simple, rather than a complex, task
  - repeated recording does not degrade image quality
  - ease of encryption and better tolerance to channel noise

Chroma Subsampling

- since humans see color with much less spatial resolution than they see black and white
  - it makes sense to “decimate” the chrominance signal
- interesting (but not necessarily informative!) names have arisen to label the different schemes used
- numbers are given stating how many pixel values, per 4 original pixels, are actually sent:

Chroma Subsampling

- 4:4:4 no chroma subsampling
  - each Y Cb Cr transmitted
- 4:2:2 horiz. subsampling of Cb Cr by 2
- 4:1:1 subsamples horizontally by 4
- 4:2:0 subsamples in both dimensions horizontal & vertical by 2
  - theoretically, an average chroma pixel is positioned between rows & columns
  - commonly used in JPEG and MPEG



Textbook: Fundamentals of Multimedia • Z.-N. Li et al.

ITU-R digital video specifications

- CIF = Common Intermediate Format by
  - CCITT = International Telegraph and Telephone Consultative Committee, now superseded by
  - ITU = International Telecommunication Union for both telecommunications (ITU-T) and radio frequency matters (ITU-R) under one United Nations body
- idea of CIF, VHS quality: format for lower bitrate, progressive (noninterlaced) scan
- QCIF = Quarter-CIF, and is for even lower bitrate
- CIF/QCIF resolutions are evenly divisible by 8, and all except 88 are divisible by 16; convenient for block-based video coding in H.261 and H.263

	Rec. 601 525/60 NTSC	Rec. 601 625/50 PAL/SECAM	CIF	QCIF
Luminance resolution	720 × 480	720 × 576	352 × 288	176 × 144
Chrominance resolution	360 × 480	360 × 576	176 × 144	88 × 72
Color subsampling	4:2:2	4:2:2	4:2:0	4:2:0
Aspect ratio	4:3	4:3	4:3	4:3
Fields/sec	60	50	30	30
Interlaced	Yes	Yes	No	No

HDTV

- High Definition TV
- main thrust is not to increase the "definition" in each unit area, but to increase the visual field especially in its width
  - first generation of HDTV was based on an analog technology developed by Sony and NHK in Japan in the late 1970s
  - MUSE (MUltiple sub-Nyquist Sampling Encoding) was an improved NHK HDTV with hybrid analog/digital technologies that was put in use in the 1990s
    - 1,125 scan lines, interlaced (60 fields per second), and 16:9 aspect ratio
- uncompressed HDTV demand > 20 MHz bandwidth
  - will not fit in current 6 MHz or 8 MHz channels
  - various compression techniques being investigated
  - HDTV signals will be transmitted using more than one channel even after compression

HDTV

- for video, MPEG-2 is chosen as the compression standard
- for audio, AC-3 is the standard
  - supports the so-called 5.1 channel Dolby surround sound, i.e., five surround channels plus a subwoofer channel
- salient difference between conventional TV and HDTV:
  - HDTV has a much wider aspect ratio of 16:9 instead of 4:3
  - HDTV moves toward progressive (non-interlaced) scan
  - interlacing introduces serrated edges to moving objects and flickers along horizontal edges

Standards for Video

CCIR	-	*Consultative Committee for International Radio*
CIF	-	*Common Intermediate Format (approximately VHS quality)*
QCIF	-	*Quarter CIF*

	HDTV	CCIR 601 NTSC	CCIR 601 PAL	CIF	QCIF
Luminance Resolution	1920 x 1080	720 x 486	720 x 576	352 x 288	176 x 144
Chrominance Resolution	960 x 540	360 x 486	360 x 576	176 x 144	88 x 72
Color Subsampling	4:2:2	4:2:2	4:2:2	4:2:0	4:2:0
Fields/sec	120	60	50	30	30
Aspect Ratio	16:9	4:3	4:3	4:3	4:3
Interlacing	Yes	Yes	Yes	No	No

Advanced Digital TV formats supported by ATSC

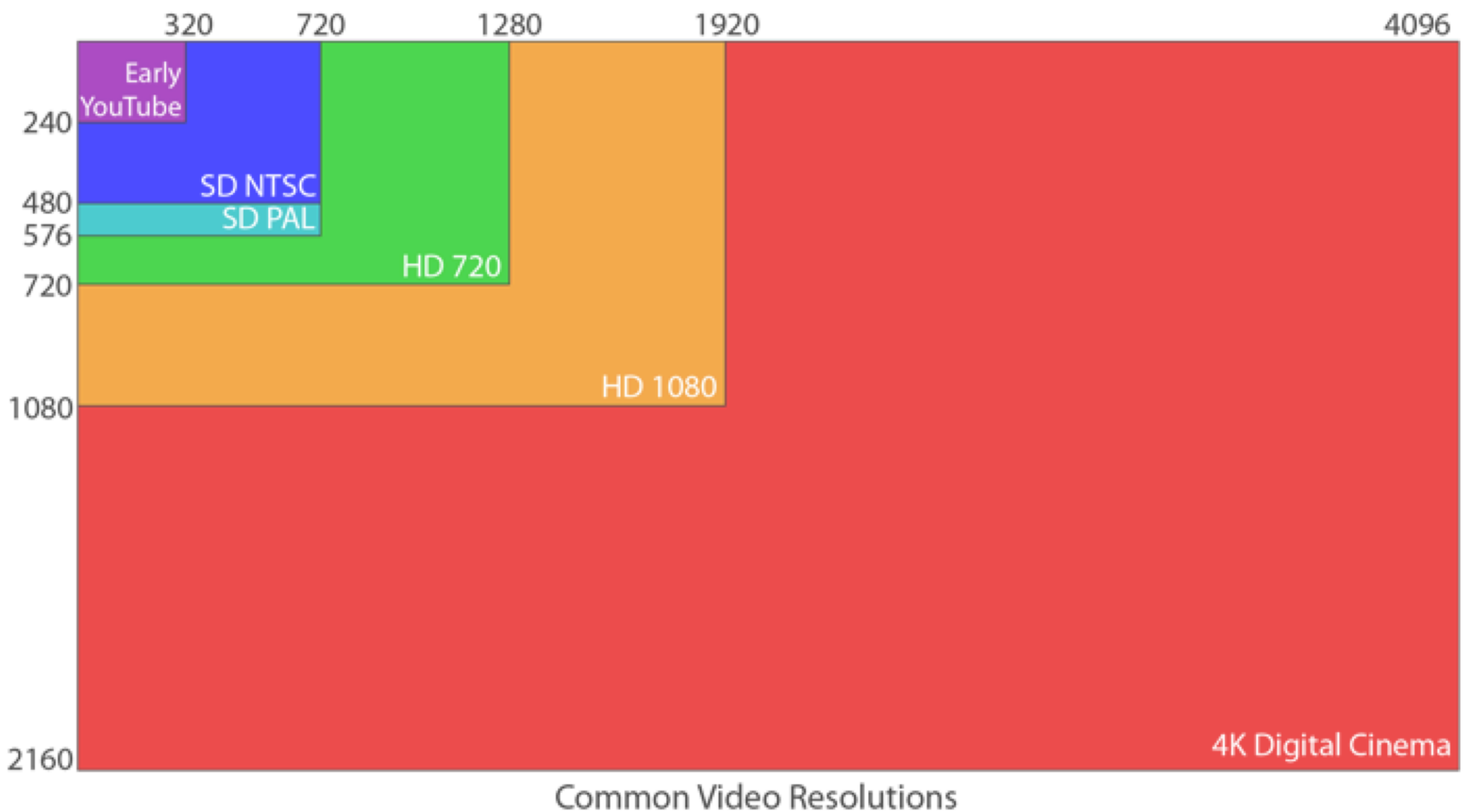
- boom of proposals for digital HDTV
- "grand alliance" = General Instruments + MIT + Zenith + AT&T
  - and by Thomson, Philips, Sarnoff, and others
- →ATSC = Advanced Television Systems Committee

Number of active pixels per line	Number of active lines	Aspect ratio	Picture rate
1,920	1,080	16:9	60P 60I 30P 24P
1,280	720	16:9	60P 30P 24P
720	480	16:9 or 4:3	60P 60I 30P 24P
640	480	4:3	60P 60I 30P 24P

Ultra High Definition TV (UHDTV)

- new generation of HDTV
- standards announced in 2012
- support
  - **4K UHDTV:**
    - 2160P
    - 3,840 ~ 2,160 progressive scan
  - **8K UHDTV:**
    - 4320P
    - 7,680 ~ 4,320 progressive scan
- aspect ratio 16:9
- bit-depth up to 12 bits
- chroma subsampling 4:2:0 | 4:2:2
- supported frame rate increased to 120 fps
- superior picture quality
  - comparable to IMAX movies
  - require higher bandwidth & | bitrate
- in 2013 ATSC called for proposals to support 4K UHDTV (2160P) at 60 fps

Definition



320
720
1280
1920
4096
Early YouTube
240
SD NTSC
480
SD PAL
576
HD 720
720
HD 1080
1080
4K Digital Cinema
2160
Common Video Resolutions

Background Photo:
The Milk Maid

Video Display Interfaces

There have been a wide range of video display interfaces, supporting video signals of different formats (analog or digital, interlaced or progressive), different frame rates, and different resolutions.

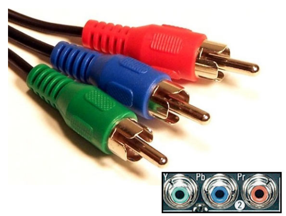
Analog Display Interfaces

- Connectors for typical analog display interfaces.
  - Component video | Composite video | S-video | VGA




Analog Display Interfaces

- Component Video
  - 3 separate video signals for RGB planes
  - best color reproduction
  - no “crosstalk”
  - requires bandwidth+ & synchro



- Composite Video — 1 Signal
  - chromix 2 & lumi
  - mixed into 1 carrier wave
  - → put chroma at high-freq
  - separated at receiver end
  - interference

- S-Video — 2 Signals
  - compromise 2 wires
  - lumi & chromi
  - less crosstalk
  - +crucial gray-scale information

Video Graphics Array (VGA)

- IBM in 1987 with its PS/2 personal computers
- resolutions
  - initial
    - 640~480 using 15-pin D-subminiature VGA connector
  - then from
    - 640 ~ 400 pixels at 70Hz (24MHz of signal bandwidth)
  - to
    - 1, 280 ~ 1, 024 pixels (SXGA) at 85Hz (160MHz)
  - and up to
    - 2, 048 ~ 1, 536 (QXGA) at 85Hz (388MHz)
- signals based on analog component
  - RGB HV
  - red, green, blue, horizontal sync, vertical sync
- carries DDC
    - = Display Data Channel
  - data defined by VESA
    - = Video Electronics Standards Association
- suffers from interferences when cable is long

Digital Display Interfaces

- emerged in 1980s CGA = Color Graphics Adapter
- Digital Visual Interface (DVI), High-Definition Multimedia Interface (HDMI), and DisplayPort
- Connectors of different digital display interfaces
- DVI | HDMI | DisplayPort

Digital Visual Interface (DVI)

- by DDWG
  - = Digital Display Working Group
  - transfer digital video signals, from a computer's video card to a monitor
- uncompressed digital video
- support multiple modes
  - DVI-D (digital only)
  - DVI-A (analog only)
  - DVI-I (digital and analog)
- backward compatible with VGA
  - adapter needed
- transmission format is based on PanelLink
  - high-speed serial link technology
  - using TMDS
  - = transition minimized differential signaling
- video card
  - reads display's EDID
    - = extended display identification data
  - chooses preferred mode or native resolution
- single-link mode
  - max pixel clock frequency 165MHz
  - maximum res 2.75 megapixels at the 60Hz refresh rate
  - max 16:9 screen res 1,920 ~ 1,080 at 60 Hz
- dual link
  - higher res
  - 2,560 x 1,600 at 60 Hz

High-Definition Multimedia Interface (HDMI)

- newer digital audio/video interface
- backward-compatible with DVI
- by the consumer electronics industry & widely used since 2002
- specification identical to those of DVI
- difference:
  - 1. no analog signal & VGA incompatible
  - 2. color space
    - DVI limited to RGB color range (0–255);
    - HDMI supports both RGB and YCbCr 4:4:4 or 4:2:2
  - 3. supports digital audio

- HDMI 1.0
  - max pixel clock rate 165MHz
  - support 1080P and WUXGA (1,920 ~ 1,200) at 60 Hz
- HDMI 1.3
  - to 340MHz
  - WQXGA, 2, 560~1, 600 over a single digital link
- HDMI 2.0
  - released in 2013
  - 4K resolution at 60 fps

DisplayPort

- by VESA 2006
- first display interface to use packetized data transmission, like the Internet or Ethernet
  - based on micro packets
  - can embed clock signal
  - higher res yet fewer pins
- extensible
  - new features can be added over time without significant changes to physical interface itself
- transmit audio & video | video | audio
  - video signal path: 6–16 bits per color channel
  - audio path: up to 8 channels of 24-bit 192kHz uncompressed PCM audio | compressed audio
  - dedicated bi-directional channel carries device management and control data
- to replace VGA and DVI - higher video bandwidth
  - enough for
  - 4 simultaneous 1080P 60Hz displays, or
  - 4K video at 60 Hz
- backward compatibility to VGA and DVI by active adapters
- DisplayPort versus HDMI
  - more bandwidth
  - accommodates multiple streams of audio and video to separate devices
  - VESA specification is royalty-free; HDMI charges an annual fee to manufacturers
  - → DisplayPort >> HDMI

Background Photo:
The Milk Maid

3DVideo and TV

3D pictures & movies → enable experience of immersion

rapid progress in research & development of 3D technology + success of Avatar film 2009 → peak

! However, not in the frame of this course