Multimedia Technology

Section # 11: Video

Instructor: George Xylomenos

Department: Informatics

Contents

- Nature of video
- Analog TV
- Digital video
- High Definition TV
- Animation

Nature of video

Class: Multimedia Technology, **Section # 12:** Video

Instructor: George Xylomenos, **Department:** Informatics

What is video? (1 of 4)

- Video: a sequence of still images
  - Played back at a fixed rate
  - In video we call each full image a frame
  - Frame rate = playback rate
  - Measured in frames per second (fps)
- Digital video has two ancestors
  - Motion pictures
  - Analog television

What is video? (2 of 4)

- Motion pictures or movies or films
  - Each frame is (basically) a photograph
  - Recorded on photographic film
  - At the right frame rate, we see motion
- Analog television
  - A camera scans the frame line by line
  - Transmission by modulating radio waves
  - The demodulated signal drives a screen

What is video? (3 of 4)

- Television screens
  - A frame consists of a sequence of lines
    - Each line drawn left to right
    - Lines drawn top to bottom
  - Either signal from an antenna
    - Analog or digital
  - Or signal from a storage device
    - VCR, laser disk, game console with RF modulator

What is video? (4 of 4)

- Cathode Ray Tubes (CRTs)
  - The original TV screens
  - Image drawn by shooting electrons at screen
  - Phosphors emit light and then decay
  - The screen needs to be refreshed
  - Refresh rate >= frame rate
- Liquid Crystal Displays (LCDs)
  - No need to refresh the screen

Refresh vs redraw (1 of 3)

- How many fps to sense motion?
  - At 10 fps we have (jerky) motion
  - Smooth motion at 24+ fps (movies)
  - Analog TVs synchronized with AC power
    - Europe: 50 Hz, US: 60 Hz,
    - Frame rates were half that: 25/30 fps
- But CRTs suffer from flicker at 25/30 fps
  - The image decays faster than the frame rate
  - We sense the intensity going up and down

Refresh vs redraw (2 of 3)

- Solution: interlaced scanning
  - We split each frame into odd and even lines
  - Each half frame is called a field
  - We transmit odd and even in sequence
  - Screen is refreshed 50/60 times per second
    - The entire frame is redrawn 25/30 times
  - But some detail is lost
    - Say that we have a very thin horizontal line
    - It may appear and disappear in alternate fields!

Refresh vs redraw (3 of 3)

- LCDs do not need periodic refreshing
  - Their image does not decay
  - We can use progressive scanning
    - All lines drawn in each period
  - Interlaced scanning for TV compatibility
- Comparing interlaced to progressive
  - Interlaced has less vertical detail
  - Multiply total vertical lines by 0.7
    - This is called the Kell factor

Digitizing video (1 of 4)

- Analog TV and Video
  - The input signal drives the electron gun
    - There is no memory buffer!
  - Varies the intensity of the beam
  - Includes retrace or sync signals
    - Horizontal (every line) and vertical (every field)
  - During retrace the screen does not change
  - But the signal keeps getting transmitted!

Digitizing video (2 of 4)

- How many samples to take?
- Vertical: based on scan lines
  - We usually consider an entire frame
    - Not the interlaced fields
- Horizontal resolution: not obvious
  - The signal within a line is continuous
    - Can take any value at any point in time
  - Multiple options exist

Digitizing video (3 of 4)

- Bandwidth-based
  - We can use the sampling theorem
  - Bandwidth depends on the input
    - TV bandwidth is higher than VCR bandwidth
- Experimental
  - Draw a card with thin vertical BW lines
  - How many can we see?
  - This also depends on bandwidth

Digitizing video (4 of 4)

- Aspect ratio-based
  - Aspect ratio: height : width of screen
  - 4:3 (conventional), 16:9 (wide)
  - We start with the vertical resolution
  - We define horizontal resolution indirectly
    - Vertical resolution * aspect ratio
- Convenience-based
  - Start with aspect-ratio based
  - Round up for convenience (e.g. multiple of 8)

Viewing distance (1 of 4)

- Human vision has its own limitations
  - After some point, our eyes merge pixels
    - This is the basis of dithering and antialising
  - How far can we detect individual pixels
    - 2000 x pixel height
    - Pixels may not be square!
  - How large is a pixel?
    - Screen height / scan lines = pixel height

Viewing distance (2 of 4)

- Normalized viewing ratio
  - Viewing distance limit / screen height
    - Which is 2000 / scan lines
  - Multiply by screen height to get distance
- Why this ratio instead of 2000 x pixel height?
  - Each TV standard has fixed scan lines
  - The normalized ratio is fixed!
  - For a specific TV, we just need the height

Viewing distance (3 of 4)

- NTSC: 2000 / 484 = 4.13
  - Say that the screen is 9 inches high
  - Distance: 4.13 * 9 = 37.17 inches = 94.4 cm
- HDTV 1080p: 2000 / 1080 = 1.85
  - Screen height remains at 9 inches
  - Distance: 1.85 * 9 = 16.65 inches = 42.3 cm
- The largest the screen for a TV system…
- …the further away we can stand from it

Viewing distance (4 of 4)

- How to get the screen height?
  - Screen sizes are given as diagonals (e.g., 47”)
  - To get the height, we need the aspect ratio
  - Say that we have a 47” screen with 16:9 aspect
  - Assume that h is the screen height
  - Then the screen width is (16/9)h
  - So $47^2=h^2 + h^2(16/9)^2$
  - Solve for h (and then multiply by 2000)

Analog TV

Class: Multimedia Technology, **Section # 11:** Video

Instructor: George Xylomenos, **Department:** Informatics

Analog TV (1 of 8)

- Analog TV systems have a long history
  - Initially TV was black and white
  - Color was added much later
  - Color TVs were expensive
  - TV systems needed to support both
- Luminance/Chrominance systems
  - Transform of RGB to three signals
  - Black and white TVs only use luminance signal
  - Color TVs also use the two chrominance signals

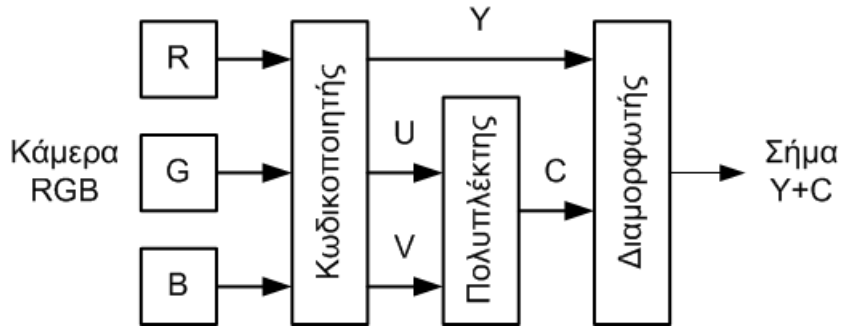
Analog TV (2 of 8)

- RGB to YUV (in PAL)
  - Y = 0.299 R + 0.587 G + 0.114 B
  - U = (B – Y) * 0.492
  - V = (R – Y) * 0.877
- RGB to YIQ (in NTSC)
  - Y = 0.299 R + 0.587 G + 0.114 B
  - I = 0.596 R – 0.274 G – 0.321 B
  - Q = 0.211 R – 0.523 G + 0.311 B
- Reverse transform for display

Analog TV (3 of 8)

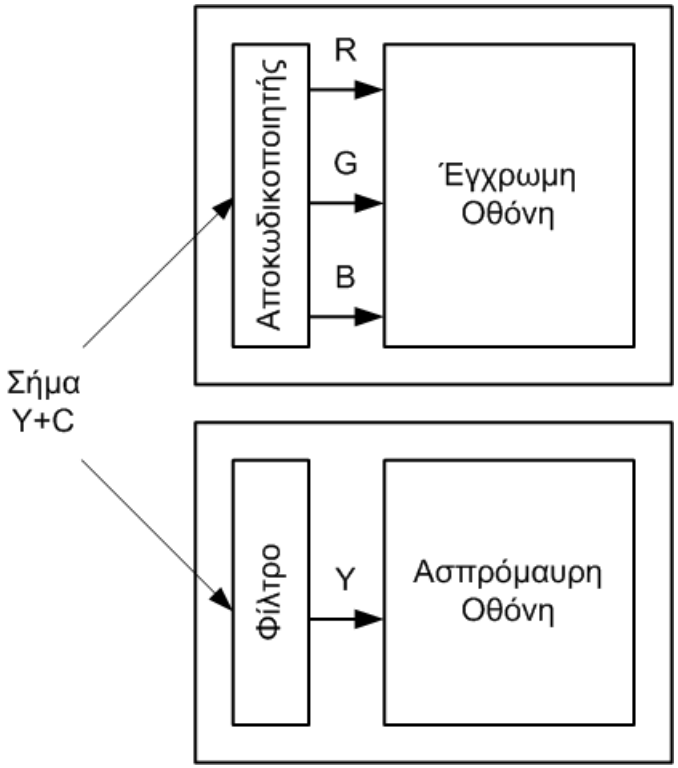
- Luminance sent with more bandwidth
  - Initially, only luminance was sent
  - Chrominance was added later
  - It had to fit in what was available
- Fortunately, our eyes are fine with this
  - Far more sensitive to brightness
  - Far less sensitive to color

Analog TV (4 of 8)



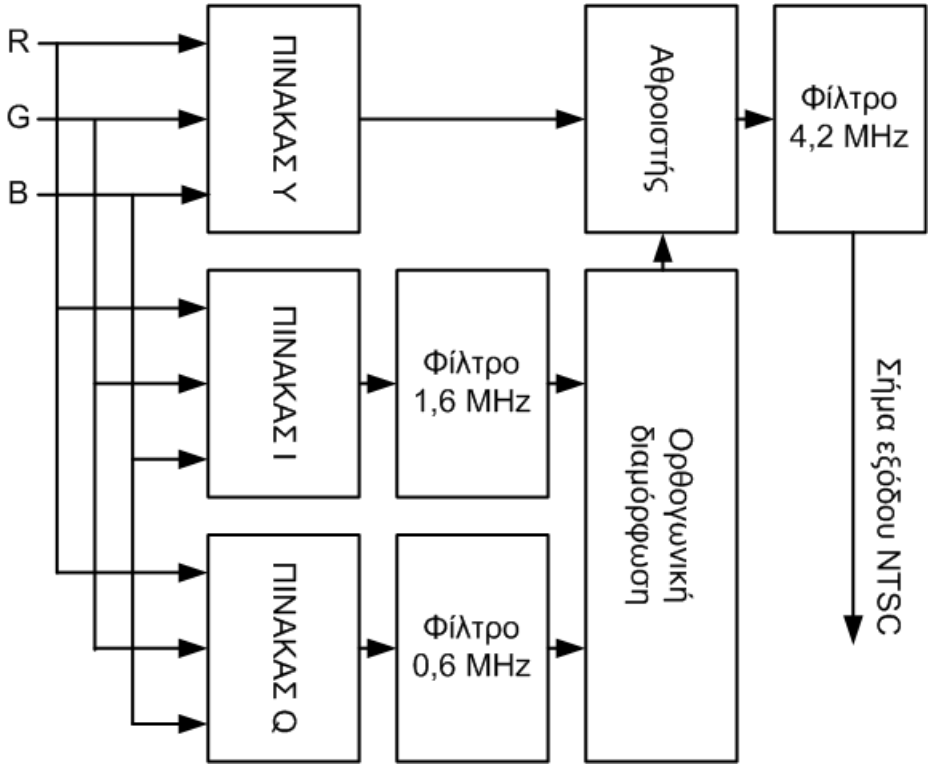
- Color difference signals (chrominance)
  - U and V are what is left after taking Y out
  - Also called Y, B-Y, R-Y
  - U and V multiplexed into C (chroma)
  - Y and C are combined by modulator

Analog TV (5 of 8)



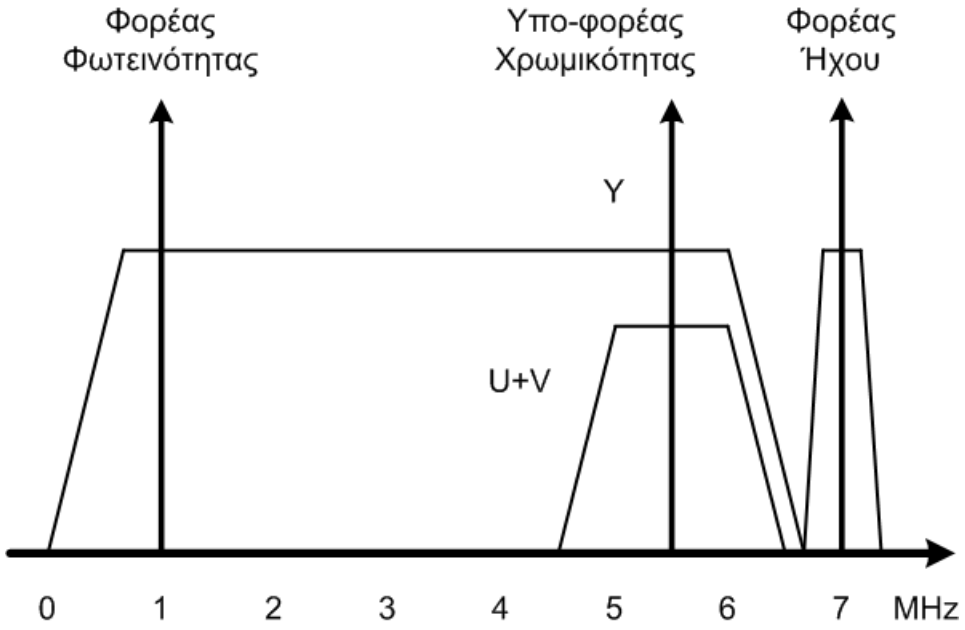
- Signal demultiplexing
  - Black and white TVs just filter out chrominance
  - Color TVs do the full transform

Analog TV (6 of 8)



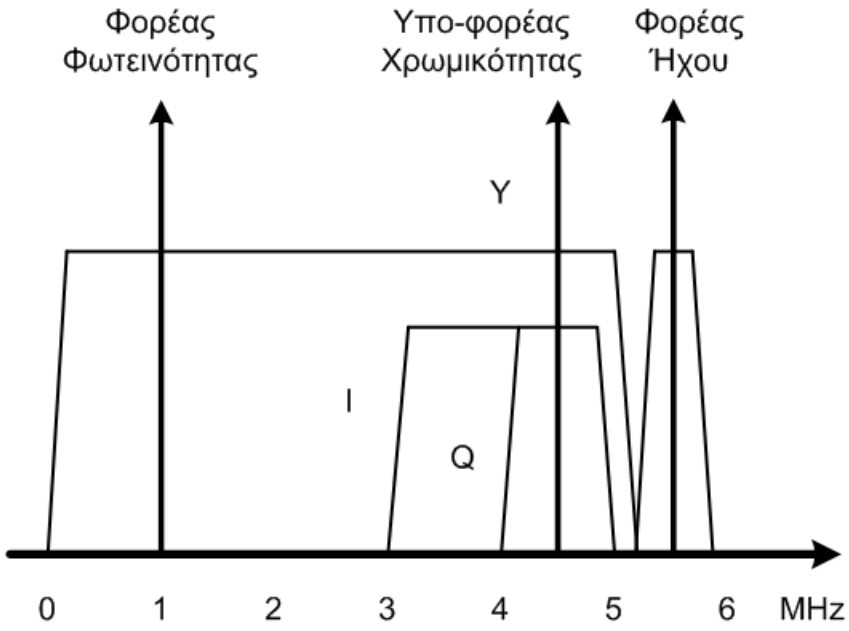
- Multiplexing in YIQ
  - Similar to YUV, but more compatible with BW

Analog TV (7 of 8)



- Signal multiplexing (PAL, 8 MHz channels)
  - Chrominance subcarrier carefully chosen
  - More bandwidth than NTSC

Analog TV (8 of 8)



- Signal multiplexing (NTSC, 6 MHz channels)
  - I and Q have different bandwidths
  - Compatible with previous BW standard

Analog TV systems (1 of 4)

- NTSC (National Television Systems Committee)
  - 525 scan lines, 484 visible
  - 6 MHz channels, amplitude modulation
  - ~30 Hz frame rate, ~60 Hz refresh rate
- PAL (Phase Alternating Line)
  - 625 scan lines, 575 visible
  - 8 MHz channels, amplitude modulation
  - 25 Hz frame rate, 50 Hz refresh rate

Analog TV systems (2 of 4)

- SECAM (SEquential Couleur Avec Memoire)
  - Like PAL but with frequency modulation
  - Better image quality (and color)
  - Invented in France, used in Eastern Europe
    - To prevent getting western TV
    - East Germans could not watch West German TV
  - NTSC used in the US
  - PAL eventually used throughput Europe

Analog TV systems (3 of 4)

Σύστημα	Γραμμές	Λεπτομέρεια	Εύρος (MHz)	Y (MHz)	I/U (MHz)	Q/V (MHz)	Πεδία / Πλαίσια (Hz)
NTSC	525/484	340/242	6.0	4.2	1.6	0.6	59.94/29.97
PAL	625/575	400/290	8.0	5.5	1.8	1.8	50/25
SECAM	625/575	400/290	8.0	6.0	2.0	2.0	50/25

- Summary of analog TV systems
  - Scan lines / visible lines
  - Progressive / Interlaced scanning detail
    - Conversion based on Kell factor

Analog TV systems (4 of 4)

- What does “visible lines” mean?
  - Scan line period: time between two scan lines
    - Includes horizontal retrace
  - Frame (field) period: time between frames (fields)
    - Includes vertical retrace
  - Frame : line period = scan lines
    - Some of these are not shown
    - Hence, the difference with visible lines

Analog video connectors

- Composite video
  - Multiplexes luminance and chrominance
  - Some crosstalk between them
- S-Video
  - Separate lines for luminance and chrominance
- Component video
  - Separate RGB (VGA) or YCbCr lines
  - Harder to keep in sign over longer distances

Digital video

Class: Multimedia Technology, **Section # 11:** Video

Instructor: George Xylomenos, **Department:** Informatics

How to digitize video? (1 of 2)

- Digital and analog video
  - Broad compatibility to allow conversion
  - Similar “resolutions” and frame rates
- Digitization of composite signal
  - All signal components sampled together
  - No provision for different treatment
  - Maintains interference between components
  - Used only for transmission (satellites)

How to digitize video? (2 of 2)

- Digitization of components
  - Allows different sampling rates
  - Best option for digital processing
  - In principle, can do with RGB
    - Cameras are RGB after all
  - In practice, nearly always with YUV/YIQ
    - Suitable for transmission
    - Exploits the limitations of human vision

CCIR-601 standard (1 of 4)

- The CCIR-601 digital video standard
  - Designed for TV studios
  - Interlace scanning (it is for TV!)
    - Higher quality for studio use
    - Reduced quality for transmission
  - Bandwidth per signal component
    - 6 MHz for luminance (Y)
    - 3 MHz for each chrominance (U and V)

CCIR-601 standard (2 of 4)

- Sampling rates
  - Luminance: 13.5 MHz
    - NTSC: 63.56 µs per scan line, 52 µs visible
    - PAL/SECAM: 64 µs per scan line, 52 µs visible
    - 702 visible samples in both cases
  - 720 luminance samples (18 are black)
  - 360x2 chrominance samples (4:2:2)
  - 8 bit per sample for each component

CCIR-601 standard (3 of 4)

- CCIR-601 for PAL/SECAM
  - 720 x 576 (visible frame) at 25 fps
    - NTSC is 720 x 480 at 29.97 fps
- Transmission (with non visible areas)
  - $13.5 \times 10^6 \times 8 + 2 \times 6.75 \times 10^6 \times 8 = 216$ Mbps
- Transmission (visible areas only)
  - $(720 \times 576 \times 25 + 2 \times 360 \times 576 \times 25) \times 8 = 166$ Mbps
  - $(720 \times 480 \times 30 + 2 \times 360 \times 480 \times 30) \times 8 = 166$ Mbps

CCIR-601 standard (4 of 4)

- Reduced quality for transmission
  - Lower sampling rate (4:2:0)
  - We drop half of the chrominance samples
    - Averages the samples from two lines
- Transmission (with non visible areas)
  - $13.5 \times 10^6 \times 8 + 2 \times 3.375 \times 10^6 \times 8 = 162$ Mbps
- Transmission (visible areas only)
  - $(720 \times 576 \times 25 + 2 \times 360 \times 288 \times 25) \times 8 = 124$ Mbps
  - $(720 \times 480 \times 30 + 2 \times 360 \times 240 \times 30) \times 8 = 124$ Mbps

Other standards (1 of 4)

- SIF: Standard Interchange Format
  - This is equivalent to analog TV
  - One quarter the resolution of CCIR-601
    - SIF for NTSC: 360 x 240 luminance
    - SIF for PAL/SECAM: 360 x 288 luminance
  - Progressive scanning at 29.97 or 25 fps
  - Subsampling at (4:1:1)
    - (4:1:1) signifies progressive scanning
    - (4:2:0) signifies interlaced scanning

Other standards (2 of 4)

- CIF: Common Interchange Format
  - Used across the world for conferencing
    - Similar to SIF but mix of NTSC and PAL/SECAM
  - 360 x 288 for luminance (PAL/SECAM)
  - Scanning: progressive at 30 fps (NTSC)
  - Subsampling at (4:1:1)
    - Subsampling of chrominance
    - 180 x 144 per component

Other standards (3 of 4)

- CIF variants
  - Subsampling fixed at (4:1:1)
  - Progressive scanning fixed at 30 fps
- 4CIF: 720 x 576 for luminance
- 16CIF: 1440 x 1152 for luminance
- QCIF: 180 x 144 for luminance
  - Also allows 15 and 7.5 fps
  - Used in very early conferencing standards

Other standards (4 of 4)

- Even more variants exist!
  - Different horizontal resolution for computers
    - Square pixels with 4:3 aspect ratio
      - In NTSC and PAL pixels are NOT square!
    - Need to adjust horizontal resolution
  - Resolution rounded to multiples of 16
    - Used in many compression standards
    - Based on four 8x8 square tiles (from JPEG)

Resolutions redux

Σύστημα	Οριζόντια	Κατακόρυφη	Ανανέωση
CCIR-601/US	720/360	480/240	59.94-I
CCIR-601/EUR	720/360	576/288	50-I
SIF/US	360/180	240/120	29.97-P
SIF/EUR	360/180	288/144	25-P
16CIF	1440/720	1152/576	30-P
4CIF	720/360	576/288	30-P
CIF	360/180	288/144	30-P
QCIF	180/90	144/72	15/7.5-P

- Different resolutions and frame rates
  - Luminance / chrominance
  - P or I for scanning

Digital video connectors

- DVI-D (the digital part)
  - Different pins for each component
  - More pins for pixel clock and screen info
- HDMI
  - Based on packets, also carries audio
  - CEC channel (control) and audio return channel
- DisplayPort
  - Also based on packets, with audio (like HDMI)
  - Supports multiple screens

High Definition TV

Class: Multimedia Technology, **Section # 11:** Video

Instructor: George Xylomenos, **Department:** Informatics

HDTV (1 of 3)

- HDTV: refers to very different systems
  - Today: only digital systems
  - Up to 2000 scan lines
  - (16:9) aspect ratio
- Why different HDTV systems?
  - Coexistence with analog TV
    - Content compatibility (resolutions, fps)
    - Channel compatibility (channel bandwidth)

HDTV (2 of 3)

- US: Advanced Television Systems Committee (ATSC)
  - Transition ended in 2009
  - Variants to suit every need
    - Frame rates of 24, 30 ή 60 fps
    - Progressive or interlaced scanning
- Europe: Digital Video Broadcasting (DVB)
  - DVB-S, DVB-C, DVB-T, DVB-H
  - No paneuropean transition
    - Each country transitioned differently

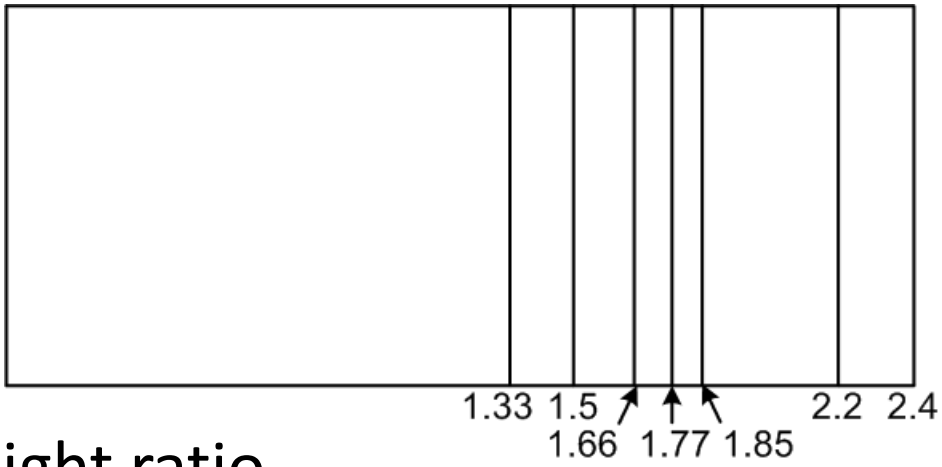
HDTV (3 of 3)

- ATSC: Three quality levels
  - SDTV: corresponds to SIF
    - Similar detail to analog TV
  - EDTV: corresponds to CCIR-601
    - Higher definition
  - HDTV: higher resolution with 3 options
    - 720p: 1280 x 720 progressive
    - 1080i: 1920 x 1080 interlaced
    - 1080p: 1920 x 1080 progressive

HD Video terminology

- HD Ready: 720p (1280x720)
  - The original HD format
- Full HD: 1080p (1920x1080)
  - When it came out, HD Ready was retrofitted
- 2k: 2560 x 1440
  - Also called QHD (4 times 720p)
- 4k: 3840 x 2160
  - We now count the horizontal resolution!

Aspect ratios



- Width to height ratio
  - Analog TV: 1.33 (4:3)
  - 35 mm still film: 1.5 (3:2)
  - Computers: 1.66 (15:9)
  - HDTV: 1.77 (16:9)
  - Motion pictures: 1.85-2.2-2.4
    - Anamorphic lenses fit these into 35mm movie film!

Animation

Class: Multimedia Technology, **Section # 11:** Video

Instructor: George Xylomenos, **Department:** Informatics

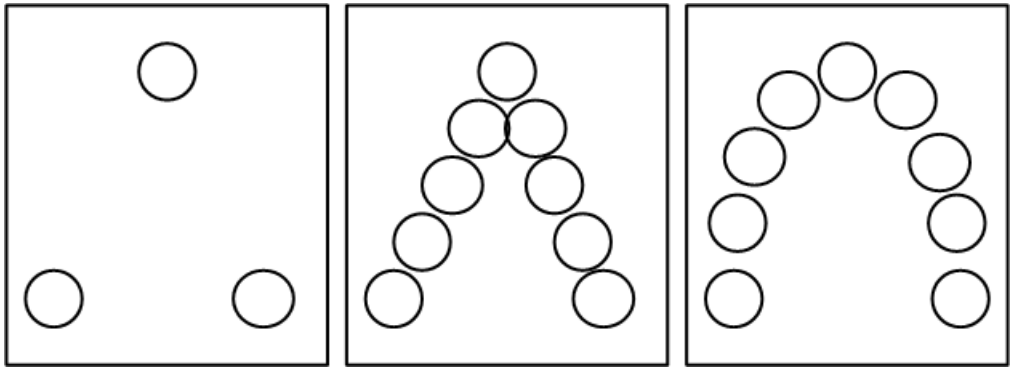
Animation (1 to 5)

- Dynamic form of graphics
  - Computer generated
  - Based on paintings or drawings
- Key frames
  - Edge or characteristic positions of drawing
  - Direct drawn or scanned from paper
  - Programmatically generated

Animation (2 to 5)

- Motion generation
  - Key frames: drawn
  - Intermediate frames: calculated
- Linear interpolation
  - Consider each point of a drawing
  - Create a linear trajectory from start to end
  - Draw the point for each frame
  - Realistic only for simple trajectories

Animation (3 to 5)



- Spline curves
  - The trajectory is a curve
  - Which fits the points in each keyframe
  - Smoother interpolation between frames
    - More realistic than linear

Animation (4 to 5)

- Wireframe movement
  - Used in modern animation
  - Each object represented by a wireframe
    - Two or three dimensional
  - Interpolation for the movement of each point
    - Calculation of intermediate positions
    - Drawing of lines between them
  - Projection of texture on the wireframe

Animation (5 to 5)

- Physics models
  - Calculation of forces affecting objects
    - Push, gravity, collision, deformation
  - Special libraries (PhysX)
  - Custom hardware (PPU)
  - Simplifies programmer's job
    - No need to calculate each one individually

Double buffering

- Drawing directly on refresh buffer
  - What happens if we read it at the same time
  - A frame can have partial lines in it
- Two refresh buffers
  - One used to update the screen
  - The other used for drawing
  - When drawing is finished, they are switched

Transmission of animation

- Symbolic transmission
  - Symbolic representation of objects
  - Commands to move objects
  - Small but variable bandwidth
  - Requires image drawing at the receiver
- Raster transmission
  - Image drawn at sender
  - Entire raster is transmitted
  - Large but fixed bandwidth

End of Section # 11

Class: Multimedia Technology, **Section # 11:** Video

Instructor: George Xylomenos, **Department:** Informatics