**Motion**

- sequence of frames
- frame
  - 2d array of pixels
- pixel pitch = size of a pixel
- if h = v, we call this a square pixel

**CRT Concepts**

- scan line
- horizontal retrace
- vertical retrace
- raster (gr. rustum)
- shadow mask

**Video**

- Representation of Motion
- CRT Concepts
- Video Characteristics

**Principles & Applications of Multimedia**

Dr. Antonio C. Siochi
PCSE Department, CNU

Motion sequence of frames
frame
2d array of pixels
pixel pitch = size of a pixel
if h = v, we call this a square pixel
**CRT CONCEPTS**

- electron beam impinges on phosphor coating, resulting in glow
- b/w = 1 gun, color = 3 guns + 3 phosphors
- one frame = one complete scan (480 visible scan lines)

**VIDEO CHARACTERISTICS**

- aspect ratio: ratio of frame width to height
- standard TV is 4:3
- Wide screen (e.g., some DVDs) 16:9
- movies 1.85:1 or 2.35:1 (even wider)

**VIDEO CHARACTERISTICS**

- to perceive motion, show succession of images: image, black, image, black, ...
- flash rate = images / second
- must be high enough to give illusion of motion (afterimages)
- must be high enough to avoid flicker
- flicker = fluctuating brightness

**FLASH v. FRAME RATE**

- flash rate depends upon ambient light levels
- higher rate needed for higher levels
- movie theater: 48 images / sec (48 Hz)
- film stock expensive, so flash same frame 2x
- frame rate is 24fps! This is adequate for motion illusion.
**Other Rates**

- TV viewing area is brighter - 60Hz flash rate required
- Office areas brighter yet - 70Hz

**TV Frame Rates**

- TV frame rate is nominally 30fps
- Amount of data required to send 30fps too much for TV bandwidth
- Can’t send fewer frames, else start to lose motion illusion and greater risk of flicker
- Send 1/2 a frame, 60 times / sec
- 1/2 frame = every other scan line (interlace)

**Limited Bandwidth**

- Assume a frame consists of 480 lines
- We can only send 240 lines at a time (limited bandwidth)
- Can send 240 lines (field) in 1/60th second
- So send 1st 240 lines, then 2nd 240 lines
- This will take a total of 2/60th or 1/30 second

**Interlaced Video**

- Diagram of interlaced video display
Interlace problems
stills from video - need to combine two fields
(de-interlace video)

if motion is rapid, subject will have moved -
won’t be in same relative position in each field

Scanning Notation
lines per raster / rate / interlace
US/Japan 525/59.94/2:1(480 picture lines)
European 625/50/2:1 (576 picture lines)
not all of lines in a raster contain picture - some
contain timing information/overhead
**Horizontal Resolution**

- Measured in terms of lines.
- Confusing: not number of lines top to bottom (that is always 525 total, or 480 picture).
- Number of vertical line pairs that can be discerned along a horizontal line.

**Pixels?**

- Scan line has no inherent horizontal resolution.
- Use a pixel clock to divide each line into samples (pixels).

<table>
<thead>
<tr>
<th>VHS</th>
<th>SVHS</th>
<th>Beta</th>
<th>8mm</th>
<th>Hi8</th>
<th>miniDV</th>
</tr>
</thead>
<tbody>
<tr>
<td>240</td>
<td>425</td>
<td>500</td>
<td>300</td>
<td>425</td>
<td>720</td>
</tr>
</tbody>
</table>

**NTSC Signal**

- White (0.714 V)
- Black (0.055 V)
- Blank (0 V)
- Sync (~0.286 V)
- Pixel clock

- Horizontal retrace
- Active line signal

**Interlaced Video**
**PROGRESSIVE SCAN**

- no fields - top to bottom, all scan lines
- denoted “p” (interlaced is “i”)
- emerging digital formats

<table>
<thead>
<tr>
<th>480p</th>
<th>640 x 480</th>
</tr>
</thead>
<tbody>
<tr>
<td>720p</td>
<td>1280 x 720</td>
</tr>
<tr>
<td>1080i</td>
<td>1920 x 1080</td>
</tr>
<tr>
<td>1080p</td>
<td>1920 x 1080</td>
</tr>
</tbody>
</table>

**PIXELS?**

- how to relate pixels v. lines
- assume square pixels
- multiply lines by aspect ratio
- 480 lines * 4/3 = 640 (pixels per line)
- why: aspect ratio is width / height, aka pixels per line / lines

**COLOR**

- NTSC - how to fit color into BW signal
- backwards compatibility issue
- strategy: humans not equally sensitive to colors; humans more sensitive to intensity; therefore reduce amount of color information in favor of intensity
- chroma - color signal
- luma - intensity signal

**NTSC INTERLEAVE**

- NTSC Interleave
**Interleave**
- luma signal not changed, chroma signal inserted in between
- BW receivers only detect luma
- Color TVs use comb filter to separate chroma from luma
- But at 60 fields/sec, audio signal would be affected (no space to fit both color and audio)

**Reduce Field Rate**
- from 60 to 59.94 fields per second
- 60 fields is now longer than 1 second!
- Drop Frame - don’t use (skip) two frames at the start of every minute, except for every 10th minute
- on average, one frame in 1000 is dropped
- 6000 frames, drop 6 gives 5994 frames

**Time Code**
- HH:MM:SS:FF
- drop frame will drop frames 00:00 and 00:01 once a minute, except for each 10th minute

**Different Color Schemes**
- Component - use three signals
  - RGB, YUV, YIQ, YPbPr, YCbCr
- S-Video - use two signal (combine color)
  - Luma - Chroma
- Composite - use one signal (combine all)
  - NTSC interleave
**Quality?**
- best-worst: Component, S-Video, Composite
- why: combination of signals causes interference, harder to separate, loss of information

**Color Coding for Video**
- RGB will not fit in NTSC bandwidth
- YUV: Y represents luminance, U, V chrominance
- Majority of bandwidth given to Y. U, V use less
- HVR more sensitive to luminance than color
- represent color as a difference

**Convert RGB to YUV**

<table>
<thead>
<tr>
<th></th>
<th>Y'</th>
<th>U</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.299</td>
<td>-.299</td>
<td>.701</td>
</tr>
<tr>
<td></td>
<td>.587</td>
<td>-.587</td>
<td>-.587</td>
</tr>
<tr>
<td></td>
<td>.144</td>
<td>.866</td>
<td>-.144</td>
</tr>
</tbody>
</table>

R' = $\begin{bmatrix} \cdot299 & \cdot587 & \cdot144 \end{bmatrix}$

**Equivalent Form:**

\[
\begin{align*}
U &= -.299R' + -.587G' + .866B' \\
Y &= .299R' + .587G' + .144B' \\
U+Y &= 0 + 0 + B' \\
\text{So, } U &= B' - Y, \text{ hence it's a difference.}
\end{align*}
\]

What is V?
**Equivalent Form:**

\[
V = 0.701R' - 0.587G' - 0.144B' \\
Y = 0.299R' + 0.587G' + 0.144B' \\
V + Y = R' + 0 + 0
\]

So, \( V = R' - Y \), hence it’s a difference.

**What if \( R' = G' = B' \)?

\[
Y' = 0.299R' + 0.587R' + 0.144R' = (0.299 + 0.587 + 0.144)R' = R' \\
U = (-0.299 + -0.587 + 0.886)R' = 0
\]

similarly for \( V \)

- grayscale means \( U, V \) are zero (no color)!

**YIQ**

- Version of YUV, where \( Y \) is the same but
  - \( I = (R' - Y')\cos(33) - (B' - Y')\sin(33) \)
  - \( Q = (R' - Y')\sin(33) + (B' - Y')\cos(33) \)
- shifts color more into skin tones
- used by NTSC. (YUV used by PAL)

**YCbCr**

- variation on YUV
- used in Digital Video (MPEG, JPEG)
**COMPONENT VIDEO**

- YUV, YIQ, YCbCr, YPbPr
- Luminance and both color components are kept separate
- Need three channels (cables)
- High bandwidth, won’t fit NTSC

**S-VIDEO**

- Combine U and V into single color signal, C
- Y' / C designates S-video

**COMPOSITE**

- Y' and C are combined into single signal
- Only one channel required

**NTSC ENCODER**

- Y'
- U
- V
- mod
- cos
- sin
- mod
- S-Video
- Composite
**PAL**

- Phase Alternating Line
- Western Europe, China
- Alternate phase (sign) on each line -U, +U
- Average the signals, cancel the chroma
- Allows Y/C separation

<table>
<thead>
<tr>
<th>Y0, -U0, -V0</th>
<th>Y0, -U0, -V0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1, +U1, +V1</td>
<td>(Y1+Y0)/2, (+U1-U0)/2, (+V1-V0)/2</td>
</tr>
<tr>
<td>Y2, -U2, -V2</td>
<td>(Y2+Y1)/2, (-U2+U1)/2, (-V2+V1)/2</td>
</tr>
<tr>
<td>Y3, +U3, +V3</td>
<td>(Y3+Y2)/2, (+U3-U2)/2, (+V3-V2)/2</td>
</tr>
</tbody>
</table>

**NTSC/PAL FOOTPRINT**

- NTSC and PAL both combine Y/C signals
- Signals will interfere to some extent
- Irreversible change in color information
- NTSC - interference between frequency components
- PAL - averaging of alternating line signals

**DIGITAL VIDEO**

- Pixels, rather than varying voltage
- Commonly uses YCbCr for color coding
- Bitrate rather than bandwidth is issue

**BIT RATES**

- Display audio/video requires display or transmission speed/capacity (bits/sec)
- Single speed CD data rate is 150Kbytes/sec
- Video with bitrate > 150Kbytes/sec will not play smoothly
DV (NTSC) Example

- 525 lines/frame
- 858 px/line (720 visible)
- 30 fps
- 2 bytes/px (4:2:2)
- 8 bits/byte
- = 216Mbps DV data rate
- with compression, ~27Mbps (220MB/min)