Analog and Digital Video Basics

Nimrod Peleg
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Video Compression: list of topics

• Analog and Digital Video Concepts
• Block-Based Motion Estimation
• Resolution Conversion
• H.261: A Standard for VideoConferencing
• MPEG-1: A Standard for CD-ROM Based App.
• MPEG-2 and HDTV: All Digital TV
• H.263: A Standard for VideoPhone
• MPEG-4: Content-Based Description
Analog Video Signal: Raster Scan
Odd and Even Scan Lines

1280 pixels wide

720 pixels tall

\[
1280 / 720 = 1.78 \text{ so a 720p signal is 1.78 times wider than tall (called a 16:9 image)}
\]
Analog Video Signal: Image line

- **white**: 1V
- **black**: 0.3V
- **sync**: 0V

The diagram shows a non-interlaced RS170 black-and-white NTSC signal with a pulse length of 63.55 us and a repetition rate of 242 image lines per second. Each line consists of 5 black segments, 3 vertical sync segments, and 12 black segments.
Analog Video Standards

• All video standards are in color.

• Almost any color can be reproduced by mixing the 3 additive primaries:

  R (red), G (green), B (blue)

• 3 main different representations:
  – Composite
  – Component or S-Video (Y/C)
Composite Video
Component Analog Video

• Each primary is considered as a separate monochromatic video signal
• Basic presentation:
  
• Other RGB based:
  – YIQ
  – YCrCb
  – YUV
  – HSI

To Color Spaces Demo
Composite Video Signal

Encoding the Chrominance over Luminance into one signal (saving bandwidth):

– **NTSC** (National TV System Committee)
  North America, Japan
– **PAL** (Phased Alternation Line)
  Europe (Including Israel)
– **SECAM** (Systeme Electronique Color Avec Memoire)
  France, Russia and more
## Analog Standards Comparison

<table>
<thead>
<tr>
<th></th>
<th>NTSC</th>
<th>PAL/SECAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defined</td>
<td>1952</td>
<td>1960</td>
</tr>
<tr>
<td>Scan Lines/Field</td>
<td>525/262.5</td>
<td>625/312.5</td>
</tr>
<tr>
<td>Active horiz. lines</td>
<td>480</td>
<td>576</td>
</tr>
<tr>
<td>Subcarrier Freq.</td>
<td>3.58MHz</td>
<td>4.43MHz</td>
</tr>
<tr>
<td>Interlacing</td>
<td>2:1</td>
<td>2:1</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>4:3</td>
<td>4:3</td>
</tr>
<tr>
<td>Horiz. Resol.(pel/line)</td>
<td>720</td>
<td>720</td>
</tr>
<tr>
<td>Frames/Sec</td>
<td>29.97</td>
<td>25</td>
</tr>
<tr>
<td>Component Color</td>
<td>YUV</td>
<td>YCbCr</td>
</tr>
</tbody>
</table>
Analog Video Equipment

- Cameras
  - Vidicon, Film, CCD

- Video Tapes (magnetic):
  - Betacam, VHS, SVHS, U-matic, 8mm ....

- Optical Video Disk

- Displays

All for all video standards!
First TV sets

before 1935: "Mechanical Television Era". The display had a small motor with a spinning disc and a neon lamp, which worked together to give a blurry reddish-orange picture about half the size of a business card!

1939 - (GE-HM171) 5" tabletop, wood (mahogany), 3 channels, vision only - no sound!

From: http://www.tvhistory.tv/
Digital Video

• Developed with **CD-ROM Technology**

• Brings *computers and communication* together in a truly revolutionary matter:
  – Personal computer
  – VideoPhone, FAX, HDTV, Live video (with processing), Local image printer,
    Video Conferencing, ......
Digital Video Formats

• For a number of years: professional TV studios used D1 (component) and D2 (composite) digital formats.

• CCIR digitization (CCIR601) and interfacing (CCIR656) for digital video is base line for all formats, using component form known as 4:2:2 (Y, Cb, Cr).
CCIR Digitization

• For component video signals (studio source) with BW=6MHz, CCIR sampling rate is 13.5MHz, independent of scanning standard

• This rate represents $864 \times F_h$ for 625 systems and $858 \times F_h$ for 525 systems.

• Active lines per frame is 720 for both.
• For 8 bits/sample: $13.5M \times 8 = 108M$ bit/sec.
Digital Video (CCIR 601)

- **Coded Signals**: Y, Cb, Cr

- **Samples/line**: 858 (NTSC) / 864 (PAL)
  - for color components: 429 / 432

- **Active samples**: 720
  - for color components: 360

- **Quantizer**: Uniform PCM, 8 bit/sample (Y,Cb,Cr)

- **Gray levels Scale**: 0 - 255
  - Y: 220 Q levels (black:16, gray-white:235)
  - Cb,Cr: 225 Q levels (zero: 128)
Digital Video Signal

- **TrueColor**: RGB, 24 bit (~16M colors)

- **Resolution**: lack of sufficient resolution causes pixellation (blockization).

- **Synchronization**: No need (“computer made”).

- **Conversion**: A/D & D/A after cameras and before display (still too expensive).

- **The bottleneck**: BITRATE
BitRates

- CD Quality digital audio:
  44.1KHz * 16bps *2 (stereo) = ~1.4Mbps

- HDTV: about 1Gbps

One picture worth (almost) a 1000 words...
### Digital Video Resolution (CCIR601, 4:2:2)

<table>
<thead>
<tr>
<th></th>
<th>525/60 (NTSC)</th>
<th>625/50 (PAL)</th>
<th>CIF</th>
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<tbody>
<tr>
<td><strong>Active pel/line</strong></td>
<td></td>
<td></td>
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<tr>
<td>Lum (Y)</td>
<td>720</td>
<td>720</td>
<td>360</td>
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<tr>
<td>Chroma (U,V)</td>
<td>360</td>
<td>360</td>
<td>180</td>
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<tr>
<td><strong>Active lines/pic</strong></td>
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<tr>
<td>Lum (Y)</td>
<td>480</td>
<td>576</td>
<td>288</td>
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<tr>
<td>Chroma (U,V)</td>
<td>480</td>
<td>576</td>
<td>144</td>
</tr>
<tr>
<td>Interlacing</td>
<td>2:1</td>
<td>2:1</td>
<td>1:1</td>
</tr>
<tr>
<td>Rate/Aspect Ratio</td>
<td>60/4:3</td>
<td>50/4:3</td>
<td>30/4:3</td>
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</tbody>
</table>
## Network protocols and Bitrates

- Conventional telephone: 0.3-56Kbps
- ISDN: 64-144Kbps
- T-1: 1.5Mbps
- Ethernet (Packet based): 10M/100M bps
- Broadband ISDN: 100-200Mbps
- ATM (Cell based): 155Mbps …..
- Fast Ethernet: 1Gbps ….
Proprietary Video Formats

• DVI, Indeo
• QuickTime
• CD-I
• PhotoCD
• CDTV
• And many more….

Intel
Apple
Philips
Eastman Kodak
Commodore
Why Digital Video?

- Quality
- Error correction
- Interactivity
- Computer control (s/w)
- Real-time playback and all kinds of editing
- Integration of many multimedia platforms
- And more .......
A Summary of Video Formats

• CCIR Size (D1) Progressive Pictures:
  – NTSC - 720x480 (29.97 Pictures/Sec)
  – PAL - 720x576 (25 Pictures/Sec)

• CCIR Size (D1) Interlaced Pictures:
  – NTSC - 720x(240x2) (29.97 Pictures/Sec)
  – PAL - 720x(288x2) (25 Pictures/Sec)

• HD1 (Half D1) Progressive Pictures:
  – NTSC – 352x480 (29.97 Pictures/Sec)
  – PAL – 352x576 (25 Pictures/Sec)

• HD1 (Half D1) Interlaced Pictures:
  – NTSC – 352x(240x2) (29.97 Pictures/Sec)
  – PAL – 352x(288x2) (25 Pictures/Sec)
Video Formats  (Cont’d)

• **SIF (Source Input Format):**
  – NTSC – 352x240  (29.97 Pictures/Sec)
  – PAL – 352x288   (25 Pictures/Sec)

• **QSIF:**
  – NTSC – 176x112  (29.97 Pictures/Sec)
  – PAL – 176x144   (25 Pictures/Sec)

• **CIF (Common Intermediate Format):**
  – 352x288        (30 Pictures/Sec)

• **QCIF Size Pictures:**
  – 176x144        (30 Pictures/Sec)
Video Chroma SubSampling

RGB  575

YUV 4:2:2

YUV 4:2:0

YUV 4:1:1

The basic line sampling rate of 3.375MHz is common to both PAL and NTSC TV systems.
YCbCr 4:x:y Chroma Formats

<table>
<thead>
<tr>
<th>YCbCr</th>
<th>4:4:4</th>
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YCbCr 4:2:2
Color Decimation: 4:1:1 etc.

Half color Bandwidth !!
Color Decimation Effect

[Taken from: Wikipedia, “Chroma subsampling”]
Color decimation Artifacts: Moving text example

Original, single field. The moving text has some motion blur applied to it.

4:2:0 **progressive** sampling (single field) applied to moving interlaced material. The chroma leads and trails the moving text.

4:2:0 **interlaced** sampling (single field) applied to moving interlaced material.

Original still image.

4:2:0 **progressive** sampling applied to a still image. Both fields are shown.

4:2:0 **interlaced** sampling applied to a still image. Both fields are shown.
Why?

In the 4:2:0 interlaced scheme, vertical resolution of the chroma is **roughly halved** since the chroma samples effectively describe an area **2 samples wide by 4 samples tall** instead of 2X2.

- As well, the spatial displacement between both fields can result in the appearance of block-like chroma artifacts.
Hebrew Literature: analog video

• טלואיזיה בשחור-לבן ובצבע, בצב, מט”ח - 1982
• אוניברסיטת פתוחה