Video on Flat Panel Displays

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Image Quality?
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- Basics of Driving
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- Motion Blur

References, textbooks, papers

- R. M. Soneira: Display Artifacts and Image Quality, Information Display 9/05
- G. de Haan, PHILIPS, various publications
- N. Balram: Video Fundamentals, SID Short Course
Overview

Yesterday

Today

• Is this simple to do?

• Will the image quality be better?
Video Formats & Interfaces

• Analog video
  - NTSC
  - PAL
  - SECAM, ...

• Digital Video
  - MPEG2
  - H264, ...

• PC signals
  - Analog VGA
  - DVI, HMDI

• Movie 24p

Interfaces

- Composite (CVBS)
- S-Video (Y/C)
- Component (YUV)
- Analog HD component (YPbPr)
- Analog PC graphics (VGA)
- Digital PC graphics (DVI-HDCP)
- DVI-HDCP from PC
- HD-Ready TV
- IP - TV
- Tuner often built in

Many different signals have to be handled by modern TV sets!
Signal Processing Artefacts

Analog PAL camera captured & shown on PC

This could happen!

Original
De-interlacing by frame repetition
Doubling frame rate by repetition

Image quality depends nowadays more on software than on display technology
Raster Scan vs. Matrix Drive: Signals

Raster Scan: Serial Data

Matrix Drive: Parallel Data

Data (video)

H-Sync

V-Sync

1 Line (serial)

1 Frame

Data

Column 1

Column 2

(1 Line (parallel))

Row 1

Row 2

1 2 1 2

(pixel)

(selected line)

'tOld fashioned’ serial waveform must be processed by FPD’s!
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Basics of Driving

Signal Processing Tasks

Motion Blur
Typical Flat Panel Signal Processing Design & System

Universal Front-end processing unit

Analogue & digital inputs

DAC

Analogue display

Digital display

LCD dedicated back-end unit

PDP dedicated back-end unit

DLP dedicated back-end unit

Digital display

Here
Typical Tasks for Front-End Video Processing

- HDTV demodulation and decoding
- NTSC/PAL/SECAM decoding (luma, chroma, jitter removal)
- ADC conversion and synchronization to all PC formats
- Scaling of graphics and video inputs
- Video aspect ratio conversion
- Video noise reduction (analog & digital)
- Frame rate conversion
- De-interlacing of SD and HD video
- Image enhancement (e.g. edge enhancement)
- Picture-In-Picture (PIP)
- Colour Management
Typical Tasks for Back-End Video Processing

All: Output formatting for panel driving

- Overdrive for response time reduction
- Local dimming
- Field sequential color

- Sub-frame drive
- Flicker free coding
- Power level control (dimming)

- Sub-frame drive
- Sequential color for single panel DLP
- Keystone correction
Video on FPDs

Analog input

Digital input

Digital output: Display data
Selected Topics on Image Processing for FPDs

Tasks
- Resolution and frame rate
  - Easy to change for CRTs by graphics adapter
  - FPD resolution and frame rate are fixed
- Video is interlaced (also 1080i),
  FPDs are non-interlaced (progressive)

Therefore needed for FPDs
- Scaling (e.g. PAL SD TV → Full HD or laptop panel)
- Frame rate conversion (e.g. 50 Hz [source] → 60 Hz [laptop panel])
- De-Interlacing (interlaced [DVD] → non-interlaced [panel])

All-in-one image processors for FPDs (incl. projectors) are available
All - In - One – Interface & Timing Controller

SAA6714 Block Diagram (PHILIPS)
Scaling

• **Linear Scaling**
  - Resolution conversion (up- & down scaling)
  - Picture-in-Picture (PIP), …

• **Nonlinear scaling**
  - Aspect ratio conversion (e.g. 4:3 ↔ 16:9)

• **Variable scaling**
  - Keystone correction (projection)

**Methods:**
- Pixel repetition or dropping
- Interpolation (linear, cubic, …)
- Frequency domain
## Scaling Example: Character from $5 \times 7$ to $7 \times 9$ Pixel

<table>
<thead>
<tr>
<th>Original $5 \times 7$</th>
<th>'Upscaling':</th>
<th>Most easiest method:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$7 \rightarrow 9$ rows/lines</td>
<td>Double 2 rows and 2 columns</td>
</tr>
<tr>
<td></td>
<td>$5 \rightarrow 7$ columns</td>
<td></td>
</tr>
</tbody>
</table>

### Strategy:
- Display $1^{st}$ and $4^{th}$ row twice

### ... then:
- Display $1^{st}$ and $3^{rd}$ column twice

Is this good?
**Upscaling**

Examples:
- 5 x 7 = 35 pixel are upscaled to 63 pixel (7 x 9)
- This equals an upscaling factor of $\frac{63}{37} \approx 1.7$

- SD-Video (e.g. PAL-DVD 4:3) has 442,368 pixel
- FHD TV-set: 1920 x 1080 = 2,073,600 pixel (16:9)
- This results in an upscaling factor of $\frac{2}{0.45} \approx 4.7$

"Never ever SD on HD"
Scaling Example: Character from $5 \times 7$ to $4 \times 6$ Pixel

Original $5 \times 7$

Downscaling:
- 7 $\rightarrow$ 6 rows
- 5 $\rightarrow$ 4 columns

Most easiest method:
- Drop 1 row and 1 column

Strategy:
- Drop center row (4th)

... then:
- Drop center column (3rd)

Examples for downscaling: 10 MP pictures on PCs, medical X-ray images

Is this still readable?
Enhanced Scaling

- Any scaling (up or down) reduce image quality (blur, ...)
- Best quality when signal resolution equals FPD resolution
- New FPDs should be bought with scaling option for future resolutions
Scaling Methods

- **Spatial**
  - e.g. interpolation
  - Problem: Spatial invariance

- **Frequency Domain**
  - e.g. FIR filtering via FFT
  - Problem: Window function
Scaling Examples

Spatial scaling applying decimating and interpolating low-pass filters

**Original**

**Up scaling**

**Zero stuffing**

**Down scaling**

**Decimating low-pass filter**

**Interpolating low-pass filter**
Results of Scaling for LCD

- Upscaled 1 : 1.3
- Original 1 : 1
- Downscaled 1 : 0.8

(adjusted to same size)
Comparison of Scaling Algorithms for 1 : 1.3 Up Scaling

Commercial scaler of LCD

Advanced algorithm with subpixel resampling and root filtering

Sampedro, Blankenbach
SID IDRC 2002

Subpixel show different gray shades

Image quality of scaling can depend on foreground & background!
Subpixel Resampling

Grey scale value vs Position

Original

Pixel resampling

Subpixel resampling

Standard

Subpixel

Microsoft Clear Type

Grey scale value vs Position

Original

Pixel

Subpixel

Also applicable for digital interfaces
Comparison of Scaling Algorithms

Poor spatial scaling for pixel repetition and dropping

Good spatial scaling by proper interpolation filters

(magnified images)
Frame Rate Conversion

- **Frame repetition/dropping**
  - Okay for PC graphics
  - Causes judder for video

- **Linear interpolation**
  - Used for video
  - Causes blurring/double images

- **Motion-compensated interpolation** *(motion-vector-steered)*
  - Used in high quality standards conversion and 100 Hz TVs

- **Object-motion-based interpolation**
Frame Rate Conversion Visualization

- Original picture
- Interpolated picture

Time: 50 Hz input pictures vs. 100 Hz output pictures
Algorithm with simply merging Frame 1 with Frame 2 will fail:

2 light blue balls (= blue + white)!
Frame Rate Conversion

Motion interpolation - smooth movement

Spatial position

Judder from repeats

Source frame nr. : 1 2 2 3 3 4 4 5 5 6
Output frame nr. : 1 2 3 4 5 6
**Frame Rate Conversion Example**

FPDs: 50 Hz → 60 Hz: 5 frames @ 50 Hz → 6 frames @ 60 Hz (100 ms)

50 Hz → 75 Hz analogously, but easier to draw:

Same image is shown twice → no movement of ball

→ Motion artefacts (jerkiness, judder, smear) will occur!
Frame Rate Conversion Image Quality Degradation

Picture repetition leads to motion blur if the difference in picture rate of input and output exceeds the 30 Hz.
Frame Rate Conversion Image Quality Degradation

Judder and Blur

- Temporal Aliasing causes jerky motion – “judder”
- Up-conversion by repetition causes judder and blur because of eye tracking (see § Motion Blur)
Motion estimation could be complex including occlusions and revealing
Frame Rate Conversion Motion Estimation

Input Frame 1

Interpolated Frame Produced by FRC Algorithm

Input Frame 2

Image sequence showing multiple motions, occlusions, and complex motion.

How to estimate and calculate the bird's wing movement?
De - Interlacing

Odd

Vertical

Horizontal

1 3 5 7

+                      +

EVEN

3 5 7

2 4 6 8

=              =

Sub-frame 1         sub-frame 2

= superimposed image

Motion Artefacts (false contour, combing)
De - Interlacing Methods

- Spatial interpolation ("Bob")
- Temporal interpolation ("Weave")
- Spatio-temporal interpolation
- Median filtering
- Motion-adaptive interpolation
- Motion-compensated interpolation
- Inverse 3-2 and 2-2 pulldown (for film)
- Other (statistical estimation, model-based etc)
De - Interlacing

Temporal interpolation
Adding odd and even frames (fields)

Combing / Feathering
caused by improper handling of motion
De – Interlacing: Moving Edges

- Hardest problem in de-interlacing because odd and even lines are in different places.
- Combining odd and even lines causes feathering.
- Using spatial interpolation causes jaggies/staircasing.
De - Interlacing Improvements

Standard vertical interpolation
(better than only merging odd and even frames, see slides before)

Directional Correlational Deinterlacing algorithm
(DCDi™ by FAROUDJA)
(detects the directions of edges in the image. A vector interpolation algorithm correlated to these angles)
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Basics of Driving

Signal Processing Tasks

Motion Blur
Blur Effects

- **Spatial Blur**
  by limited bandwidth, jitter, …
  e.g. MTF, analogue path
  see ‘Display Metrology’

- **Motion Blur**
  by hold type
  displays (e.g. AM)
Motion Blur Basics

- Motion blur is caused by AM techniques due to lack of ‘auto-tracking‘ by human vision (PDP has similar issues on subframe coding)

- Impulsive displays like CRTs don’t suffer of motion blur

<table>
<thead>
<tr>
<th>Visualization</th>
<th>Perceived</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>'Display &amp; hold‘</td>
</tr>
<tr>
<td>CRT</td>
<td>'Flashing‘</td>
</tr>
</tbody>
</table>
Effect of Eye Movement

Non - Hold Type (CRT)

Hold Type (AMLCD, PDP similar)
Effect of Eye Movement on CRTs (Impulsive Drive)

White box is moved with 4 pixels per 60 Hz frame

Examined line

Display x

On Display, x

CRT

On eye, x

Eye movement

Perceived image by eye
Effect of Eye Movement on 60 Hz LCDs (Hold Type)

60 Hz LCD

On Display, x

1 F

t

Eye movement

On eye, x

1 F

t

Perceived image by eye

Unsharp edge ≡ blurring of 3 pixels
Effect of Eye Movement on 120 Hz LCDs (Hold Type)

120 Hz LCD

On Display, x

Eye movement

On eye, x

Perceived image by eye

Unsharp edge ≡ reduced blurring of 1 pixel
Effect of Eye Movement on Displays

White box is moved with 4 pixels per 60 Hz frame

Examined line

Display x

Perceived image by eye

CRT

60 Hz LCD

120 Hz LCD

- CRT has best motion picture quality
- LCD with 120 Hz is better than 60 Hz
## Displaying Moving Objects

<table>
<thead>
<tr>
<th></th>
<th>Original (2 pictures ‘movie’)</th>
<th>Non - Hold Type (CRT)</th>
<th>Hold Type (AM technologies)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frame 1</strong></td>
<td><img src="image" alt="Frame 1 Original" /></td>
<td><img src="image" alt="Frame 1 Non-Hold" /></td>
<td><img src="image" alt="Frame 1 Hold" /></td>
</tr>
<tr>
<td><em>(Picture 1 is completely written on the display)</em></td>
<td><img src="image" alt="Frame 1 Original" /></td>
<td><img src="image" alt="Frame 1 Non-Hold" /></td>
<td><img src="image" alt="Frame 1 Hold" /></td>
</tr>
<tr>
<td><strong>Frame 2</strong></td>
<td><img src="image" alt="Frame 2 Original" /></td>
<td><img src="image" alt="Frame 2 Non-Hold" /></td>
<td><img src="image" alt="Frame 2 Hold" /></td>
</tr>
<tr>
<td><em>(T = Frame 1 + 1/2 Frame 2)</em></td>
<td><img src="image" alt="Frame 2 Original" /></td>
<td><img src="image" alt="Frame 2 Non-Hold" /></td>
<td><img src="image" alt="Frame 2 Hold" /></td>
</tr>
<tr>
<td><em>(Half of picture 2 is written on the display)</em></td>
<td><img src="image" alt="Frame 2 Original" /></td>
<td><img src="image" alt="Frame 2 Non-Hold" /></td>
<td><img src="image" alt="Frame 2 Hold" /></td>
</tr>
</tbody>
</table>

Leftover of frame 1 not visible due to phosphor decay

$\frac{3}{4} T_{\text{Frame}}$

Smearing!
PDPs: Motion Artefacts by Sub-Frame Driving

Many motion artifacts etc. of PDPs can be minimized by massive signal processing.
Motion Blur Reduction Techniques

- Frequency Doubling
  - No luminance loss
  - Fit for LCD and PDP
  - Fast & advanced signal processing
  - Fast & advanced signal processing

- Impulsive Drive (like CRT)
  - Fits for LCD and PDP
  - Luminance loss
  - Flicker may occur

- Professional
  - Only for LED LCDs
  - Luminance loss
  - Flicker may occur

Commercial (1x0 & 2x0 Hz)

… like FRC incl. motion compensation & 24p
Comparison by SAMSUNG

Conventional 60Hz (MPRT ~ 15ms)

Impulsive driving (MPRT ~ 12ms)

120Hz McFi driving (MPRT ~ 8ms)
Impulsive Backlight for LCD Hold-Type Technologies

Frame 1
- Write grey level data to display
- Backlight OFF
- $T_{\text{Blackframe}} = \frac{1}{2} T_{\text{Frame}}$

Frame 2
- Write grey level data to display
- Backlight ON
- $T_{\text{Display}} = \frac{1}{2} T_{\text{Frame}}$

Result: 8.3 ms instead of 16.7 ms
→ fast switching LC required

No smearing
Impulsive Backlight for LCD Hold-Type Technologies

Scrolling of 'black' backlight sections due to response time
Comparison by SIEMENS

M. Zachmann (Pforzheim U) et al.

Evaluate your display with PIXPERAN (freeware)
Motion Blur for Movies

- Movies have originally 24 Hz ('analogue for theaters')
- Movies on DVDs or Blue-Ray have 50 Hz (PAL) or 60 Hz (NTSC)
- Frame rate conversion (FRC) can fail for 24 Hz movies

→ 24 Hz detection algorithm and dedicated motion compensation
Movie to Video Frame Rate Conversion

• Conversion of 24 frames/sec into 60 fields/sec:
  4 movie frames mapped to 5 video frames (even + odd = 10)

• In this process, one movie frame is mapped into 3 video fields, the next into 2, etc...
  Referred to as “3:2 pulldown”

• Similar process used to convert 25 frames/sec to 50 fields/sec (PAL) and 30 frames/sec to 60 fields/sec (“2:2 pulldown”)
Frame Rate Conversion Techniques (I)

PAL Video 50 Hz $\Rightarrow$ Motion blur on Hold type displays (LCD, ...)

PAL Video 100 Hz repeated $\Rightarrow$ judder

PAL Video 100 Hz motion compensated $\Rightarrow$ no judder (if algorithm OK)

calculated
Frame Rate Conversion Techniques (II)

Movie 24 Hz (24p) Original

Movie 60 Hz 3:2 pull down repeated ⇒ judder, jerkiness

Movie 120 Hz motion compensated ⇒ no judder (if algorithm OK)
Frame Rate Conversion Techniques (II)

3:2 pull down  
Motion compensated film mode
Summary

• Signal processing necessary for displaying SD video on FLDs:
  - scaling, frame rate conversion, de-interlacing

• (Impulsive drive) CRTs have (still) best motion picture performance

• Hold type (AM, PDPs) display cause notion blur

• Compensation of motion blur by:
  - doubling (tripling) of frame rate, black frame insertion

• Processing of 24 Hz movies by 24 Hz detection & algorithms for FRC