Evaluation of Moving-Line Contrast Degradation without Motion

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Moving Lines on Hold-type Displays

Lines moving on flat panel displays (hold-type) behave strangely:
- they cause flicker,
- they tend to disappear,
- they are perceived as spreading,
- etc.

Can that sensitivity be used for evaluation of the dynamical properties of flat panel displays?

Dark line advancing on bright background, IPS LCD-monitor, 60 Hz frame frequency, 1ms exposure time.

Human eye follows motion and integrates over one frame period ⇒ perceived spreading of line

Spreading of line (w=1 pixel) on ideal hold-type display: ~ Δ+1, Δ: advancement per frame period
3 gray-levels line-patterns on 3 gray-level backgrounds, variable spatial frequency (lines per pixel).

- measurement with pursuit camera,
- evaluation of spatial contrast modulation.
Moving Lines on Hold-type Displays

max. 900 TV lines can be resolved on this display

max. 300 TV lines can be resolved on this display

high resolution image from tracking camera

evaluation via Fourier transformation

from I. I. Kawahara, M. Kasahara, T. Shinoda, IDW'07

APDC Advanced PDP Development Center Corporation www.advanced-pdp.jp
Moving Lines on Hold-type Displays

How can we measure the contrast degradation of lines in motion without high-magnification tracking camera systems?

How can we measure the contrast degradation of lines in motion without high-magnification tracking camera systems?

**IMPULSE:**

fastest event that can be shown on an electronic display;
ON or OFF for 1 frame period only.

impulse response

\[ \Delta = w \]
Moving Grating

- Optical response
- Input data
- Ideal hold-type
- Exponential RC-type

Parameters:
- Δx: space
- Δt: time
- Frame period
- Eye movement

Data Array:

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Moving Grating

- Optical response
- Input data
- Ideal hold-type
- Exponential RC-type
- Time
- Space
- Frame period
- Eye movement
- Fixed location
Periodic Responses

1 frame period hold-time: impulse responses  

20 frame periods: step responses

Frame-integrated dynamic contrast

\[
C_{\text{dyn}} = \frac{L_{\min} + I_1 \cdot (L_{\max} - L_{\min})}{L_{\min} + I_2 \cdot (L_{\max} - L_{\min})}
\]

ideal hold-type: 
\[I_1 = 1, I_2 = 0\]

\[
C_{\text{stat}} = \frac{L_{\max}}{L_{\min}}
\]

\(\Rightarrow\) not easy to determine frame limits (phase)
Periodic Responses

1 frame period hold-time: impulse responses
20 frame periods: step responses

Frame-integrated dynamic contrast

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not easy to determine frame limits (phase)
Periodic Responses

- Periodic responses - 1, 2, 3, 5 frame periods hold-time
- Frame period convolution

- Step response
- Static contrast
- Impulse response
- Dynamic contrast

Graphs showing step response and impulse response with frequency [cycles/frame] and contrast vs. time [ms].

Ideal hold type and frame-convoluted contrast contrast vs. frequency [cycles/frame].

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Variable Hold-Time Periodic Response

- **Input Data [RGB]**
- **Time [frame]**: 1 2 3 4 5

**Graphs:**
- **Ideal Hold Type**: 0 ↔ 255
- **Frame Convolution**
- **Frame Integration**
- **Frame-convoluted Contrast**
- **Frame-integrated Contrast**

**Contrast (log scale):**
- 1000
- 100
- 10
- 1

**Frequency [cycles/frame]:**
- 0 → 255

**Legend:**
- Frame conversion
- Frame integration

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display-metrology.com
Comparison of periodic impulse response measured with
- high-speed camera (oversampling, $T_x = 1\text{ms}$),
- optical transient recording (at fixed location).
Impulse Response Evaluations

MTF evaluations provide basis for comparison of DUTs but no information about contrast.

Single-shot impulse response is not characteristic for visual characteristics of LCD dynamics.

dynamic contrast (frame integrated): \(0.509/0.239 = 2.13\) \(0.706/0.284 = 2.49\)
dynamic contrast (frame convoluted): \(6.037\) \(5.662\)

Analysis of dynamic properties of displays based on the (idealized single-shot) impulse response by M. A. Klompenhouwer, e.g. SID'05 Digest, pp. 1578-1581, SID'06 Digest, pp. 1700-1703
Dynamic Modulation Transfer Function

\[ I_i(n) \]

\[ A_i \]

\[ I_p(n) \]

\[ A_p \]

\[ DMTF(V,f) = \frac{A_p(V,f)}{A_i} \]

Zhang, Teunissen, et al.

Taiichiro Kurita, Asako Saitoh, Ichiro Yuyama,
Consideration on Perceived MTF of Hold Type Display for Moving Images, IDW'98 Digest, pp. 823-826

Yuning Zhang, Kees Teunissen, Wen Song, and Xiaohua Li,
Dynamic modulation transfer function: a method to characterize the temporal performance of liquid-crystal displays,
Optics Letters 33, 6(2008), pp. 533-535
Dynamic Modulation Transfer Function

Comprises a variety of gray-level transitions.

Zeros of DMTF due to frame period convolution of moving pattern.
## Comparison of Approaches

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**Graph:**
- **x-axis:** frequency [cycles/frame]
- **y-axis:** contrast
- **Legend:**
  - Frame-convoluted Contrast
  - Frame-integrated Contrast
  - Ideal Hold Type

**Legend Box:**
- 0 ↔ 255
Conclusion

- frame synchronized driving of DUT (extended area), with hold time as variable,
- recording of luminance vs. time (at fixed location),
- **frame convolution** of optical response to reproduce SPET, or
- **frame integration** of optical response,
- evaluation of contrast of moving pattern (on retina),
- dynamic contrast vs. hold time (impulse to step response),
- complete characterization of DUT dynamics in terms of contrast.

![Graph showing contrast vs. frequency for step response, static contrast, frame-convoluted contrast, and frame-integrated contrast.](image-url)
Thank you very much for your attention

DM&S - we measure what your eyes see ...