Psychophysical study of LCD motion-blur

Sylvain Tourancheau
Patrick Le Callet

University of Nantes
IRCCyN-IVC Lab
(France)

Kjell Brunnström
Börje Andrén

Acreo AB
Video and Display Quality Lab
(Sweden)

LCD motion-blur

- LCD motion-blur occurs on the edges of moving objects
- Combination of two factors:
  - LCDs are hold-type displays: light is maintained on the screen during the frame period
  - Eye-tracking / Smooth pursuit

LCD motion-blur is not only a technical issue but also a perceptual matter

Problematic

- Motion-blur measurements are now well-established

Is perception correlated with measurements ?

- In current recommendations (VESA), motion-blur value is taken as the average of motion-blur measurements over transitions

Is this relevant regarding perception ?

Objective

- Perception of LCD motion-blur is explored through a blur-matching experiment
- 3 different displays, 20 transitions, and up to 9 speeds

- Goal is to compare perceived motion-blur with measured motion-blur

Psychophysical study of LCD motion-blur

- Objective measurements of motion-blur
- Psychophysical experiments
- Results
- Conclusion

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Methods of measurements

- Spatio-temporal measurements:

high-speed camera picturing a moving edge

  - tracking camera
  - rotating mirror
  - stationary camera + motion compensation
  - etc.

- Temporal measurements: edge profile is obtained from the temporal step-response

H. Pan, X.-F. Feng, and S. Daly, “LCD motion blur modeling and analysis,” ICIP 2005
A. B. Watson, “The SSO: A human vision model for display inspection,” SID 2006

Choice of the method

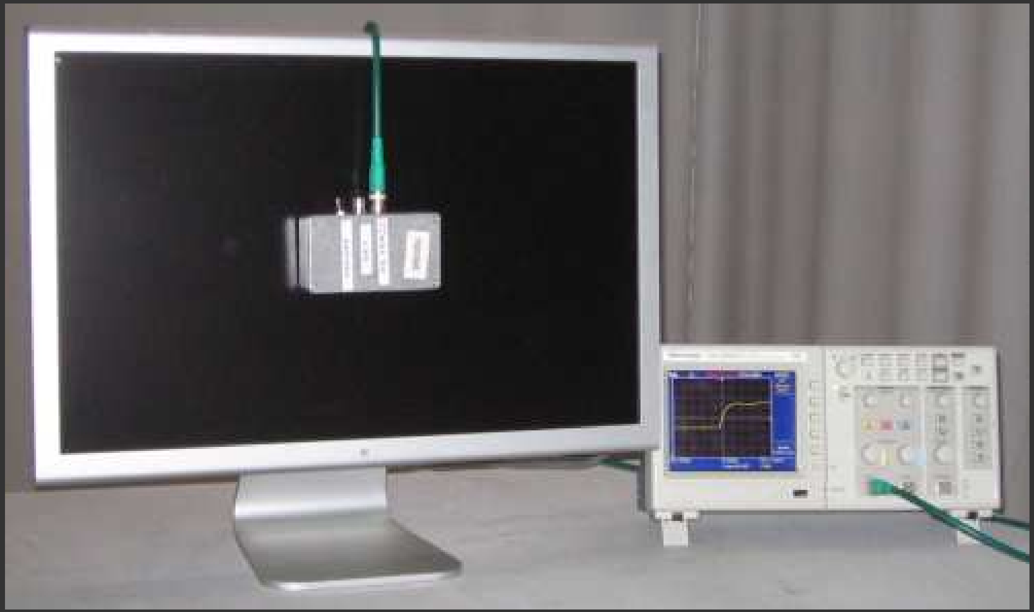
- Both methods have been compared and have shown very similar results

Tourancheau *et al.*, ‘‘LCD motion-blur estimation using different measurement methods,’’ Journal of the SID, Vol.17, 2009

- Temporal method have been chosen:
  - high sample-rate => high resolution edge profile
  - easy to carry out and less time-consuming
  - reproducible from one lab to another

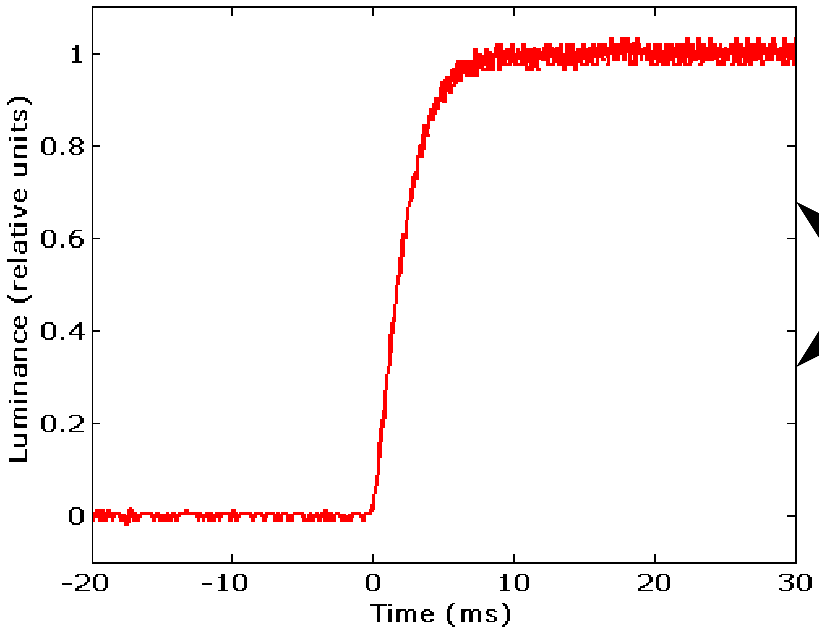
Apparatus

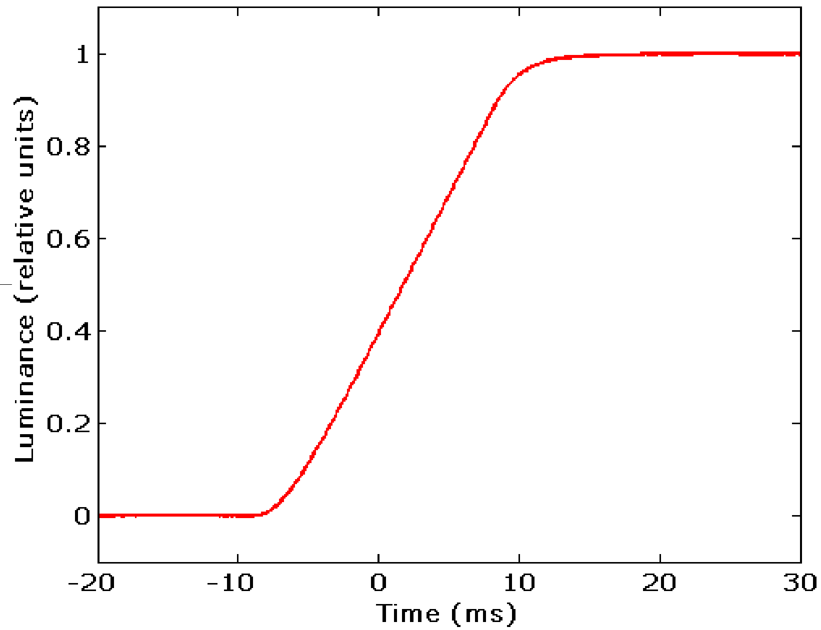
- Fast photo-diode
- Sample-rate: 10 kHz (Ts = 0.1 ms)
- Data acquired on oscilloscope



Blurred edge profile

- Obtained by a convolution of the temporal step-reponse with a unit-window with a width of one frame period

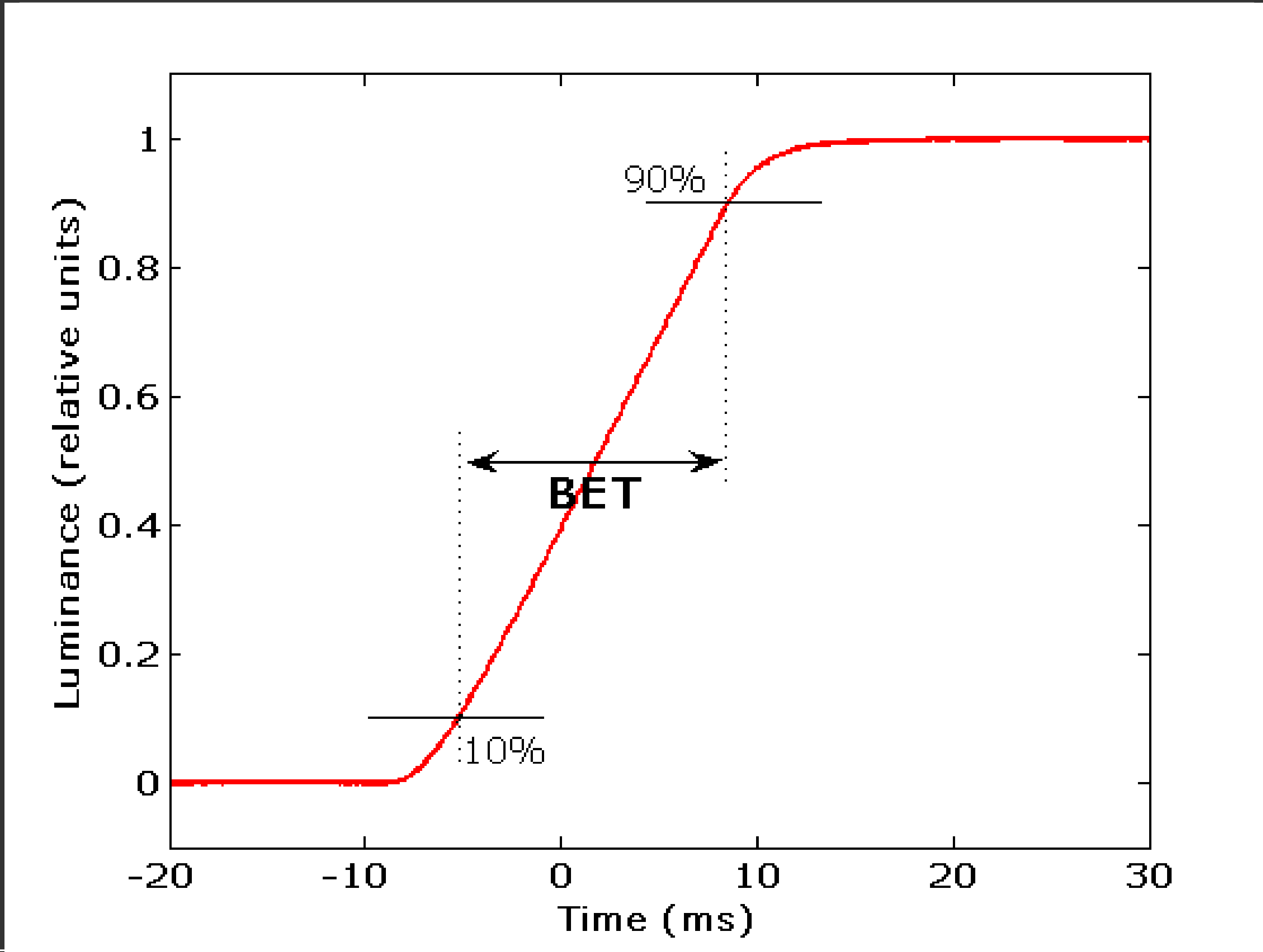




Blurred edge time

- Blurred edge profile in the temporal domain
- Blurred edge time (*BET*) is computed from 10% to 90% of the edge dynamic

Blurred edge time



Measured blur vs speed

- Time domain → Space domain
  by scaling time axis with speed V

- Blurred edge width (*BEW*):

$$\boxed{BEW_m = BET.V}$$

Measured *BEW* is proportional
to speed *V* with a factor equal to *BET*

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Description

- Blur matching experiment
- Task: Observers have to adjust the blur of a stationary edge until it matches their perception of the motion-blur occurring on a moving edge

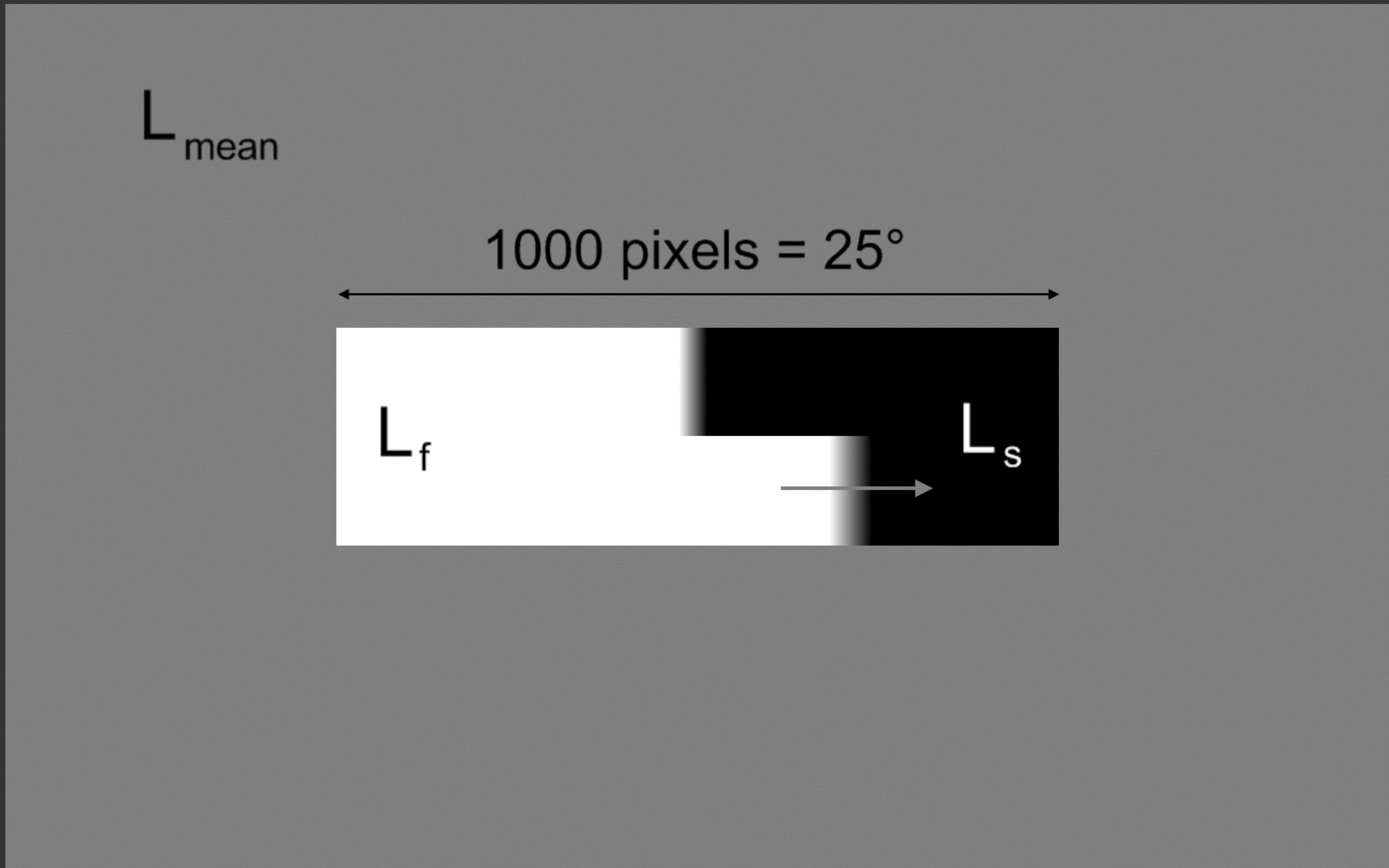
Viewing conditions

- Psychophysics test room:
  - surrounding luminance set to 10 lux
  - D65 chromaticity
- Viewing distance such as:

  1 pixel ⟷ 1.5′ visual angle
- Background luminance on the screen:

  $$L_{mean} = sqrt(L_{min}.L_{max})$$

Test field



Stimuli

- Moving edge:
  - from left to right
  - 20 grey-to-grey transitions tested (grey levels: 0, 63, 127, 191, 255)
- Stationary edge:
  - from the measured blurred edge profile for the same transition
  - adjustement of blur quantity by up- or down-scaling this measured edge profile

Displays under test

- Three displays have been tested

Apple cinema display	26’’	1920x1200@60Hz	300 cd/m²
Philips LCDTV	37’’	1920x1080@60Hz	440 cd/m²
LG monitor	30’’	2560x1600@60Hz	160 cd/m²

- Experiments have been conducted:
  - in IRCCyN (France) with Apple and Philips displays
  - in Acreo (Sweden) with LG display

Observers

- Three subjects have participated to the experiments for each display

- All possessed normal or corrected-to-normal vision (visual acuity of 0.9 or better on both eyes)

- Subjects were familiar with the procedure after several training sessions

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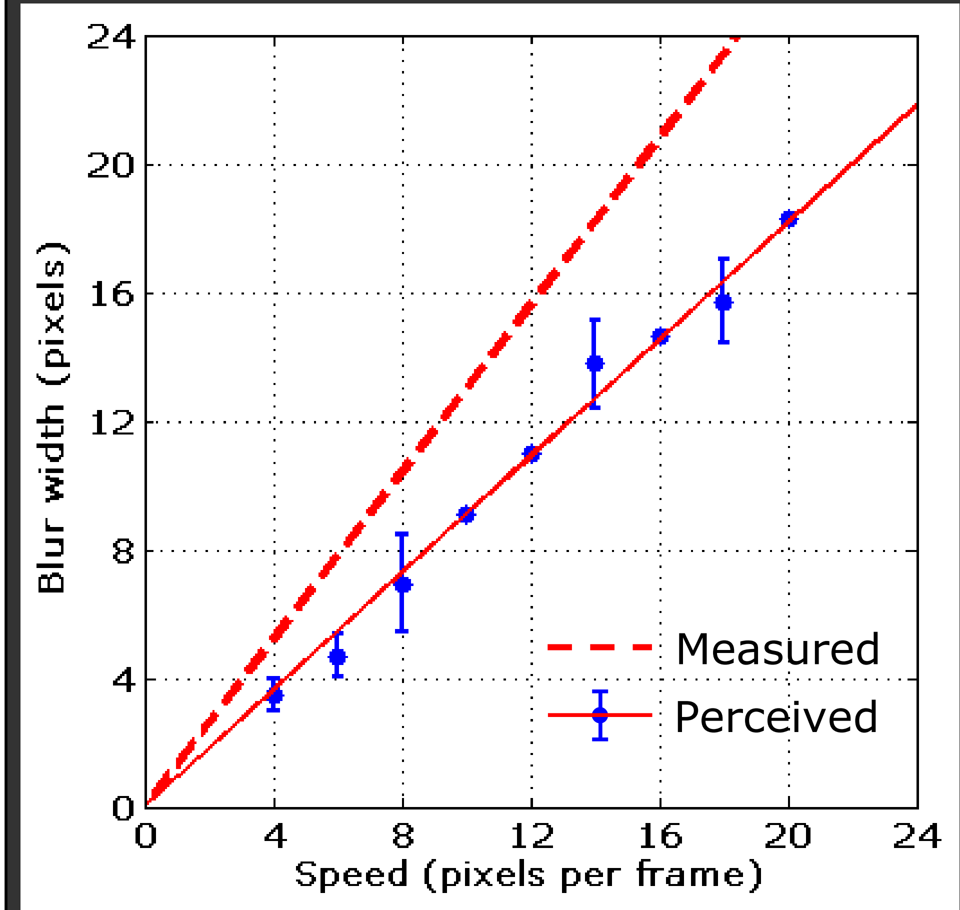
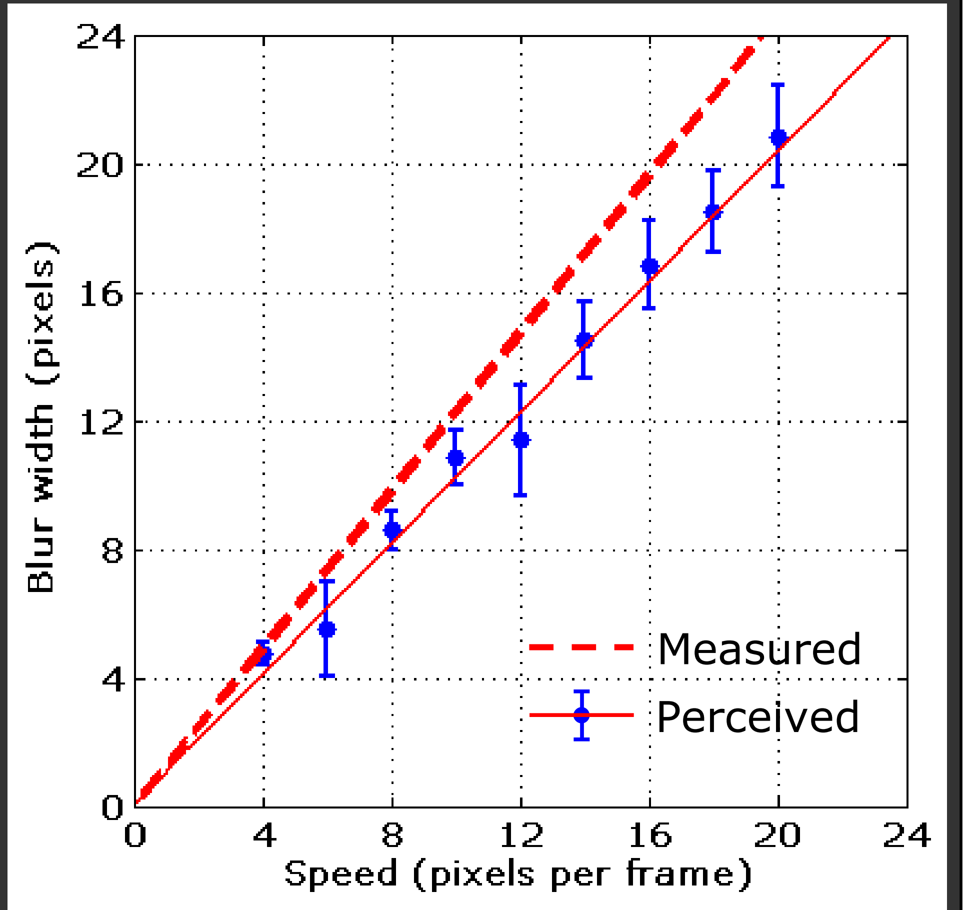
Perceived blur vs Speed

Transition 0->63



Transition 63->191



Perceived blur vs Speed

- For each transition (and display) the perceived blur BEW_p is proportional to the speed V

$$BEW_p = k.V$$

- Linear correlation between this model and subjective data is always higher than 0.982

Perceived vs Measured

- Measured motion-blur: $BEW_m = BET.V$
- Perceived motion-blur: $BEW_p = k.V$

- As a result, the relationship between perceived blur and measured blur is linear:

$$\boxed{BEW_p = A.BEW_m}$$

with $A = k/BET$

Perceived vs Measured

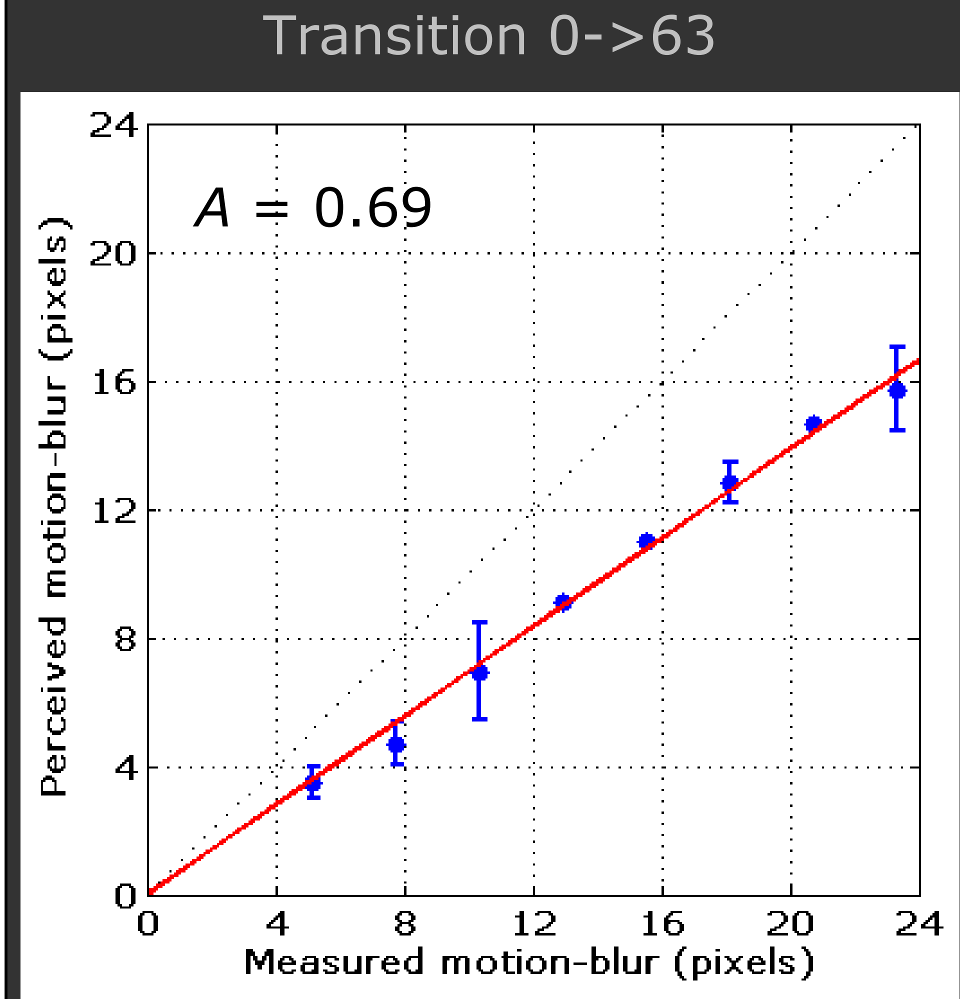
- *A* is the ratio between perceived motion-blur and measured motion-blur
- For almost all transitions and displays:

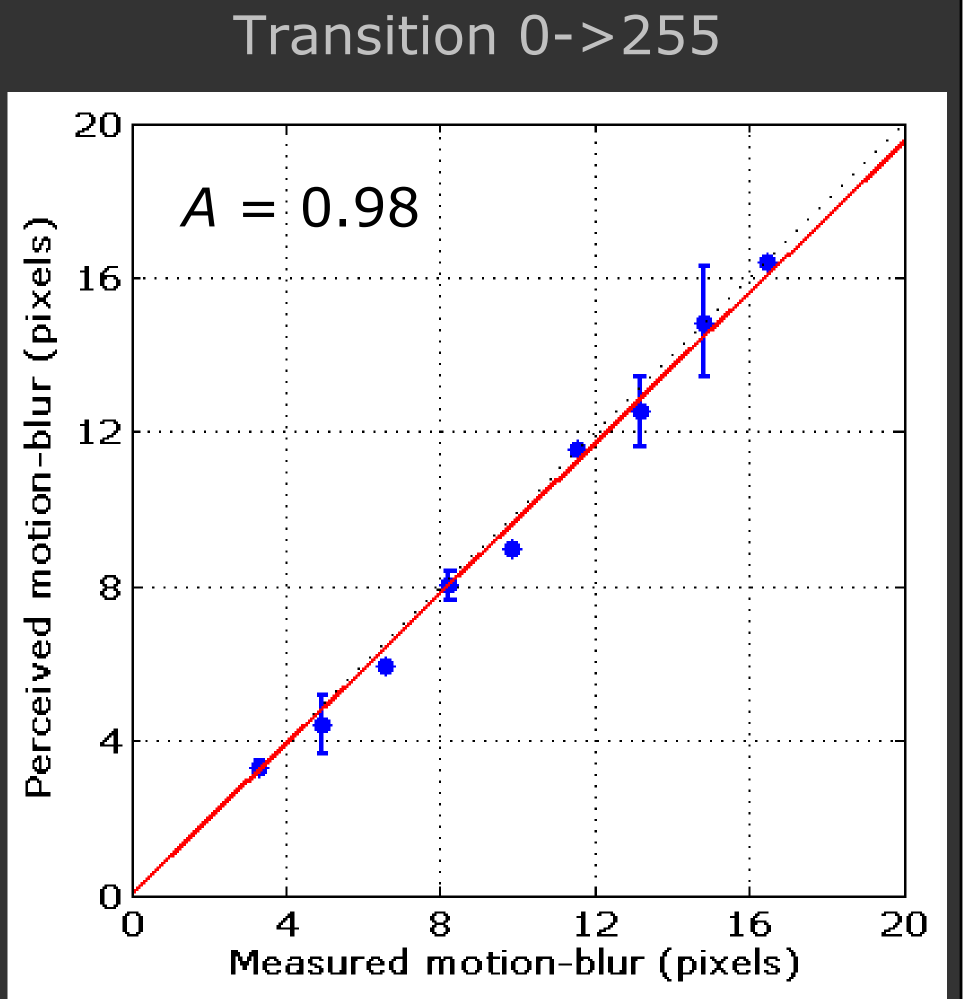
$$A<1$$

- Perceived edge is actually sharper than the edge obtained from objective measurements

This result may be related to motion-sharpening phenomenon

Perceived vs Measured

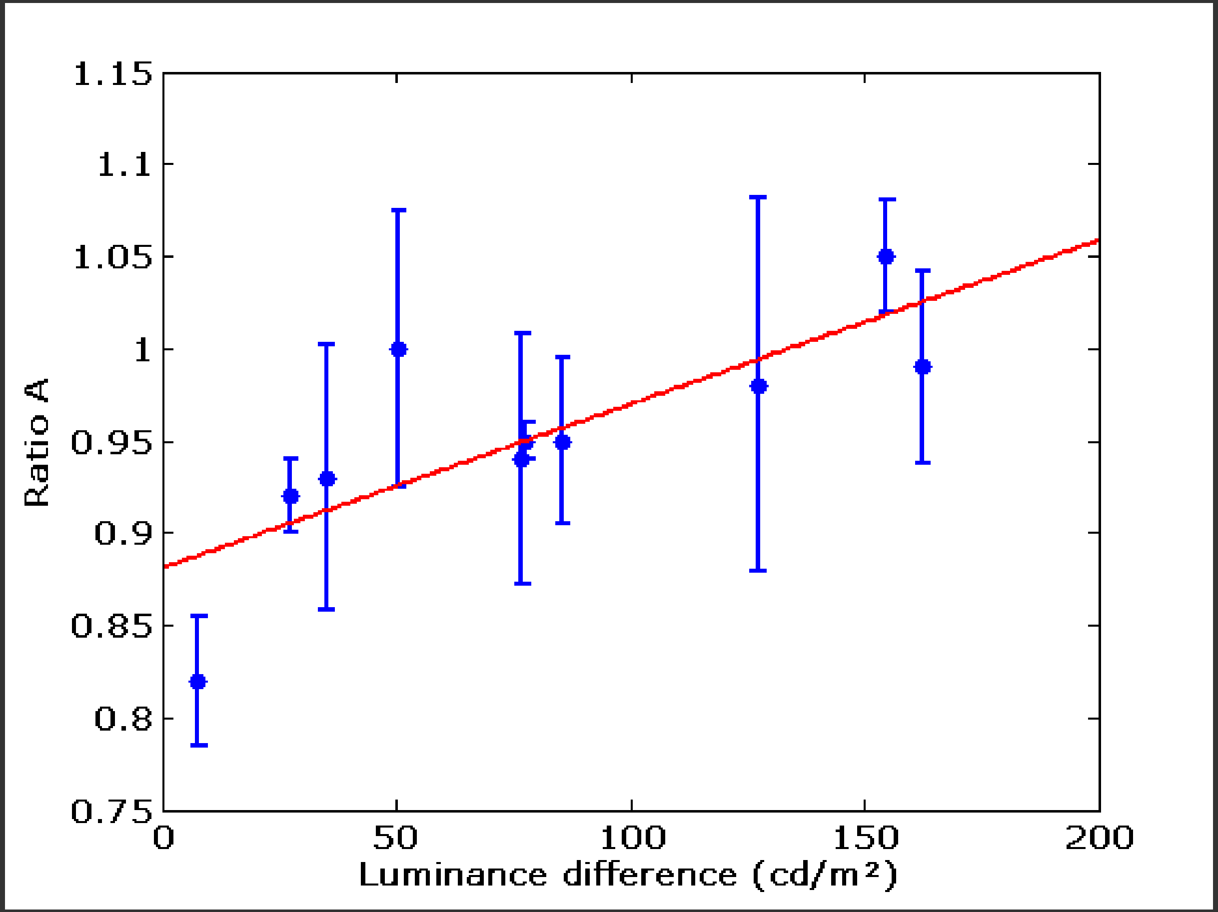




Ratio vs Contrast

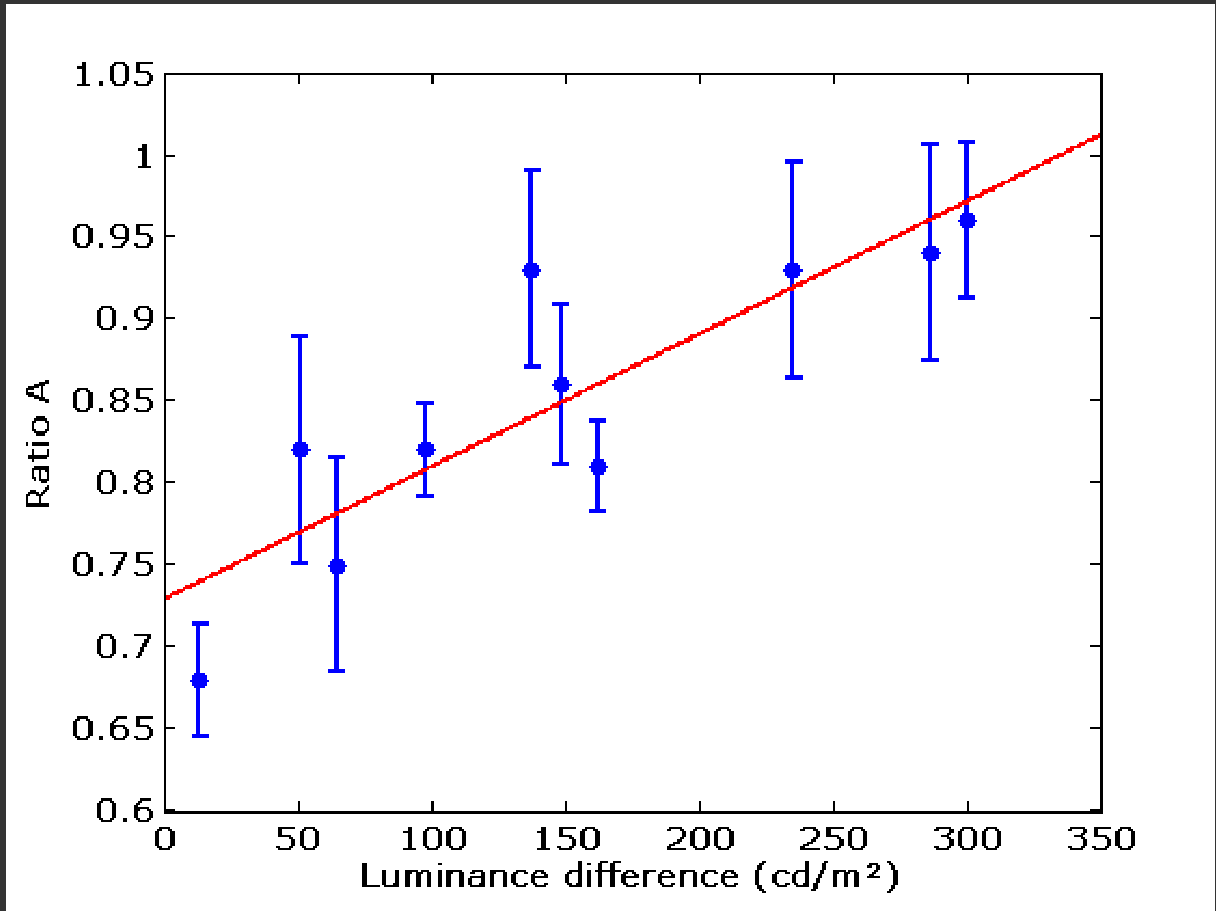
- How does this sharpening effect vary with transitions ?
- Is it affected by contrast or luminance ?

Ratio vs Contrast



Rising transitions on LG display

Ratio vs Contrast



Rising transitions on Apple display

Ratio vs Contrast

- For rising transitions, ratio *A* is decreasing as the luminance/contrast decreases.
- Linear correlation coefficient between A and some luminance/contrast values:

Display	L_{max}	$(L_{max}+L_{min})/2$	$L_{max} - L_{min}$
Apple	0.9495	0.8823	0.8681
Philips	0.6744	0.6142	0.6648
LG	0.7337	0.6120	0.7794

Ratio vs Contrast

- For rising transitions, ratio *A* (between perceived motion-blur and measured motion-blur) is lower as the contrast of the edge is decreasing
- Sharpening effect is stronger for low contrast conditions
- However, no particular relationship has been found for falling transitions

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Summary

- Objective measured motion-blur and perceived motion-blur are highly correlated
- BUT perceived blur is lower than measured blur
- This may be related to motion-sharpening phenomenon

Summary

- The ratio between perceived and measured motion-blur is decreasing with contrast for rising transitions
- This indicates that sharpening is stronger for low contrast edges
- Motion-blur measurements should be weighted as a function of transitions: HVS is less sensitive to blur for low contrast transitions

Future work

- Test more transitions to confirm this behaviour and to define weighting function
- Understand what happen with falling transitions (suggestions are welcome!)

Thank you !

Questions ?