Influence of display type and rendering method on contrast sensitivity assessment

William H.A. BEAUDOT [1], Kenzo SAKURAI [1,2]

1: Division of Human Informatics, Graduate School; 2: Department of Psychology
Tohoku Gakuin University, Sendai, Miyagi, Japan

Objective

To compare the contrast sensitivity function (CSF) measured on different display technologies through different software and hardware techniques that increase luminance resolution (from 8 bits to 16 bits including a quasi-continuous resolution), and discuss the relative advantages and limitations of each solution.

Configurations

Experimental Setup: Stimuli presented through Psykinematix v2.0 GPU/Bits# Edition [1] running on a MacBook Pro 15" under Mac OS X 10.8.5 with a NVIDIA GeForce GT 650M graphics card.

Tested Displays:

– CRT (Sony Trinitron GDM-F520)
– LCD (MacBook Pro Anti-Glare 6-bit TN LCD Display)
– Display++ (IPS LCD from CRS)

All were Gamma-corrected using ColorCal II from CRS with a mean luminance of 60 cd/m^2 and viewed at a distance that provides a Nyquist frequency of 32 cpd.

Stimulus Rendering Methods (provide various luminance resolutions):

– Standard: 8 bits (6 bits + temporal dithering)
– Bit-stealing [2]: 11.6 bits (chromatic artefacts)
– Spatial dithering [3]: 12 bits (lower spatial resolution through 4x4 pixel)
– Bits# (from CRS): 14 bits (native)
– Display++ (from CRS): 16 bits (14 bits + temporal dithering)
– Noisy-bit [4]: quasi-continuous (through stochastic dithering)

Method

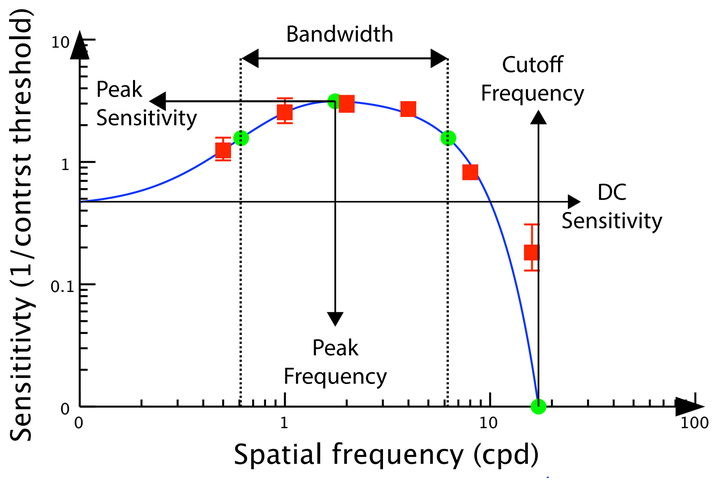
Contrast thresholds for 6 spatial frequencies (0.5, 1, 2, 4, 8, 16 cpd) were measured using a staircase method (1-up/3-down) through a discrimination procedure (horizontal/vertical judgment). Each trial consisted in a Gabor patch with a sigma of 2 degs presented for 0.5 seconds at a randomly-selected horizontal or vertical orientation. In the same session, the spatial frequencies were randomly interleaved and a full contrast sensitivity function (CSF) was obtained in less than 10 minutes.

CSF Model

The average of 10 CSF measurements for the same subject was fitted with a ***Difference of Gaussians:***

$$CSF(f) = g*(\exp(-\frac{f^2}{b^2}) - a*\exp(-\frac{f^2}{c^2}))$$

with 4 free parameters:
g, *a*: gains
b, *c*: space constants

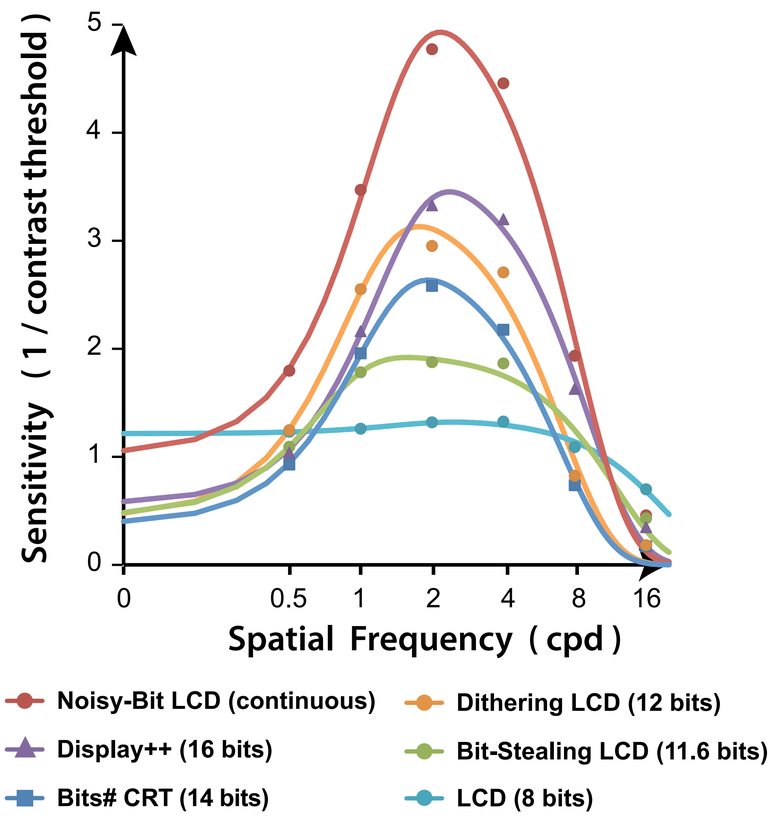


Properties of interest:

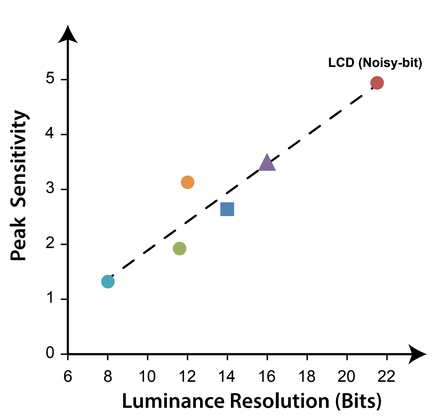
Peak frequency
Cut-off frequency
Bandwidth
Peak sensitivity
DC sensitivity

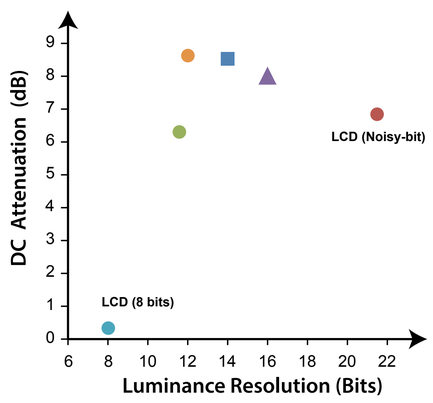
Results

Contrast Sensitivity Functions

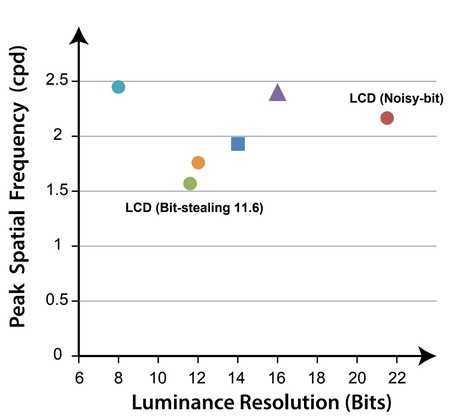


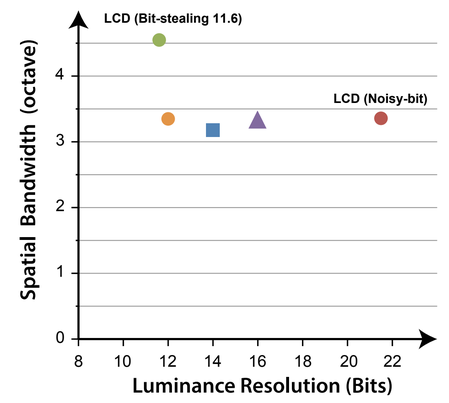
Sensitivity

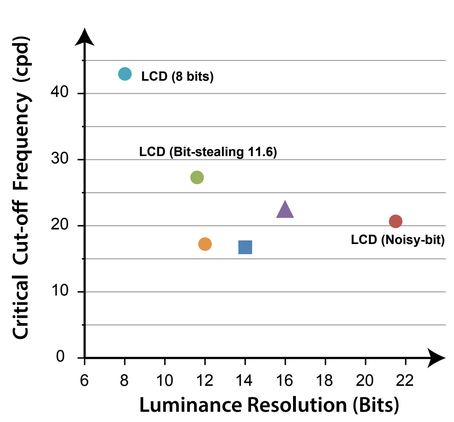




Spatial Selectivity







CRT
Same TN LCD
IPS LCD

Conclusions

1. The positive correlation between peak sensitivity and luminance resolution suggests that the **noisy-bit technique** can provide more than **20-bit of luminance resolution** !

2. The **bit-stealing technique appears insufficient** to provide a reliable CSF: peak frequency is under-estimated while cut-off frequency and bandwidth are over-estimated.

3. The **Display++ (16-bit)** and the **noisy-bit** method provide **similar estimates** for the CSF properties.

4. **More than 12-bit** luminance resolution is required to fully assess the CSF.

5. A reliable CSF can be estimated without relying on a hardware solution by using the noisy-bit method even with a low-quality LCD display !

References

1. Beaudot WHA (2009) Psykinematix: a new psychophysical tool for investigating visual impairment due to neural dysfunctions. Vision: the Journal of the Vision Society of Japan, 21(1):19–32
2. Tyler C.W. (1997) Colour bit-stealing to enhance the luminance resolution of digital displays on a single pixel basis. Spatial Vision, 10(4):369-377
3. Mulligan J.B. (1993) Methods for spatiotemporal dithering. SID'93 Digest, pp. 155–158
4. Allard R. & Faubert J. (2008) The noisy-bit method for digital displays: Converting a 256 luminance resolution into a continuous resolution. Behavior Research Methods, 40(3):735–743

Acknowledgements: Supported by JSPS Grant-in-Aid for Scientific Research (B) Grant Number 25285202
Commercial Relationships: KyberVision Japan LLC
Contact: william.beaudot@kybervision.com

Presented at the 11th Asia-Pacific Conference on Vision, Singapore, 10-12 July 2015