Influence of display type and rendering method on contrast sensitivity assessment

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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.

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.

Configurations

Experimental Setup: Stimuli presented through Psykinematix v2.0 GPU/Bits# Edition [1] running on a MacBook Pro 15" (Mid-2012) under Mac OSX 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 Model LTN154MT07 from Samsung)
– Display++ (IPS LCD from CRS)

All were Gamma-corrected using ColorCal II from CRS with a mean luminance of 60 cd/m² and viewed at a distance that provides the same 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 spatial dithering)	

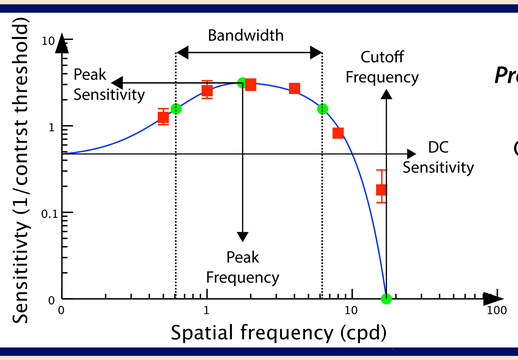
CSF Model

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:

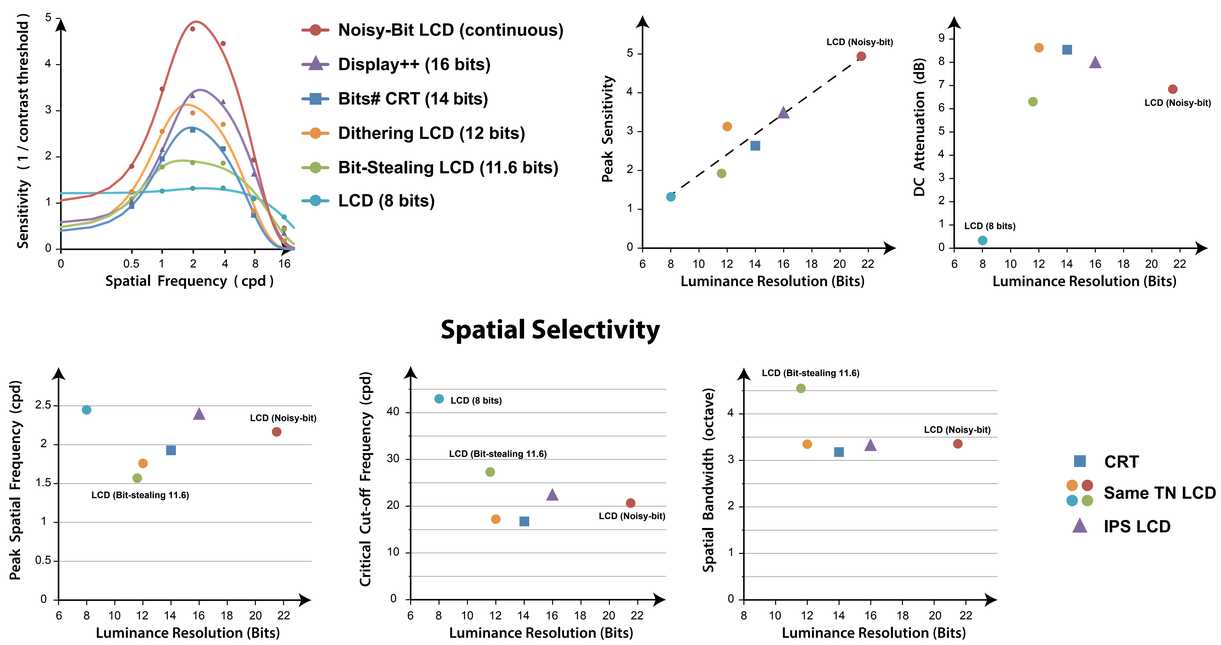
g, *a*: gains
b, *c*: space constants



Properties of interest:

Peak frequency
Cut-off frequency
Bandwidth
Peak sensitivity
DC sensitivity

Results



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

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