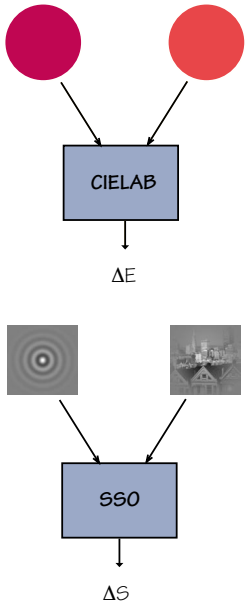
A Standard Observer for Spatial Vision

Andrew Watson
NASA Ames Research Center

Cesar Ramirez
De Anza College

Purpose

In color vision, standard observers have proven extraordinarily useful in both science and industry. We propose a similar measure for spatial vision.

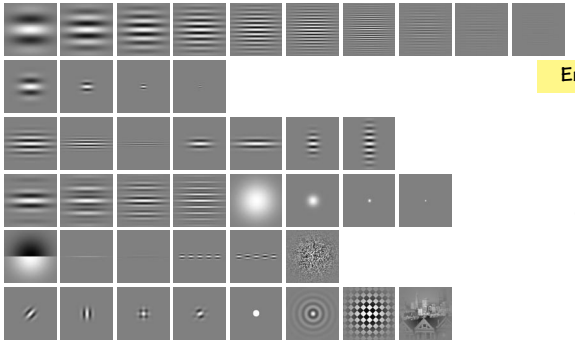


Using a vision model, a Spatial Standard Observer computes a perceptual distance between a pair of images. For simplicity, we consider only still grayscale images. To be of practical value, the vision model must be simple.

ModelFest Data

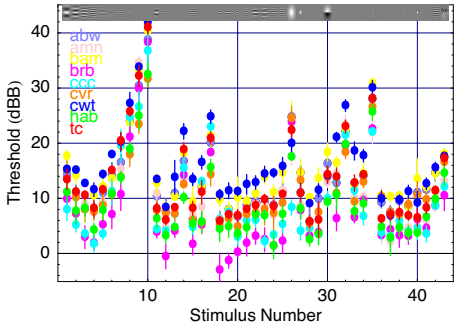
Data from ModelFest provide a basis for selecting among candidate models, and for estimating model parameters.

ModelFest Stimuli



Stimuli were 256x256 pixel images on a 120 pixel/degree display. Detection thresholds were measured using temporal 2AFC.

Data for 9 Observers

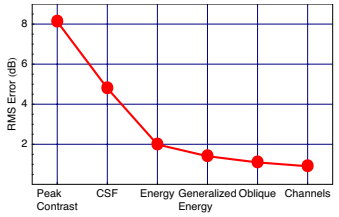


ModelFest Models

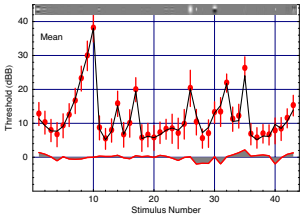
We fitted the mean ModelFest data with a large set of models that shared a basic structure with a set of optional features.

- Contrast Sensitivity Function
- Oblique Effect
- Channels
- Minkowski Pooling

Error Declines as we add model features



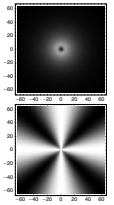
Best Fit: Gabor Channels



Best CSF: Tyler + Oblique

$$cs(f) = g\left(e^{-\frac{f}{c}} - a\,e^{-\left(\frac{f}{s}\right)^2}\right)$$

$$oe(u, v) = 1 - \frac{4\left(1 - e^{-\frac{\sqrt{u^2+v^2}}{\Omega}}\right)u^2 v^2}{(u^2+v^2)^2}$$

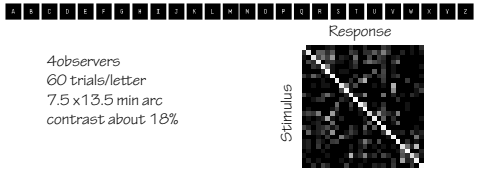


Spatial Standard Observer

Best compromise between accuracy and simplicity is provided by the Generalized Energy model. In this model there are no channels and $\beta = 2.9$. We adopt this model as the Spatial Standard Observer, Version 0.01.

Contrast → CSF (Tyler * Oblique) → Minkowski ($\beta = 2.9$)

Example: Predicting Letter Confusions



4observers
60 trials/letter
7.5 x13.5 min arc
contrast about 18%

Simple prediction based on $\exp(-\tau\Delta S)$ yields a correlation of 0.75 with off-diagonal elements of the unbiased confusion matrix. This equals the performanceof an ideal observer model with spatial uncertainty.

Other Issues

Spatial registration
Light adaptation
Masking
Non-linear output
Resolution independence
S-CIELAB

References

Carney, T., Klein, S. A., Tyler, C. W., Silverstein, A. D., Beutter, B., Levi, D., Watson, A. B., Reeves, A. J., Norcia, A. M., Chen, C.-C., Makous, W. & Eckstein, M. P. (1999). The development of an image/threshold database for designing and testing human vision models Proceedings, Human Vision, Visual Processing, and Digital Display IX, SPIE, Bellingham, WA, 3644, pp. 542-551.

Berkley, M. A., Kitterle, F. & Watkins, D. W. (1975). Grating visibility as a function of orientation and retinal eccentricity. Vision Research 15, 239-244.

Tyler, C.W., (2000). Personal communication.

Watson, A. B. (2000). "Visual detection of spatial contrast patterns: Evaluation of five simple models." Optics Express 6(1): 12-33.

Watson, A. B. and A. E. Fitzhugh (1989). "Modelling character legibility." Society for Information Display Digest of Technical Papers 20: 360-363.

Further information:
abwatson@mail.arc.nasa.gov
http://vision.arc.nasa.gov/ • http://vision.arc.nasa.gov/modelfest/
Supported by NASA Office of Life and Microgravity Science and Applications