Ahumada and Watson (2013) used visible contrast energy to predict vision thresholds for visual images. For low contrast images, their local luminance based visible contrast image v(x, y) can be computed from the contrast image c(x, y) using an “optical” low pass filter \( M_0(f_x, f_y) \) and an “inhibitory surround” low pass filter \( M_1(f_x, f_y) \),

\[
v(x, y) = \text{FFT}^{-1} \left( M_0(f_x, f_y) \left(1 - a M_1(f_x, f_y)\right) \text{FFT}(c(x, y)) \right),
\]

Barten (1994) added temporal low pass filters \( H_0(f_t) \) and \( H_1(f_t) \) to form a visible contrast “movie” \( v(x, y, t) \) as

\[
v(x, y, t) = \text{FFT}^{-1} \left( M_0(f_x, f_y) H_0(f_t) \left(1 - M_1(f_x, f_y) H_1(f_t)\right) \text{FFT}(c(x, y, t)) \right).
\]

If \( v(x, y, t) \) is masked by white noise, the detection performance of an ideal observer is a function only of the noise level and the signal energy, \( Ev = \int \int \int v(x, y, z)^2 dx dy dt = \|v(x, y, z)\|. \) Letting \( V(f_x, f_y, f_t) = \text{FFT}(v(x, y, t)) \), the final inverse need not be computed since \( Ev = \|V(f_x, f_y, f_t)\| = \int \int \int |V(f_x, f_y, f_t)|^2 df_x df_y df_t \) if the FFT is appropriately normalized.

\[
Ev = \|(M_0 C_{XY}) H_0 C_t - (M_0 M_1 C_{XY})(H_0 H_t C_t)\|,
\]

When \( \|M_1 C_{XY}\| \ll 1 \), the inhibitory response is negligible, and

\[
Ev = \|(M_0 C_{XY}) H_0 C_t\| \|H_0 C_t\|.
\]

Using Gaussian spatial filters \( M = \exp(-((f_x^2 + f_y^2)/f^2)) \) and Gamma temporal filters, \( H = 1/(1+i2\pi f t)^n \), we predicted the contrast energy threshold data of Carney et al. (2013) for

\[
c_{XY}(x,y) = \exp(-((x^2+y^2)/(2 (0.5 \text{deg})^2) \cos(2 \pi f_Y y)), f_Y = 0, 4, 11.3;
\]

\[
c_t(t) = \cos(t) = \exp(-t^2/(2 (0.25 \text{sec})^2) \text{ and}
\]

\[
c_t(t) = \cos(t) \sin(2 \pi f_T t), f_T = 1, 2, 4, 8, 15, 25 \text{Hz}.
\]

Figure 1. Data from Carney et al. (2013) [symbols] and model predictions [lines].

The model parameters were \( [f_0, f_T] = [11.4, 0.88] \text{ cpd}, [\tau_0, \tau_T] = [12.5, 12.5] \text{ msec}, [n_0, n_1] = [3, 2] \). The ideal observer noise spectral density estimate is 4.3 dBB. The RMS model fit is 1.6 dB with 20 - 6 df (\( n_1 \) was not allowed to vary). Additivity in log sensitivity is predicted to hold for \( f_Y = 4 \) and 11.3. The RMS error for 4 and 11.3 cpd additivity is 1.9 dB with 5 df.

References


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