Experimental Section

Aim: To investigate the relationship between contrast and image quality judgments.

Stimuli: Generate a distribution of images that span the full range of mean luminance values and contrasts that our CRT can display via a linear scaling and shifting the luminance distribution of image from the high dynamic range survey by Fairchild (2007).

Procedure: Subject’s rated the image quality of a small (7 by 7 deg) image patch on a 0-9 scale.

The background luminance was either black, mid-gray or white. Six subjects took part.

Results:

Each data point is the average image quality score for at least 12 image quality judgments and 6 different image patches.

Predictive model

The standard deviation of the luminance image is a poor predictor of image quality scores (Fig. 1).

Passing the image through a point-wise gamma function, improves the predictive power of the model (Fig. 2).

The value of gamma that achieves the best Spearman’s correlation (Fig. 2, inset) varies with the background luminance condition, consistent with research into lightness perception (e.g. Whittle, 1992).

Applying a point-wise non-linearity shifts the distortion of standard deviations as illustrated in the inset of Fig. 3. The range of standard deviations can be renormalized to within a given range using the following equation.

\[ \sigma' = \sigma \cdot \frac{\text{Max}}{\text{Max}'} \]

Finally, the normalized standard deviation is passed through an additional non-linearity.

\[ C = \sigma' \cdot \text{Max} \]

This metric achieves a Pearson’s correlation of R=0.95 (Fig. 4).

Absolute image quality scores can be predicted using the following equation that incorporates a threshold term \( T \) and a gradient \( m_{\text{abs}} \).

\[ IQ = \begin{cases} 0, & \text{if } C \leq 0 \\ m_{\text{abs}}(C - T), & \text{otherwise} \end{cases} \]

Finally, we find the value of \( m_{\text{abs}} \), a image dependent as illustrated in Fig. 5.

Thus we can predict relative image quality scores but not absolute image quality scores.

Application

Dynamic Range is the ratio between the greatest and the smallest luminance in an image or scene.

Natural scenes may have a dynamic range of up to seven orders of magnitude.

Display media has a dynamic range of between two to three orders of magnitude.

Thus luminance compression is necessary for image reproduction, a process known as tone-mapping.

Linear clipping is the process of clipping high or low pixel values before renormalization to the available range. Surprisingly linear clipping achieves better image quality scores than more complex tone mapping operators (Cadik et al, 2008).

Linear clipping can increase image contrast, but introduces clipping artifacts.

We investigate image quality judgments for various levels of clipping.

Results: Image quality scores can be predicted using two terms. One for contrast, another for the square root of the number of clipped pixels.

\[ IQ = m_{\text{comp}}(C - T) + m_{\text{clip}} \sqrt{N_{\text{clip}}} \]

Both \( m_{\text{comp}} \) and \( m_{\text{clip}} \) are image dependent.

Fortunately, the values of \( m_{\text{comp}} \) and \( m_{\text{clip}} \) are linearly related (Fig. 3).

\[ m_{\text{clip}} = km_{\text{comp}} + c \]

Substituting, gives

\[ IQ \propto (C - T) + k \sqrt{N_{\text{clip}}} \]

Although we are unable to fully discount \( m_{\text{comp}} \) using the average value produces a reasonable approximation of subject image quality scores (R=0.69, Fig. 2).

Finally, our proposed tone-mapping operator finds the upper and lower clipping bounds that maximizes \( IQ \).