Rapid Assessment of Contrast Sensitivity with Mobile Touch-screens

Jeffrey B. Mulligan, NASA Ames Research Center

Purpose

The need for periodic vision assessment during long-duration space flight has been recognized by the Aviation Medical Advisory Committee of the National Academy of Sciences (2002). The special late-breaking results section of this conference is an opportunity to present new developments in this area.

Approach

The images shown below depict a ‘virtual grating’ in which spatial frequency is swept in the horizontal dimension, while contrast is swept in the vertical dimension. An observable contrast sensitivity function can be traced out as the boundary of the region of visible pattern. One of the first appearances of such an image was in Cornsweet (1970), which attributed it in an unpublished photograph by F. Campbell and J. Robson.

The initial implementation demonstrated here has been done for Apple Computer’s iPh operating system, which runs on the popular iPad and iPod devices. The table below shows the display parameters of the models used. Calculations of max. and min. spatial frequencies were performed assuming a viewing distance of 20 inches, a minimum period of four pixels and a maximum period of half the largest dimension of the screen.

<table>
<thead>
<tr>
<th>Device</th>
<th>Screen size (inches)</th>
<th>Pixel pitch (pixels per inch)</th>
<th>Screen size (inches)</th>
<th>Pixel pitch (pixels per inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>iPad2</td>
<td>9.7</td>
<td>264</td>
<td>iPad4</td>
<td>9.7</td>
</tr>
<tr>
<td>iPad mini</td>
<td>9.7</td>
<td>230</td>
<td>iPod4</td>
<td>7.5</td>
</tr>
<tr>
<td>iPod5</td>
<td>9.7</td>
<td>284</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Software implementation

The implementation has been developed using an in-house scripting language known as Quip (Quark Image Processing). Quip provides an interpreted environment similar to Matlab, includes an extensive image processing library, an implementation of Shapoval’s table lookup functions, and a port of Mulligan and Stevenson’s (1994) software implementation for Unix/X11 platforms, and was tested on Apple Computer’s iOS for the iPh devices.

Stimulus Rendering

The initial 8-bit gray level resolution of the devices poses challenges for rendering the minimum threshold level stimulus. On the right is a sweep grating whose each pixel has been quantized to 8 bits. In the next panel below, the quantization error is displayed (normalized to the full-display range for clarity).

The quantization error is then converted to a 5-bit image using an iterative optimization algorithm which seeks to minimize the threshold error (Mulligan & Ahumada, 1992). This image is added to the quantized image shown at the top to produce the final image.

Additional improvements can be obtained by relaxing the defining principle to the time domain, and by shifting error from luminance to chrominance (Mulligan, 1990; Tyler, 1997).

Calibration

To facilitate field checks of calibration (and uncalibration if needed), a ratio of psychophysically based calibration procedures have been developed. Linearization (gain correction) is performed by matching luminance matches patches (under the assumptions of spatial independence). This can be done either by matching static patches or using a motion resolving method (Ahumada, 2009). Unlike the images above, which is based on a method introduced by Julesz and Cornsweet (1983), this algorithm has been extended to the color primaries and be determined using a colorimetric illuminance function (HFP) or the Anstis and Cornsweet natural rendering procedure.

CSF Estimation

Traditionally, the CSF has been measured by first estimating threshold at a set of distinct frequencies, and then fitting a curve to the estimated estimates. Luminos and colleagues have made significant improvements in the efficiency of this process by estimating the first of the CSF directly from a small number of decision trials, without the intermediate step of estimating particular thresholds (Luminos et al., 2010; Luminos & Liu, 2011; Dorr et al., 2012). We employ a similar method, fitting parametric curves (a parabola) to data from one or more stimulus.

The limited (8-bit) gray level resolution of digital displays on a single pixel basis, trades between uniform patches and dithered stripes in spatial quadrature; the perceived direction of motion depends on the viewing distance of half the largest dimension of the screen. One of the first appearances of such an image was in Cornsweet (1970), which attributed it in an unpublished photograph by F. Campbell and J. Robson.

References


