Psychophysical Calibration of Mobile Touch-Screens for Vision Testing in the Field

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Problem
Presentation of airstreams of known contrast in the measurement of contrast sensitivity requires control of nonlinearity of the input-output characteristics of the test image. This is commonly done with a calibrated photometer, but it is desirable to have a method that does not depend on additional equipment. Here we present a psychophysical method, and compare the accuracy and reliability of the results with traditional photometer measurements.

The static matching method
The patterns used to make the four frames of the motion-nulling sequence were also displayed as four strips, one above the other, as shown below. At the motion-null, the contrast in the first and third rows should be zero.

The photometer method
Traditional photometer measurements were made for the purpose of comparison. Devices were operated in "slave" mode by a remote computer which collected photometer readings after setting the display output level. Different amplifier gain settings were used to measure the high and low parts of the range. UDT photodiodes, trans-impedance amplifiers, 16 bit ADC.

The minimum-motion method
Following Anstis and Cavanagh (1981), who used motion-nulling to match the luminances of different colors, we use motion-nulling to match the luminances of spatial mixtures of different gray levels (Mulligan, 2009). In the left panel above, motion to the left is seen when the black and white stripes are brighter than the uniform gray bars, while rightward motion is seen when the gray bars are brighter. The motion will be reversed when the variable gray level inverts the two fixed levels.

The camera method
We have explored using an uncalibrated camera instead of a photometer for display calibration. Unfortunately, the "exponential ambiguity" prevents joint calibration of display and camera nonlinearity using single pixel levels, but this can be overcome by using different patterns, under the assumption of spatial independence, following the work of Grossman and Tumblin (2014). We simultaneously solve for the pixel transmission and camera response functions using sparse least-squares optimization (Lumelian, 2010).

In future work, we plan to explore using a mirror with the device's front-facing camera to perform automatic calibrations without an external camera or photometer.

Conclusions
Psychophysical methods are capable of providing satisfactory calibrations, but device artifacts such as hysteresis limit the accuracy of any method based on an inadequate device model. Artifacts are highly dependent on the particular model. Unaided camera can provide calibrations as good or better than dedicated photometers.

The camera results
Assume linear summation of plastic:
\[ L(x_1, x_2) = \frac{(L(x_1) + L(x_2))}{2} \]
The camera response model:
\[ R(x) = R_0 + (L(x))^f \]

There appear to be small but systematic differences between results obtained with the motion-nulling and static matching methods? This may be explained by pixel hysteresis.

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