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

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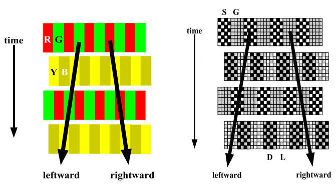
Problem

Presentation of stimuli of known contrast (as in the measurement of contrast sensitivity) requires correction of nonlinearities relating pixel values to output luminances ("gamma"). In the laboratory, this is commonly done with a calibrated photometer, but to support the calibration of mobile devices in the field, 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.

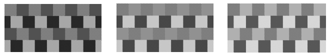
The minimum-motion method



Following Anstis and Cavanagh (1983), 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 green bars have a higher luminance than the red, while rightward motion is seen if the red bars are more luminous than the green. Similarly, in the panel on the right, leftward motion is seen when the black and white stippled bars are brighter than the uniform gray bars, while right ward motion is seen when the gray bars are brighter. The motion will be nulled when the variable gray level bisects the two fixed levels.

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.



G = 64 G = 127 G = 160

The photometer method

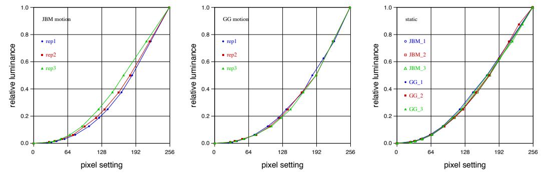
Traditional photometer measurements were made for the purpose of comparison. Devices were operated in "slave" mode by a remote computer which collected photometer readings after setting the display output level. Different amplifier gain settings were needed to measure the high and low parts of the range. UDT photodiode, transimpedance amplifier, 16 bit A/D.

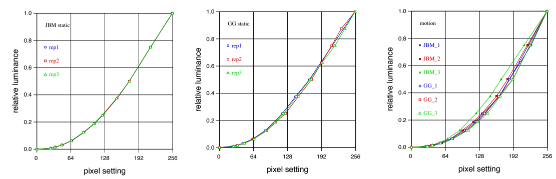
The camera method

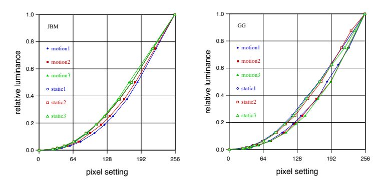
We have explored using an uncalibrated camera instead of a photometer for display calibration. Unfortunately, the "exponential ambiguity" prevents joint calibration of display and camera nonlinearities using single pixel levels, but this can be overcome using dithered patterns, under the assumption of spatial independence, following the work of Olczak and Tumblin (2014). We simultaneously solve for the pixel transmission and camera response functions using sparse Levenberg-Marquardt optimization (Lourakis, 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.

Psychophysical results for iPod3

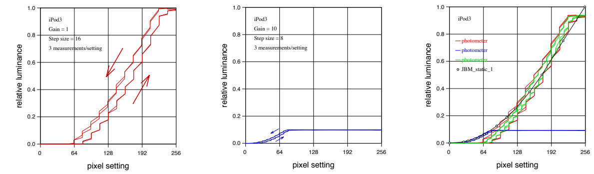




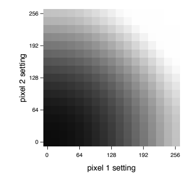


There appear to be small but systematic differences between results obtained with the motion nulling and static matching methods!? This may be explained by pixel hysteresis.

Photometric results



Camera results

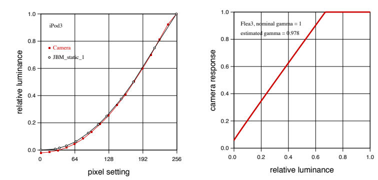


Assume linear summation of pixels:

$$L(s_1, s_2) = \frac{(L(s_1) + L(s_2))}{2}$$

Camera response model:

$$R(l) = R_0 + (k_C l)^\gamma$$



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. Uncalibrated cameras can provide calibrations as good or better than dedicated photometers.

References

Anstis, S. and Cavanagh, P. (1983). "A minimum motion technique for judging equiluminance," in *Colour vision: psychophysics and physiology*, Mollon, J. B. and Sharpe, L. T. (eds.), pp. 155-166, Academic Press.

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