The SHINE toolbox for controlling low-level image properties

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Abstract

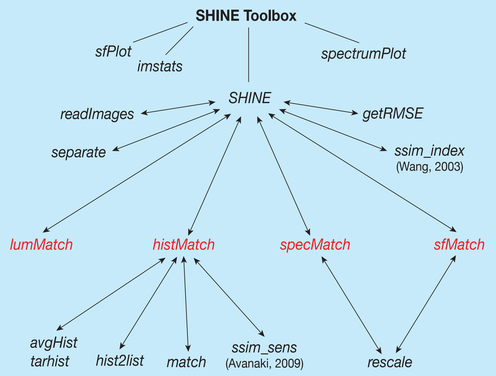
Visual perception can be influenced by top-down processes related to the observer's goals and expectations, as well as by bottom-up processes related to low-level stimulus attributes, such as luminance, contrast, and spatial frequency. When using different physical stimuli across psychological conditions, one faces the problem of disentangling the contributions of low- and high-level factors. Here we make available the SHINE (Spectrum, Histogram, and Intensity Normalization and Equalization) toolbox for Matlab*, which we have found useful for controlling a number of image properties separately or jointly (Willenbockel et al., in press; Williams, Willenbockel, & Gauthier, 2009). The toolbox features functions for specifying the (rotational average of the) Fourier amplitude spectra, normalizing and scaling mean luminance and contrast, as well as for exact histogram specification optimized for perceptual visual quality. SHINE can thus be employed for parametrically modifying a number of image properties or for equating them across stimuli to minimize potential low-level confounds in studies on higher-level processes.

The toolbox can be downloaded here: www.mapageweb.umontreal.ca/gosselif/shine.

Methods

Overview of SHINE toolbox functions

avgHist:	computes average histogram
getRMSE:	computes root mean square error
histMatch:	exact histogram matching across images
hist2list:	transforms histogram into a sorted (dark-to-light) list
imstats:	computes image statistics across images
lumMatch:	scales mean luminance and contrast
match:	basic histogram specification
readImages:	loads image set
rescale:	luminance rescaling (to avoid clipping after the IFFT)
separate:	basic figure-ground segregation
sfMatch:	equates the rotational average of the amplitude spectra
sfPlot:	plots the energy at each spatial frequency
SHINE:	main function for loading, equating, and saving
specMatch:	amplitude spectrum matching
spectrumPlot:	plots the amplitude spectrum
ssim_index:	computes the Structural Similarity index (SSIM; Wang, 2003)
ssim_sens:	computes SSIM gradient (Avanaki, 2009)
tarhist:	computes a target histogram



*SHINE is written with functions from Matlab's Image Processing Toolbox

lumMatch

```
output = (origIm-mean2(origIm))/std2(origIm)*newStd+newMean;
```

histMatch

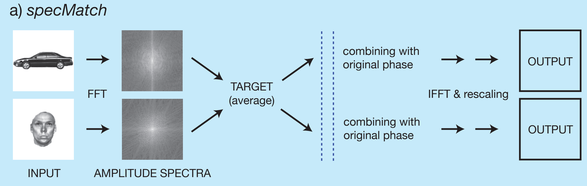
a) Basic histogram matching

b) Optional: SSIM optimization (Avanaki, 2009)

1. Let X show the original input image. Set X_{new}=X.
2. Apply the *match* function to X_{new} to obtain image Y with the given target histogram.
3. Compute the SSIM gradient [∇ySSIM(X,Y)] and SSIM index [SSIM(X,Y)] using the *ssim_sens* function.
4. If convergence is reached (e.g., output quality is good enough), then break.
5. Set X_{new}=Y+μN∇ySSIM(X,Y), where μ denotes step size and N the number of pixels, and go to 2.
6. Output Y.

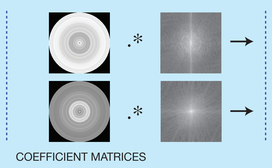
specMatch & sfMatch

a) *specMatch*



b) *sfMatch*

sfMatch includes the steps of *specMatch* and the additional computation of a coefficient for each spatial frequency, based on the target amplitude spectrum: coeff_{SF} = sum(tarSpec_{SF})/sum(origSpec_{SF}).



Results & Discussion

lumMatch

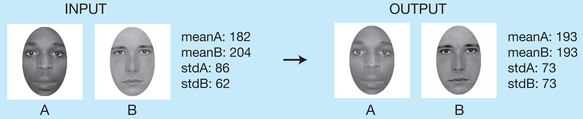


Illustration of the luminance matching function. Left: Two base face images with their mean luminance and contrast (std). Right: Output images equated in mean luminance and contrast.

histMatch

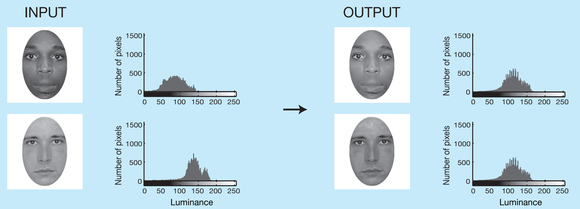


Illustration of basic histogram matching. Left: Two base face images with their luminance histograms. Right: The corresponding SHINE output images with their matched histograms. The target was obtained using the function *tarhist*.

specMatch & sfMatch

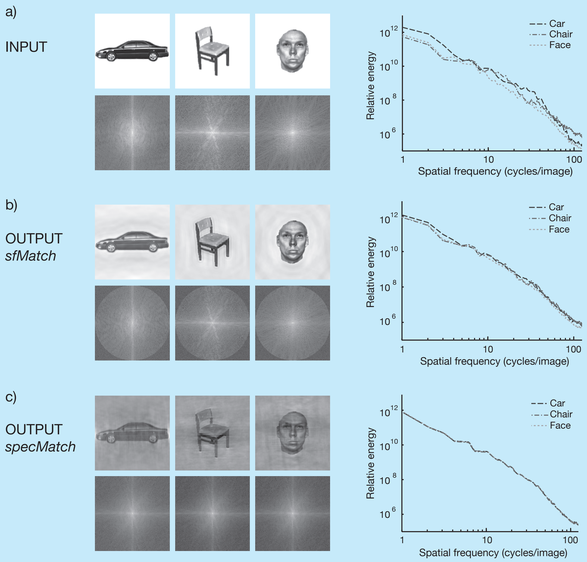
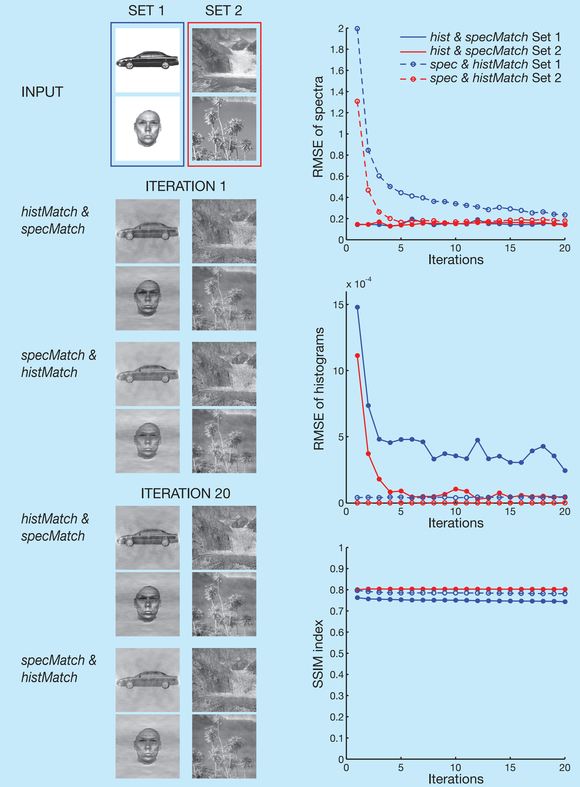


Illustration of *sfMatch* and *specMatch*. a: Source images and their amplitude spectra. b: Using *sfMatch*, the rotational average of the spectra was equated while the energy distribution across orientations was preserved. c: Using *specMatch*, the spectra were equated on spatial frequencies and orientations. The output in b) and c) is shown after the rescaling of the luminance values so that absolutely all grayscale values of the three images are in the range of 0 to 255.

Iterative approach: joint matching of histograms and spectra



In sum, SHINE is an easy-to-use Matlab toolbox for controlling low-level image properties across the foregrounds/backgrounds of an image set. The iterative equalization approach has successfully been applied to reach a high degree of joint matching of histograms and Fourier amplitudes (e.g., Williams et al., 2009).

References

Avanaki, A. N. (2009). Exact global histogram specification optimized for structural similarity. *Optical Review, 16,* 613-621.

Wang, Z. (2003). Matlab implementation of the SSIM index. Available at: www.ece.uwaterloo.ca/~z70wang/research/ssim/

Willenbockel, V., Sadr, J., Fiset, D., Horne, G. O., Gosselin, F., & Tanaka, J. W. (in press). Controlling low-level image properties: The SHINE toolbox. *Behavior Research Methods*.

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