Simplifying Tone Curves for Image Enhancement

James Bennett, james.r.bennett@uea.ac.uk (AgriFoRwArdS)
Graham Finlayson (Colour & Imaging Laboratory, University of East Anglia)

Summary

A single tone curve used to globally remap the brightness of an image is one of the simplest ways to enhance an image [1]. The precise shape of a tone curve is not strongly constrained except that it is usually limited to increasing function of brightness. We constrain the shape further to define a simple tone adjustment as one which has at most one inflexion point.

Introduction

An input greyscale distribution can be remapped to an output distribution by use of a tone curve.

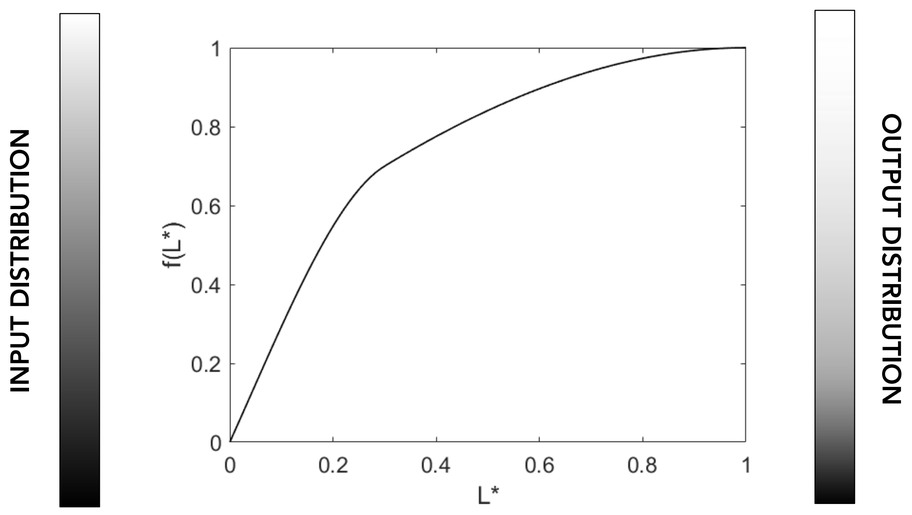

Figure 1 Tone curve mapping grey distribution to another

When applied globally to the brightness of each pixel in an image, it can lead to a visually enhanced image.

Figure 2 Right shows left image with brightness remapped by the curve in Figure 1

Tone curves may be adjusted explicitly by a photographer when editing or implicitly by changing settings in photo editing software. Tone curves may also be formed using an automatic algorithm. In each scenario the shape is not strongly constrained except for the curve being an increasing function of brightness. Tone curves that are overly wiggly can produce unnatural images.

References

[1] R. C. Gonzalez and R. E. Woods, Digital Image Processing, 3rd ed. New York: Pearson, 2008.
[2] V. Bychkovsky, S. Paris, E. Chan, and F. Durand, "Learning photographic global tonal adjustment with a database of input/output image pairs," in IEEE Conference on Computer Vision and Pattern Recognition, 2011, pp. 97–104.
[3] "Colorimetry—Part 4: CIE 1976 L*a*b* colour space," CIE International Commission on Illumination, Standard, Jun. 2019.

Solution

To avoid the tone curve having too many wiggles, we constrain the curve to have at most one inflexion point. Where $\mathbf{D}$ is a derivative operator and λ is the pivot point, the four possible cases are

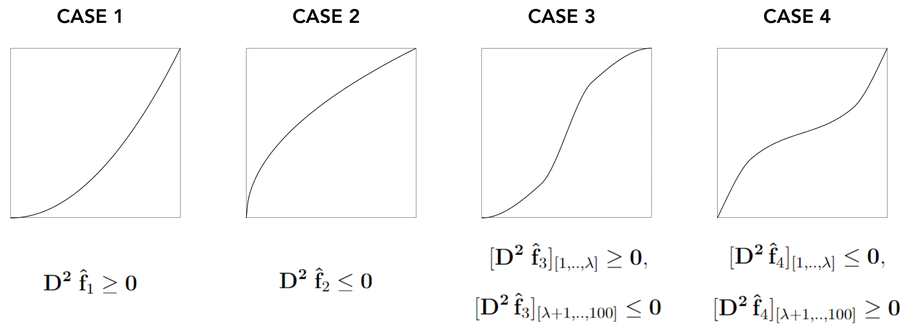

Figure 3 Four cases of tone curve shape

A tone curve $\mathbf{f}$ is found that is close to the wiggly curve $\hat{\mathbf{f}}$ subject to constraints, using a quadratic program.

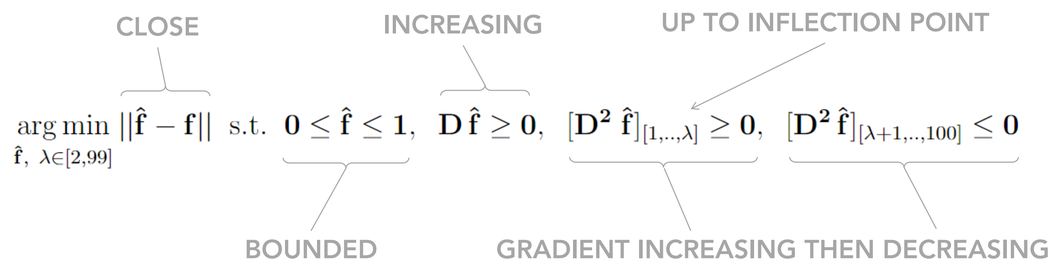

Figure 4 Minimisation for finding the simple tone curve close to the wiggly curve

Results

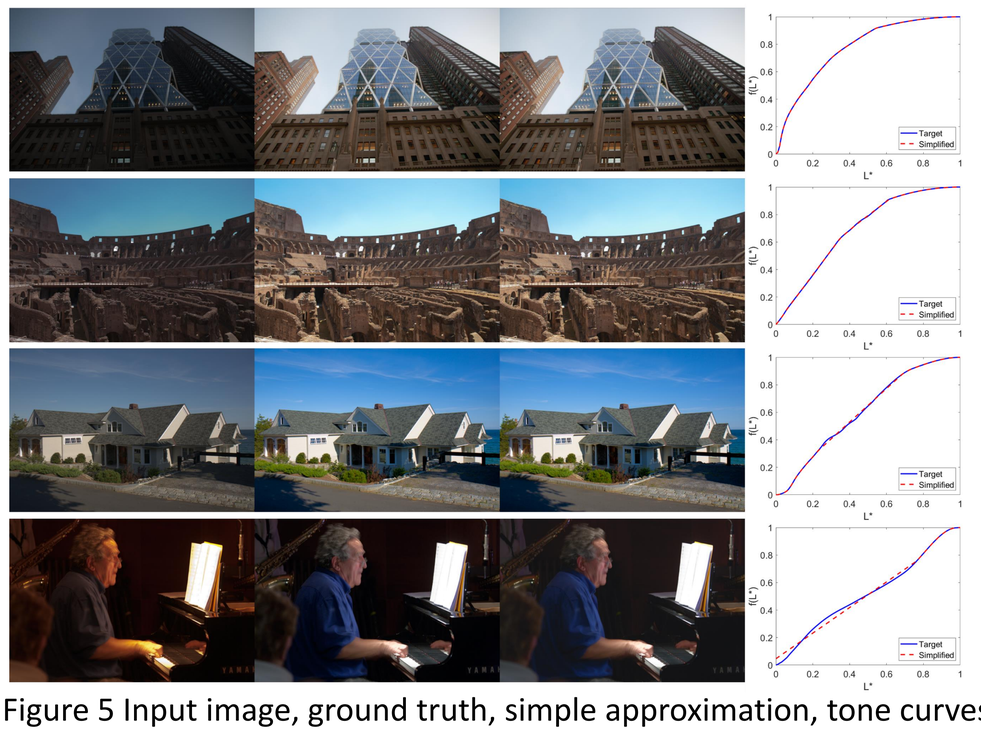

Figure 5 Input image, ground truth, simple approximation, tone curves

Table 1 Quantiles of the ΔE values for the median adjustment

Quantile	0.5	0.9	0.95	0.99	1
ΔE	0.0105	0.0675	0.107	0.277	0.958

This method is applied to the MIT-Adobe FiveK dataset [2] of 5000 images edited by 5 experts. All adjustments are well approximated by a simple tone curve since the worst median adjustment is $\Delta E < 1$ [3].

Conclusion

Tone mapping is a very powerful technique for image enhancement. We considered whether tone mappings made by users are simple or complex and presented a computational method to find the best simple tone curve that approximates a complex tone mapping. Experiments conducted on a large set of 25,000 manually tone adjust images found that the tone adjustments made were either simple or that they could be well-approximated by a simple curve adjustment.