Decolorize: Fast, Contrast Enhancing, Color to Grayscale Conversion

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Abstract: We present a new contrast enhancing color to grayscale conversion algorithm which works in real-time. It incorporates novel techniques for image sampling and dimensionality reduction, sampling color differences by Gaussian pairing and analyzing color differences by predominant component analysis. In addition to its speed and simplicity, the algorithm has the advantages of continuous mapping, global consistency, and grayscale preservation, as well as predictable luminance, saturation, and hue ordering properties.

Keywords: Color image processing; Color to grayscale conversion; Contrast enhancement; Image sampling; Dimensionality reduction.

"It isn't possible to get values and color. … You can't be at the pole and the equator at the same time. You must choose your own line, as I hope to do, and it will probably be color." — Vincent van Gogh

ADDITIONAL ILLUSTRATIONS

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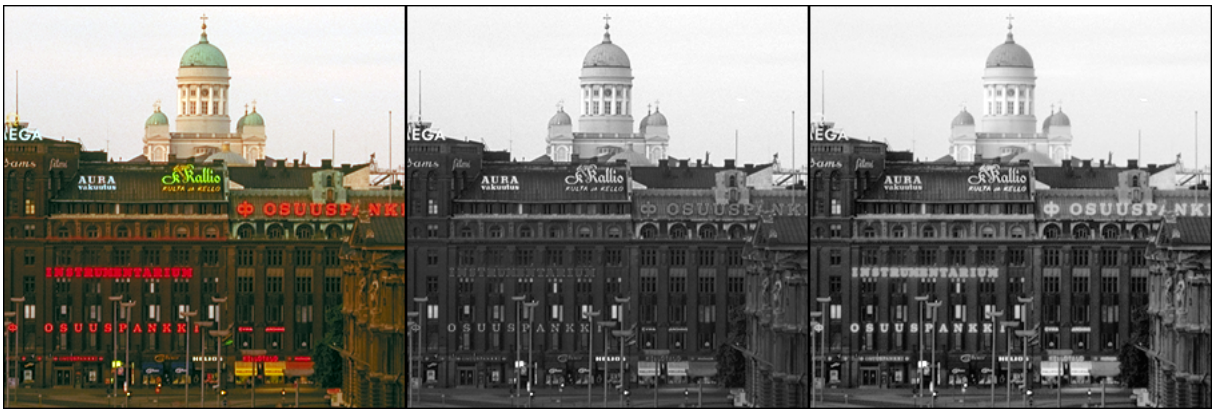


Original color image | Normal grayscale image | Our enhanced grayscale image

Figure 1: Recovering chromatic contrasts in grayscale.

Algorithm Properties	Gooch et al.	Rasche et al.	Strickland et al.	Principal Component	Normal Grayscale	Our Technique
Contrast Enhancement	+	+	+	+	–	+
Real-time Performance	–	–	+	+	+	+
Continuous Mapping	–	–	+	+	+	+
Global Consistency	–	+	–	+	+	+
Grayscale Preservation	–	–	–	–	+	+
Luminance Ordering	–	±	–	+	+	+
Saturation Ordering	–	–	–	+	–	+
Hue Ordering	–	–	–	+	–	+

+ Satisfied ± Approximated – Unsatisfied

Continuous mapping: The transformation from color to grayscale is a continuous function. This constraint reduces image artifacts, such as false contours in homogeneous image regions.

Global consistency: When two pixels have the same color in the color image, they will have the same gray level in the grayscale image. This constraint assists in image interpretation by allowing the ordering of gray levels to induce a global ordering relation on image colors.

Grayscale preservation: When a pixel in the color image is gray, it will have the same gray level in the grayscale image. This constraint assists in image interpretation by enforcing the usual relationship between gray level and luminance value.

Luminance ordering: When a sequence of pixels of increasing luminance in the color image share the same hue and saturation, they will have increasing gray levels in the grayscale image. This constraint reduces image artifacts, such as local reversals of image polarity.

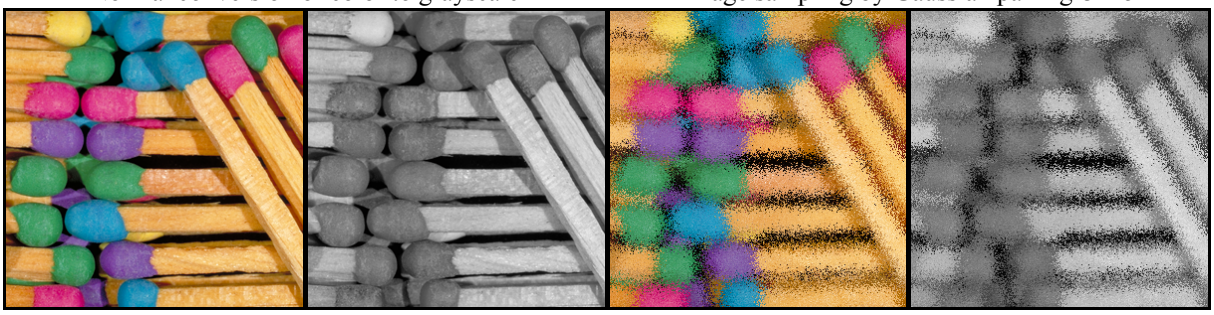
Saturation ordering: When a sequence of pixels having the same luminance and hue in the color image has a monotonic sequence of saturation values, its sequence of distinct gray levels in the grayscale image will be a concatenation of at most two monotonic sequences. This constraint reduces image artifacts when rendering smooth color gradients.

Hue ordering: When a sequence of pixels having the same luminance and saturation in the color image has a monotonic sequence of hue angles that lie on the same half of the color circle, its sequence of distinct gray levels in the grayscale image will be a concatenation of at most two monotonic sequences. This constraint reduces image artifacts when rendering smooth color gradients.

Figure 2: Properties of algorithms for color to grayscale conversion.

Stochastic Image Sampling

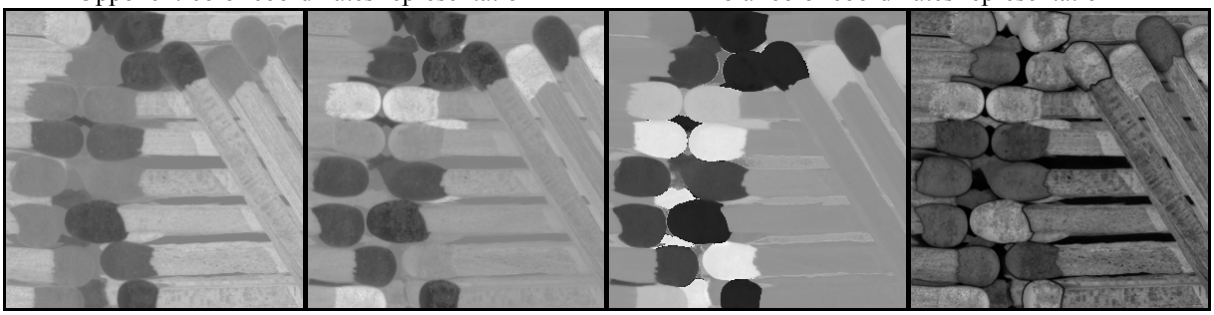
Normal conversion of color to grayscale | Image sampling by Gaussian pairing $\sigma = 5$



Original color image (R_i, G_i, B_i) | Normal grayscale image Y_i | Color sampling (R'_i, G'_i, B'_i) | Grayscale sampling Y'_i

Color Space Modeling

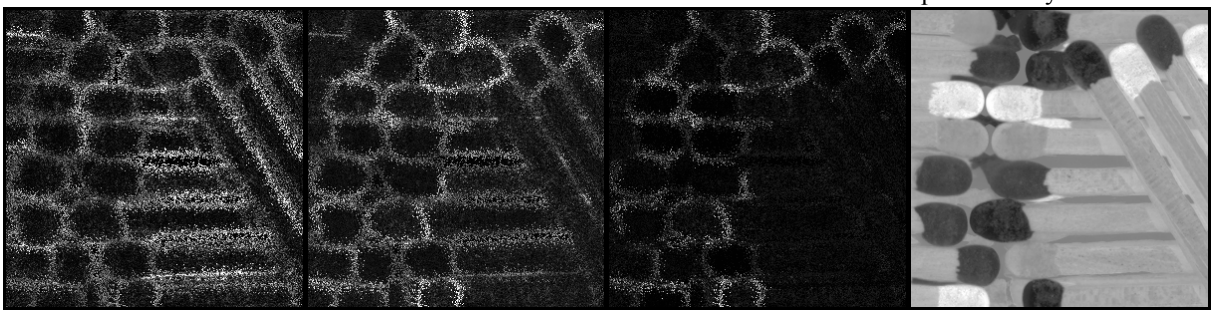
Opponent-color coordinates representation | Polar color coordinates representation



Yellow-blue image P_i | Red-green image Q_i | Hue image H_i | Saturation image S_i

Chromatic Contrast Analysis

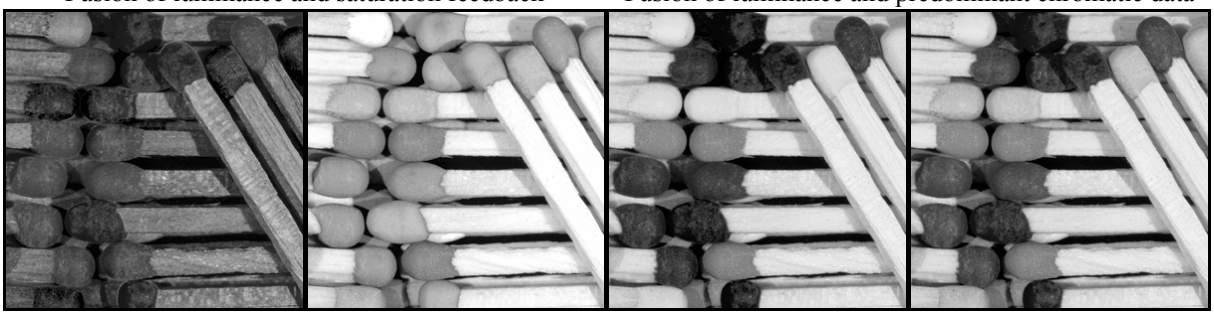
Color difference evaluation | Predominant component analysis



Color differences ΔD_i | Chromatic differences $|\Delta P_i| + |\Delta Q_i|$ | Chromatic contrast loss $c_i |\Delta P_i| + c_i |\Delta Q_i|$ | Projected chromatic image C_i

Luminance-Chrominance Fusion

Fusion of luminance and saturation feedback | Fusion of luminance and predominant chromatic data



Negative saturation effect E_i | Positive saturation effect F_i | Without saturation feedback V_i | With saturation feedback T_i

Figure 3: Stages of the decolorize algorithm for color to grayscale conversion. The final result is our enhanced grayscale image in the bottom right corner.

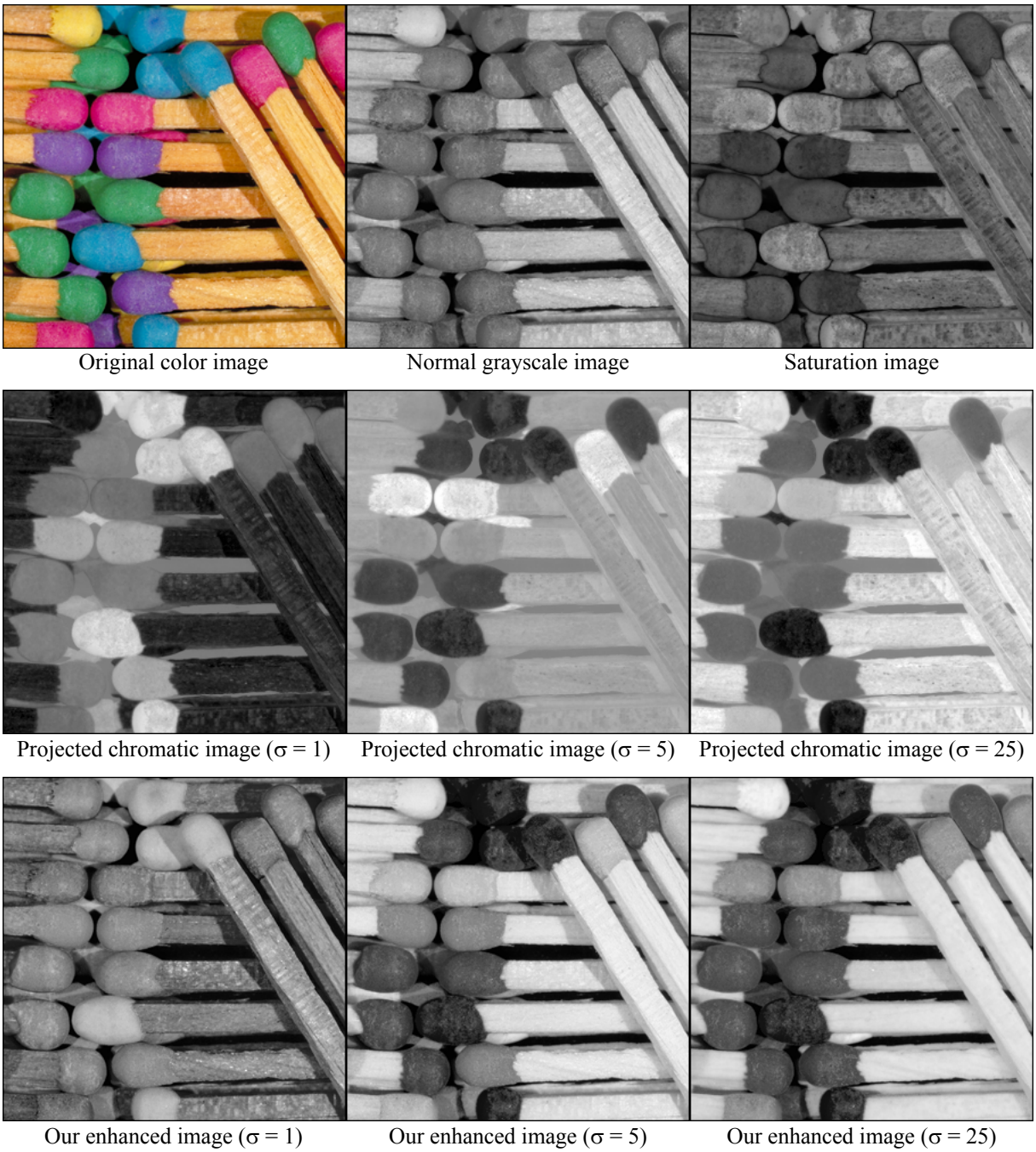


Figure 4: Focus of contrast enhancement can depend on the scale of image features.

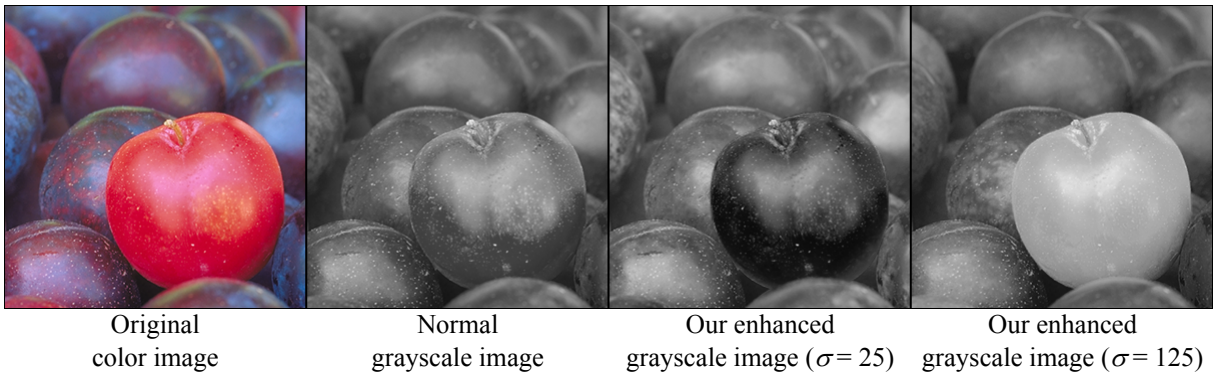
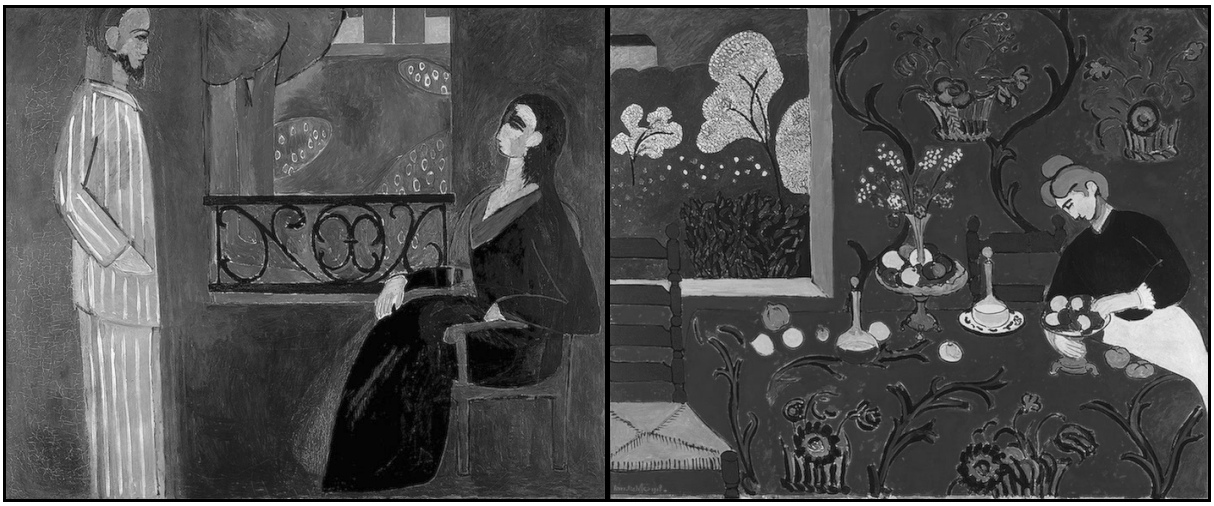


Figure 5: Polarity of contrast enhancement can depend on the scale of image features.

Original color painting
“Conversation” by Henri Matisse

Original color painting
“Red Room” by Henri Matisse



Normal grayscale image

Normal grayscale image

Our enhanced grayscale image
with moderate enhancement λ = 0.3

Our enhanced grayscale image
with moderate enhancement λ = 0.3

Figure 6: Rendering color artworks for printing in grayscale.

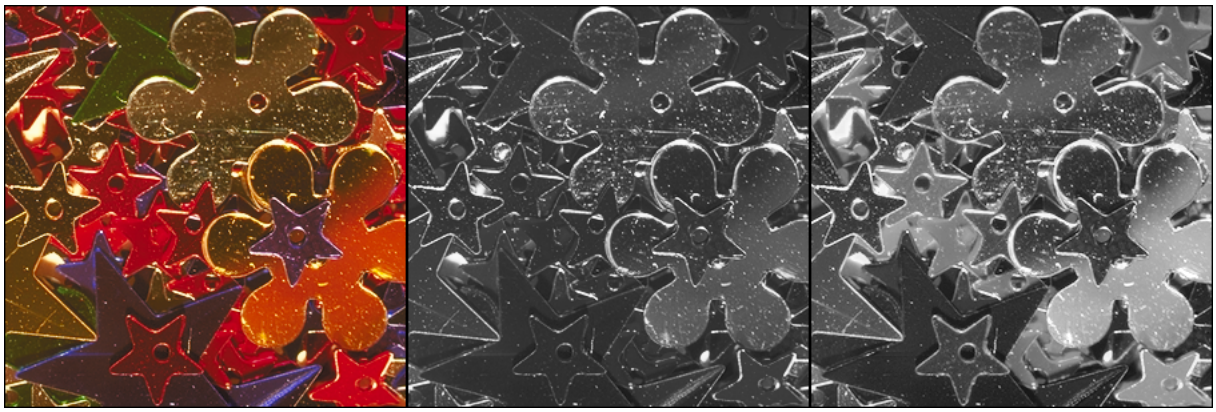
Original color image | Normal grayscale image | Our enhanced grayscale image

Original color image | Normal grayscale image | Our enhanced grayscale image

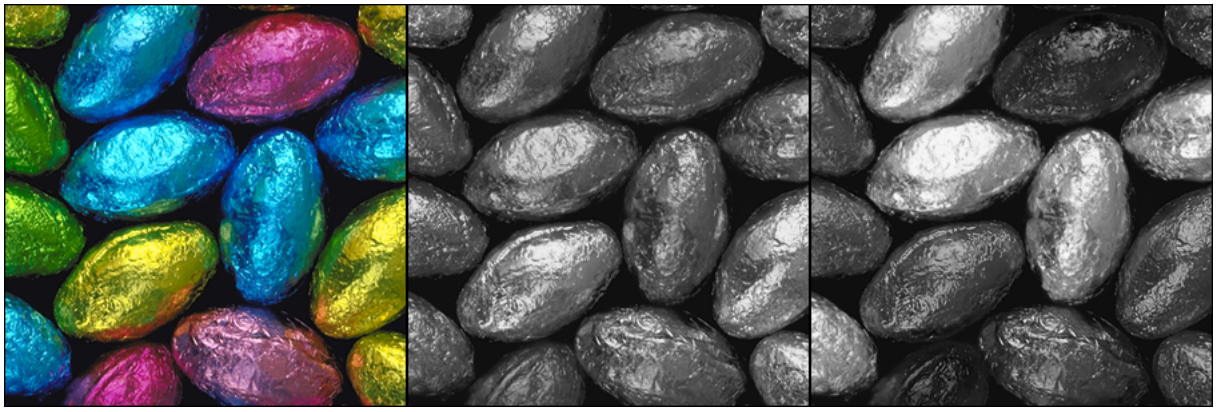
Original color image | Normal grayscale image | Our enhanced grayscale image

Original color image | Normal grayscale image | Our enhanced grayscale image

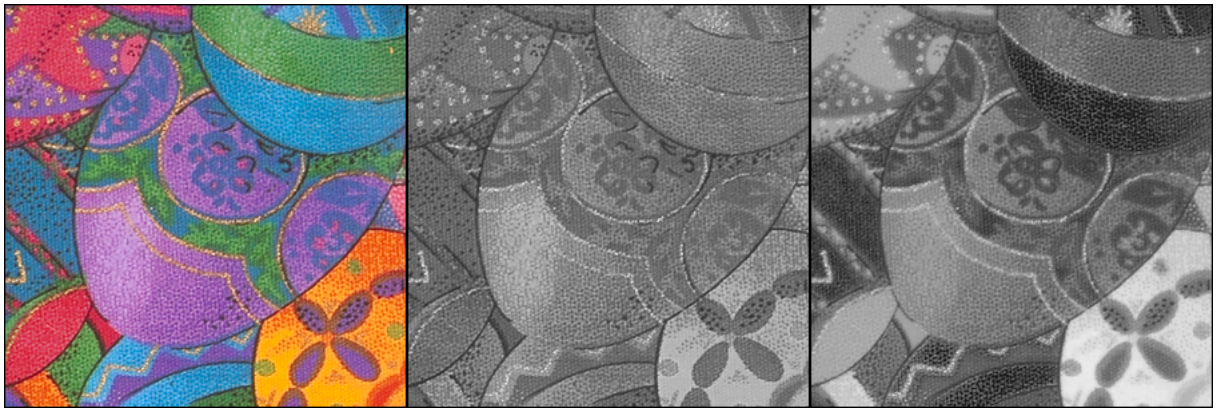
Figure 7: Contrast enhancement for color to grayscale conversion.



Original color image | Normal grayscale image | Our enhanced grayscale image



Original color image | Normal grayscale image | Our enhanced grayscale image



Original color image | Normal grayscale image | Our enhanced grayscale image

Original color image | Normal grayscale image | Our enhanced grayscale image

Figure 8: More contrast enhancement for color to grayscale conversion.

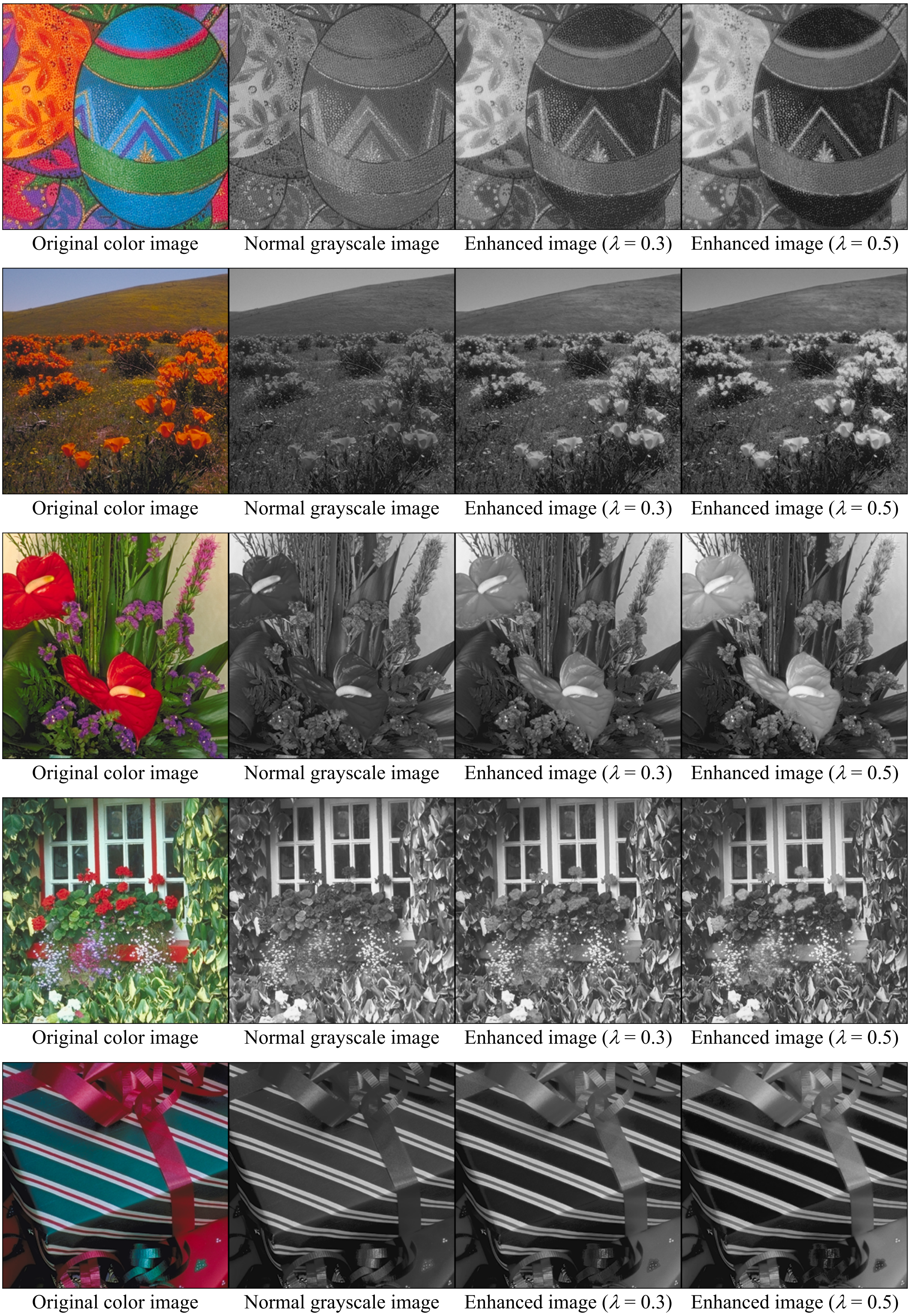


Figure 9: Controlling the effect of contrast enhancement on color to grayscale conversion.

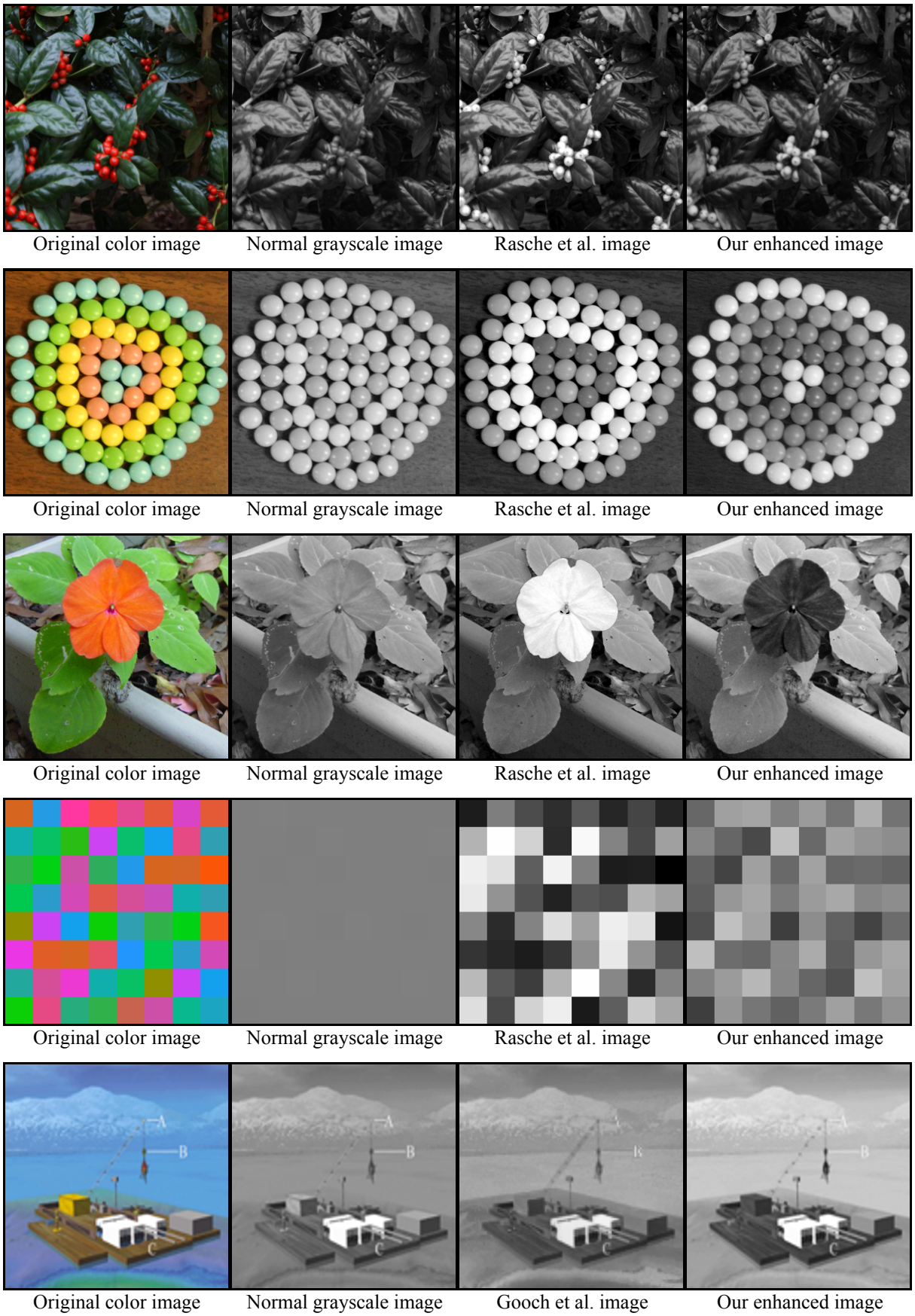


Figure 10: Comparison of contrast enhancement algorithms for color to grayscale conversion.

Parameters:

Unless otherwise stated, all our examples use $\lambda = 0.5$, $\sigma = 25$, and $\eta = 0.001$ on 300×300 images. While $\lambda = 0.5$ is quite high, it illustrates how well our technique can improve contrast. In practice, a more subtle enhancement $\lambda = 0.3$ may be preferable.

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Acknowledgements:

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