The Decolorize Algorithm

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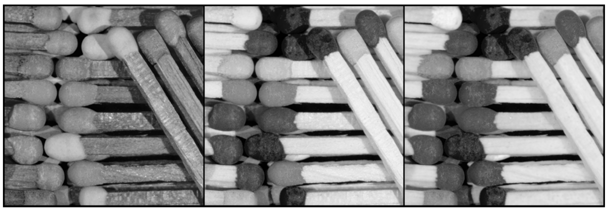
We present a novel, contrast enhancing, color to grayscale conversion technique which works in real-time. It performs global color to grayscale conversion by expressing grayscale as a continuous, image dependent, piecewise linear mapping of the RGB color primaries and their saturation.

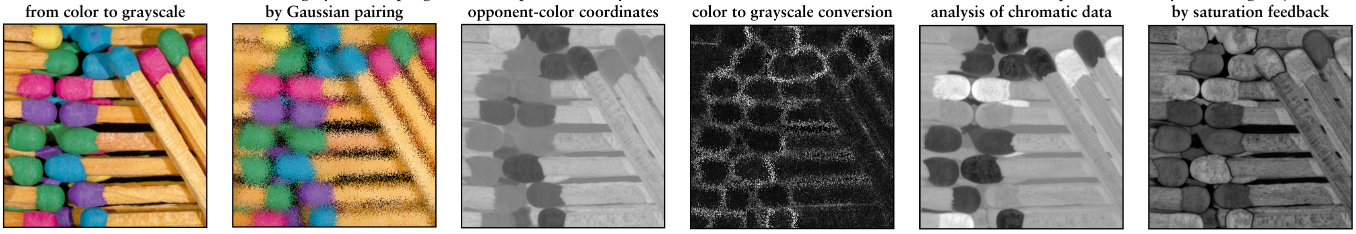
We begin with sampling by Gaussian pairing to analyze the distribution of color contrasts present in the image. We obtain a robust random sample of color differences belonging to image features of varying sizes by pairing each image pixel with a pixel chosen randomly according to a displacement vector drawn from a Gaussian distribution. The RGB image colors are converted to our YPQ color space, which consists of an achromatic luminance channel and a pair of chromatic opponent-color channels. We apply predominant component analysis to find the color axis that best represents the chromatic contrasts lost in the standard color to grayscale mapping. Unlike principal component analysis which optimizes the variability of colors, predominant component analysis optimizes the differences between colors. The predominant chromatic channel is a linear projection of the chromatic data along a color axis that captures the direction of the prevailing chromatic contrasts while reflecting the polarity of the prevailing luminance contrasts. We merge the luminance channel with the predominant chromatic channel to produce the desired degree of contrast enhancement. Finally, we use color saturation to further calibrate the dynamic range of the enhanced grayscale values. In effect, the decolorize algorithm linearly combines the luminance channel with feedback from either the predominant chromatic channel or the saturation channel, so that the enhanced contrast originates from either a linear or a polar representation of the chromatic data.

Contrast Enhancement of Detail, Local and Global Features

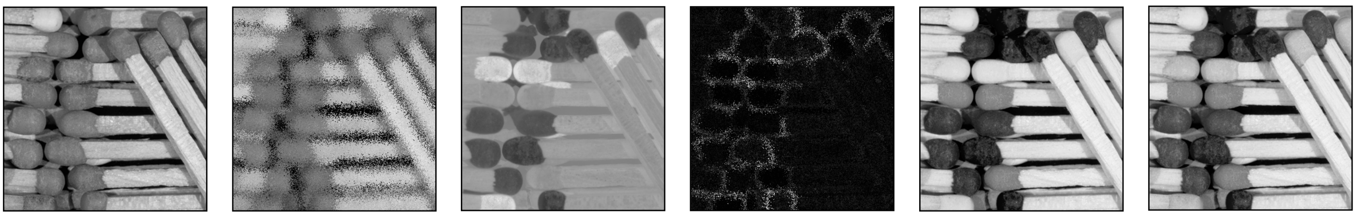


Stochastic Image Sampling | **Color Contrast Analysis** | **Fusion of Luminance and Chrominance**

Standard conversion from color to grayscale | Color & grayscale sampling by Gaussian pairing | Representation by opponent-color coordinates | Estimation of contrast loss in color to grayscale conversion | Predominant component analysis of chromatic data | Dynamic range adjustment by saturation feedback



Original color image (RGB) | Color sampling by Gaussian pairing ($\sigma = 5$) | Yellow-blue channel (P) | Chromatic contrast ($|\Delta P| + |\Delta Q|$) | Predominant chromatic channel | Saturation channel



Standard grayscale (NTSC luminance Y) | Grayscale sampling by Gaussian pairing ($\sigma = 5$) | Red-green channel (Q) | Chromatic contrast lost when replacing color by grayscale | Enhanced grayscale using chromatic data | Decolorized grayscale using chromatic & saturation data

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Rendering Colors in Grayscale

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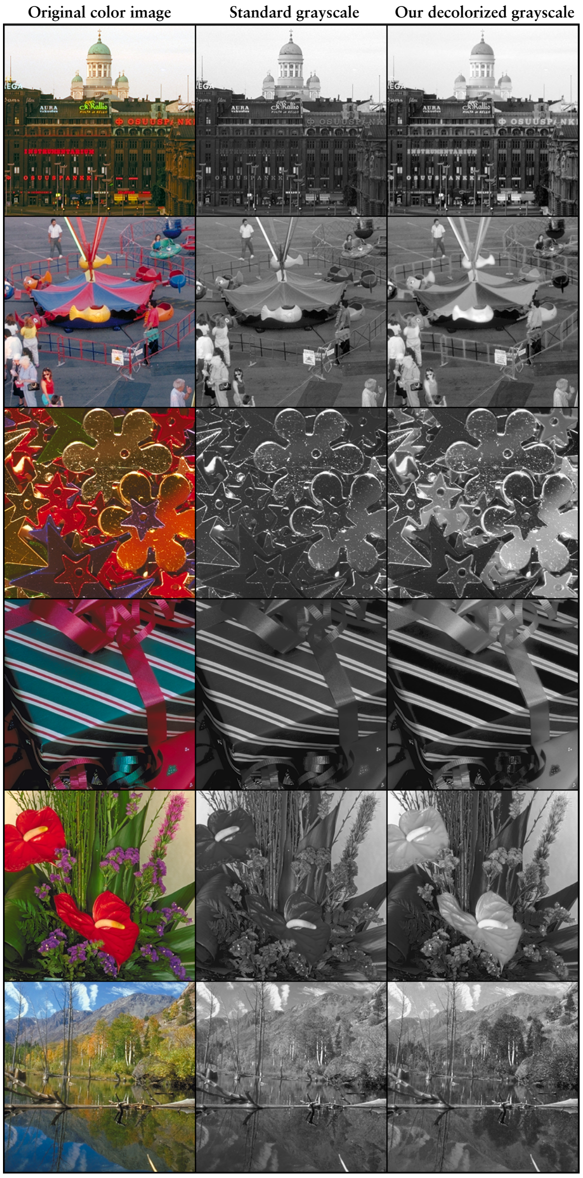
Our decolorize algorithm converts color to grayscale with less detail loss than the standard method. Our interpretive rendering technique provides a more informative depiction of a color scene. Although luminance predominates human visual processing, making it the standard color to grayscale mapping, it is not adaptive enough to capture all the perceived color contrasts. On the other hand, maximizing variation by principal component analysis can result in high contrasts but it may not appear predictable enough to be visually meaningful. Our decolorize algorithm enhances contrast in a visually meaningful way by augmenting luminance to reflect chromatic differences while preserving the polarity of shadows and highlights. The enhanced grayscale image produced by our decolorize algorithm can take the place of the luminance image in existing systems for displaying, analyzing, and recognizing images. For instance, our algorithm could readily be embedded in the driver software that renders color images on a grayscale printer. Also, our algorithm could help grayscale pattern recognition systems to take advantage of isoluminant image features. By imposing a globally consistent, image dependent, color ordering relation, our technique could enable the traditional tools of grayscale image processing to take better account of color information, thereby extending the usefulness of morphological image processing, median filters, and other order statistics methods.

We designed our algorithm to be simple to implement, fast to compute and guaranteed to give predictable results. Instead of relying on computationally intensive numerical optimization, we introduce novel techniques for image sampling and dimensionality reduction, sampling color differences by Gaussian pairing and analyzing color differences by predominant component analysis. We keep our running time linear in the number of pixels and independent of the number of colors in the image. When converting color to grayscale, achromatic pixels are always left unchanged. Light and dark shades of the same hue and saturation are always mapped to lighter and darker grays, and never the reverse. Our decolorize algorithm ensures continuous mapping, global consistency, and grayscale preservation, as well as predictable luminance, saturation, and hue ordering properties. The degree of contrast enhancement, the scale of contrast features, and the need for noise suppression can easily be adjusted.

Contrast Enhancing
Color to Grayscale Mapping



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