Find and Replace Color Gradients

New Interactive Tools for Color and Contrast Adjustment

Mark Grundland • Neil A. Dodgson

Computer Laboratory, University of Cambridge

Color and Contrast in Art

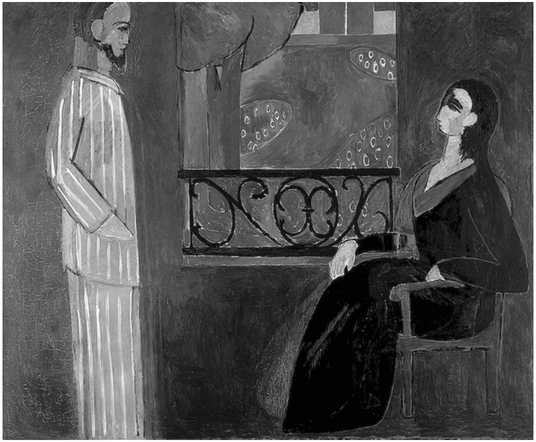
- The human eye can distinguish about 2.28 million colors.

The Turning Road, 1906
Andre Derain, 1880-1954

Color and Contrast in Art

- Contrast directs attention while color evokes emotion.

"I don't paint things.
I only paint the difference between things."
— Henri Matisse (1869-1954)



Red Room
1908

Henri Matisse
1869-1954

Conversation
1908-1912

Color and Contrast in Art

❖ **Contrast directs attention while color evokes emotion.**

"I don't paint things.
I only paint the difference between things."
— Henri Matisse (1869-1954)

Red Room 1908

Henri Matisse 1869-1954

Conversation 1908-1912

Color and Contrast Research

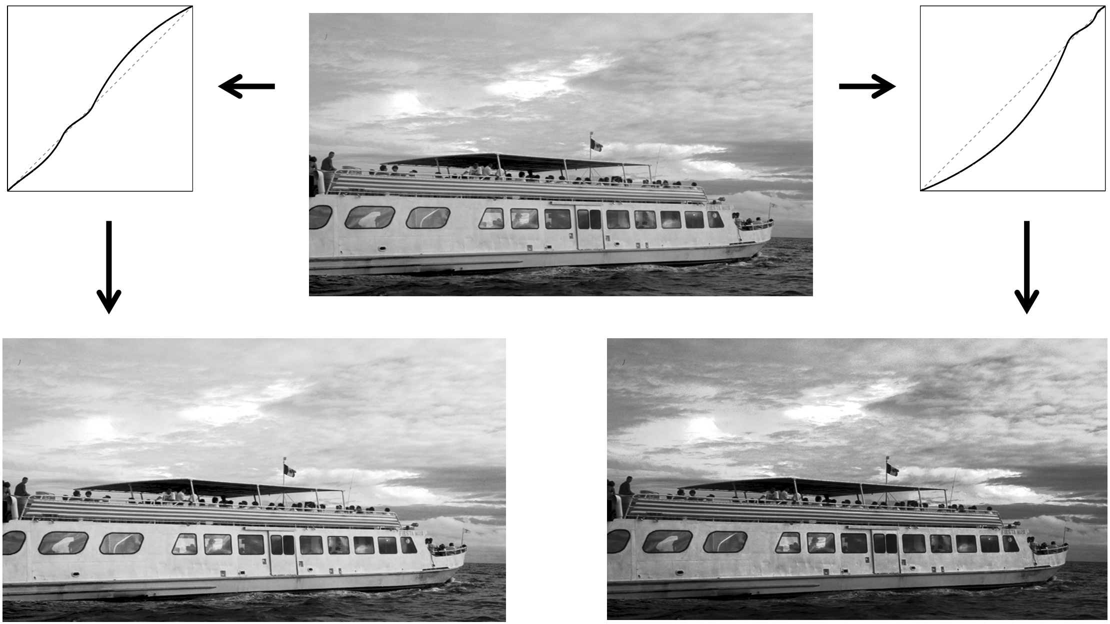
UNIVERSITY OF CAMBRIDGE
COMPUTER LABORATORY
RAINBOW RESEARCH GROUP

Making color and contrast adjustment easier to control.

- **Histogram Warping:** 1D tone transformation.
  - Automatic global color histogram specification for transferring the color scheme of one image to another.
  - Interactive global contrast enhancement by direct manipulation.
  - Interactive local contrast enhancement by contrast brushes.
- **Gamut Warping:** 3D color transformation.
  - Interactive global color and contrast adjustment by finding and replacing color gradients.

Histogram Transformation

- Formulate a global color or gray level mapping function.



Histogram Warping

- Apply a piecewise rational quadratic interpolating spline.

Standard Mapping by Linear Splines

Our Histogram Warping Technique

Problem

The contrast changes too abruptly.

Prevention of False Contour Artifacts

Solution

Apply continuously differentiable splines.

UNIVERSITY OF CAMBRIDGE
COMPUTER LABORATORY
RAINBOW RESEARCH GROUP

Histogram Warping

- Apply a piecewise rational quadratic interpolating spline.

Standard Mapping by Cubic Splines

Our Histogram Warping Technique

Prevention of False Halo Artifacts

Problem

The natural order of colors isn't preserved.

Solution

Apply monotonic interpolating splines.

Color Transfer by Example

- Apply a color space that has perceptually uniform color axes with statistically independent chromatic components.
- Map the quantiles of the color distribution of the source image to the corresponding quantiles of the target image.

Original Input Images

Color Transfer by Example

- Apply a color space that has perceptually uniform color axes with statistically independent chromatic components.
- Map the quantiles of the color distribution of the source image to the corresponding quantiles of the target image.

Output Images with Colors Exchanged

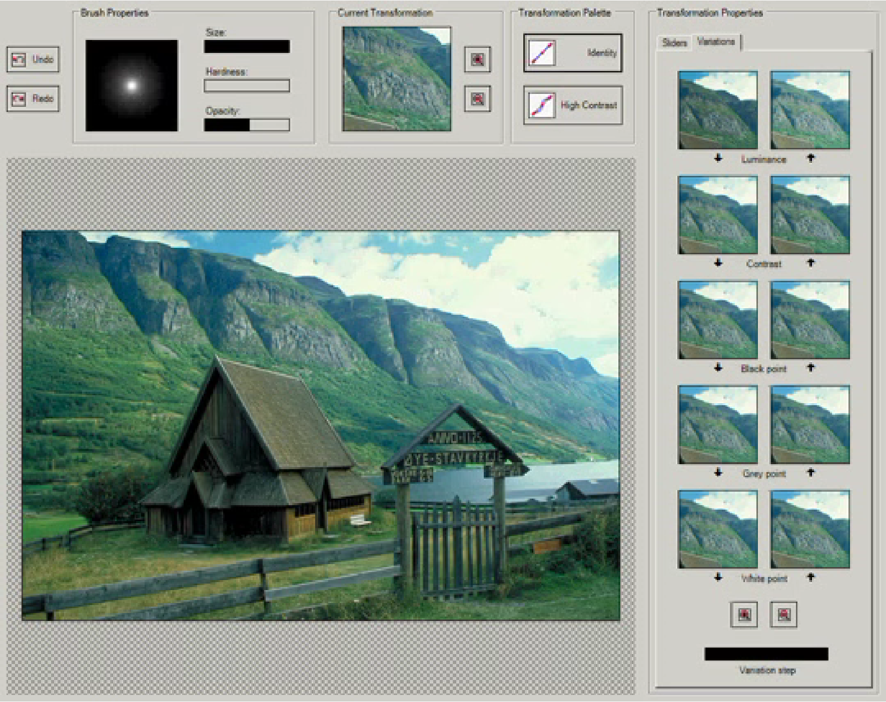
Interactive Contrast Adjustment

UNIVERSITY OF CAMBRIDGE COMPUTER LABORATORY
RAINBOW RESEARCH GROUP

❖ **Enable the user to quickly select the key tones of an image and change their contrast without affecting their color.**

UNIVERSITY OF CAMBRIDGE
COMPUTER LABORATORY
RAINBOW RESEARCH GROUP

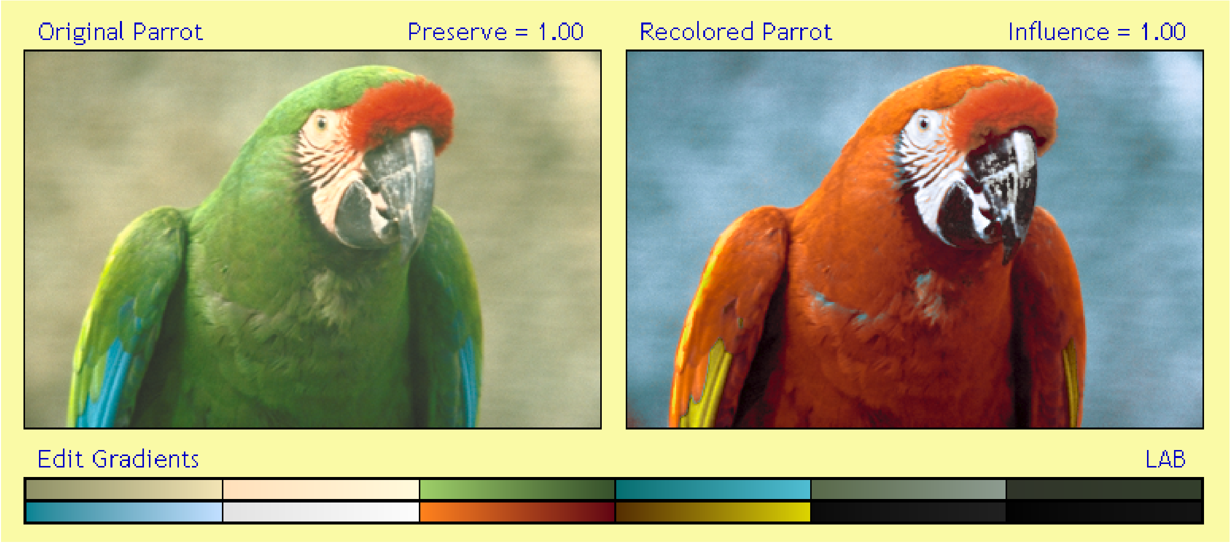
Contrast Brushes



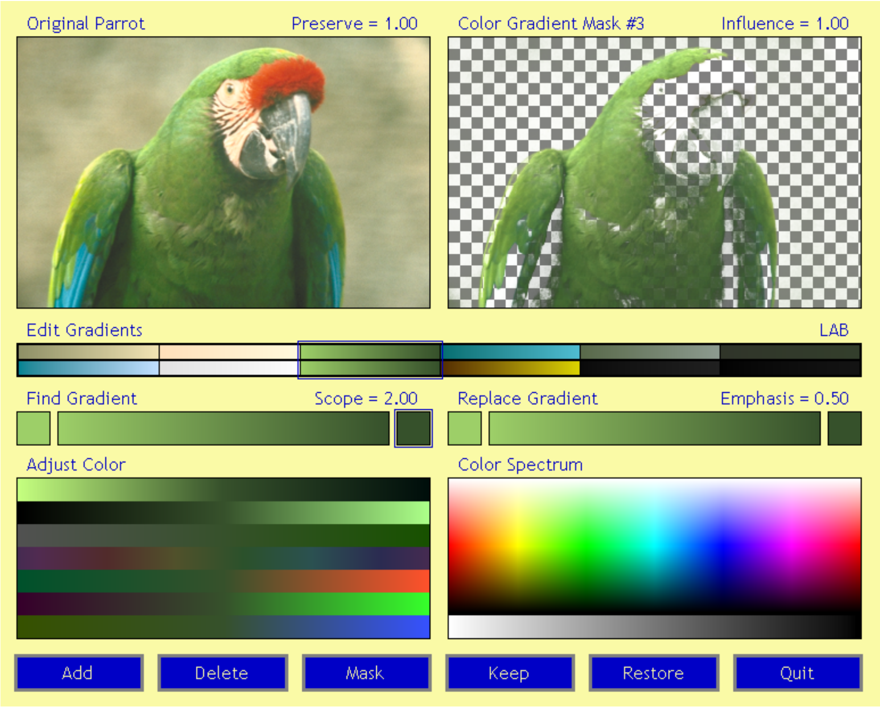
In collaboration with Rahul Vohra

Interactive Color Adjustment

- Enable the user to control the global color composition by designating a mapping of color gradients.

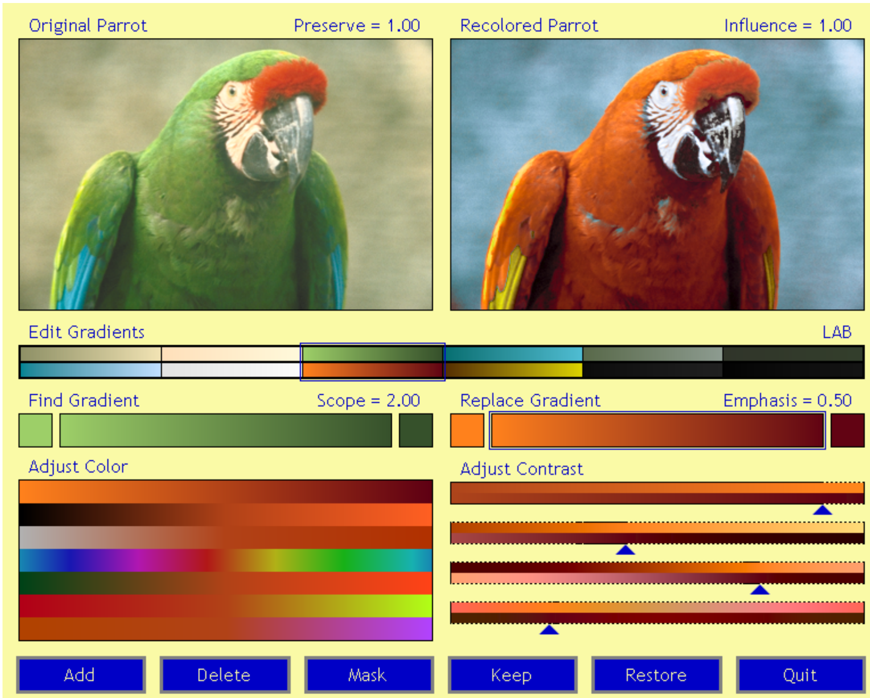


Find Color Gradient



UNIVERSITY OF CAMBRIDGE
COMPUTER LABORATORY
RAINBOW RESEARCH GROUP

Replace Color Gradient

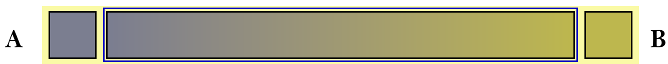


Specify Color Gradient

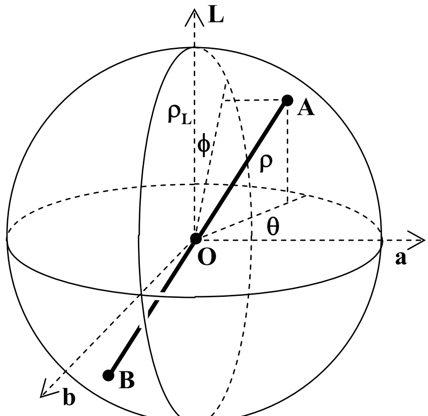
Enable the user to control color independently from contrast.

- **Cartesian Coordinates:** A geometric approach.

Line Segment in Color Space



- **Spherical Coordinates:** A perceptual approach.

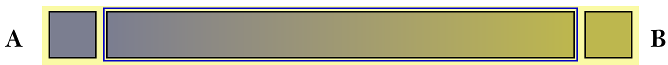


Specify Color Gradient

Enable the user to control color independently from contrast.

- **Cartesian Coordinates:** A geometric approach.

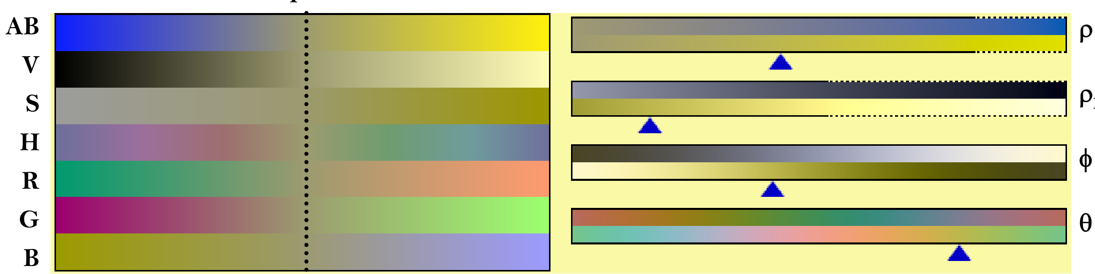
Line Segment in Color Space



- **Spherical Coordinates:** A perceptual approach.

Central Midpoint Color

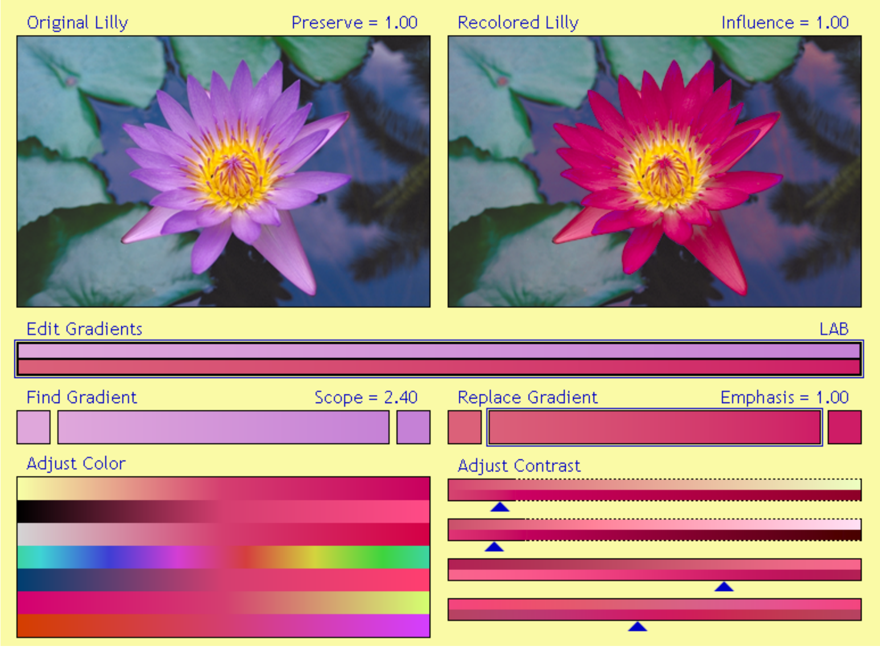
Color Contrast Radius



Color Orientation Angles

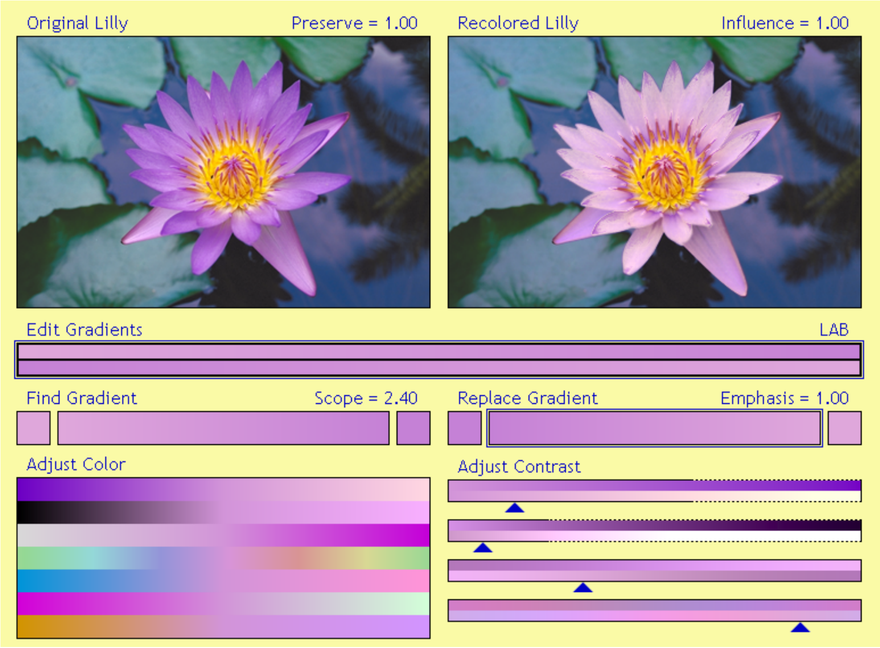
Color Gradient Transformation

- For a color shift, translate the midpoint color.



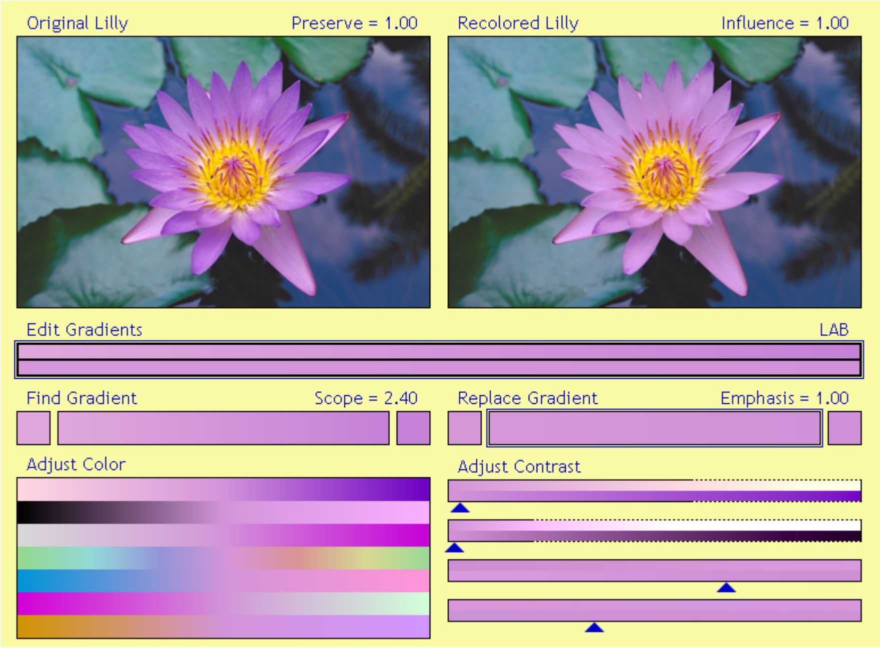
Color Gradient Transformation

- For a color inversion, reflect the endpoint colors.



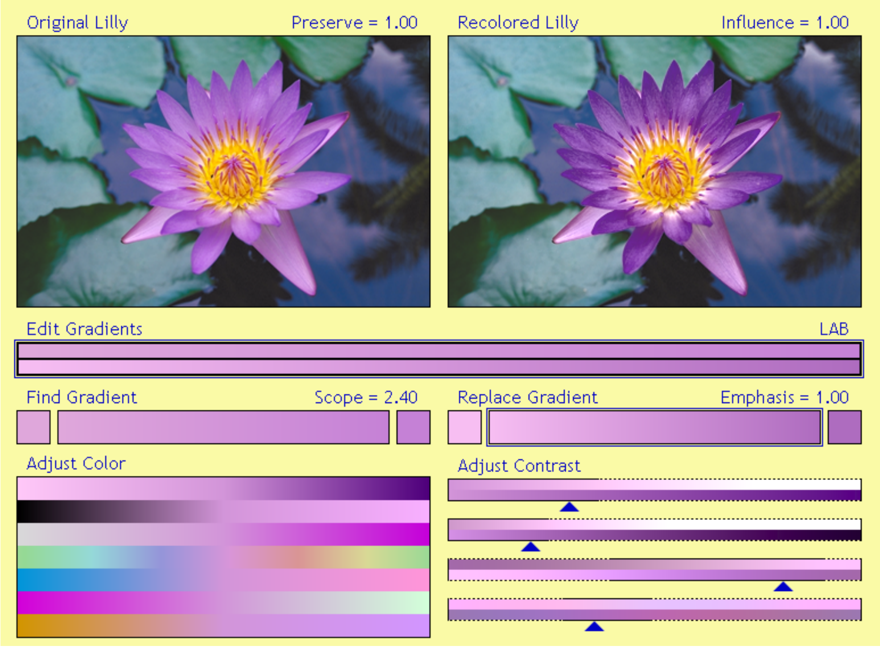
Color Gradient Transformation

❖ For a color contrast change, apply uniform scaling.



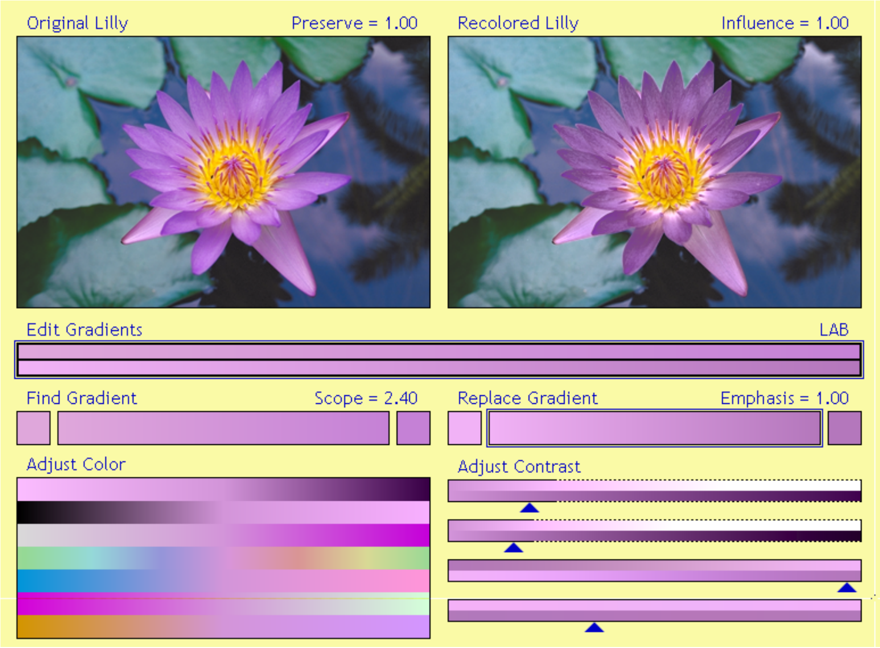
Color Gradient Transformation

- For a luminance contrast change, apply nonuniform scaling.



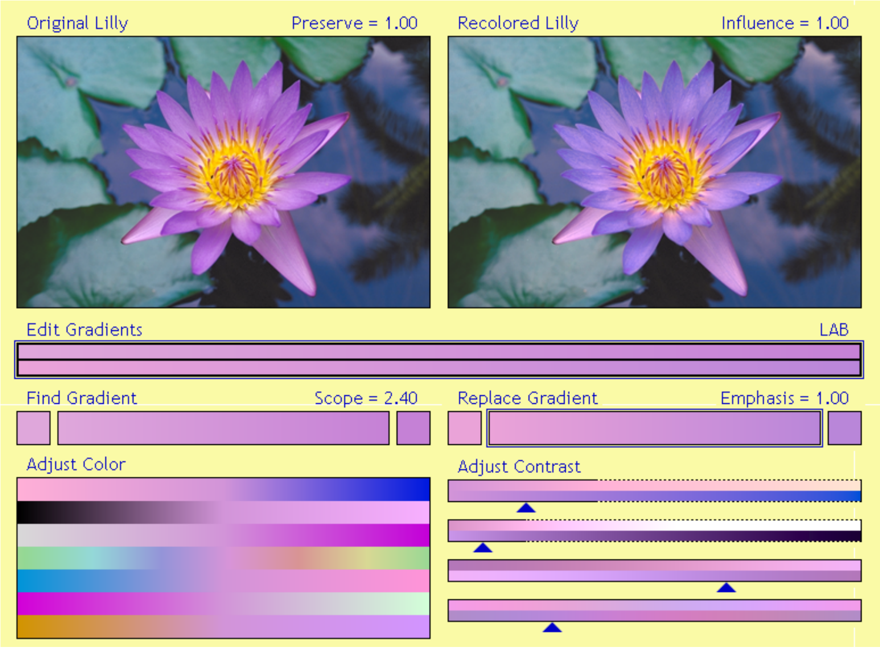
Color Gradient Transformation

❖ **For a luminance variation, rotate the luminance angle.**



Color Gradient Transformation

- For a hue variation, rotate the hue angle.

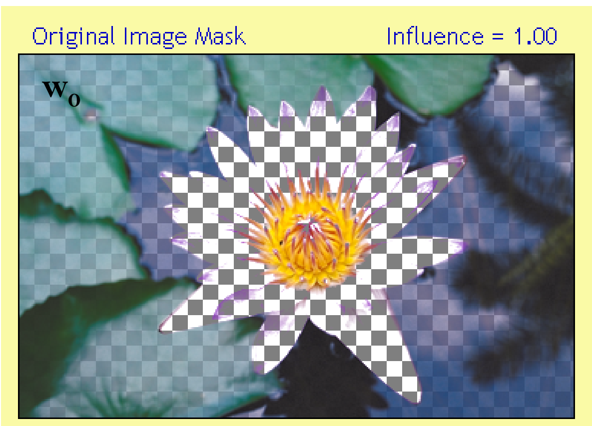


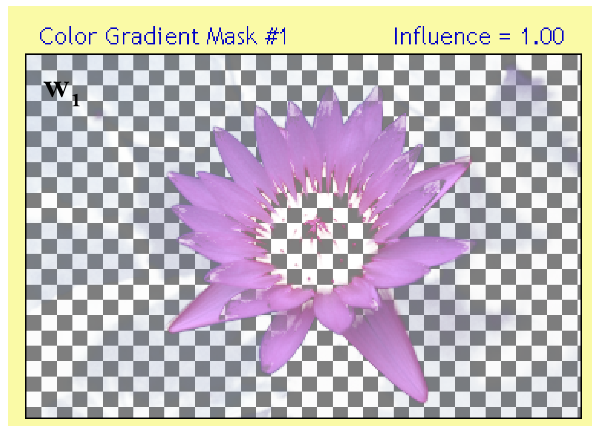
UNIVERSITY OF CAMBRIDGE
COMPUTER LABORATORY
RAINBOW RESEARCH GROUP

Color Gradient Segmentation

Each color gradient G_i has a region of influence in color space.

- **For each pixel, find its nearest gradient color in order to determine its distance D_i from the color gradient in the CIE-Lab color space.**
- **To assess the perceptual similarity, when comparing categorically different colors, use Shepard's model of generalization: $S_i = \exp(-D_i/\delta_i)$**



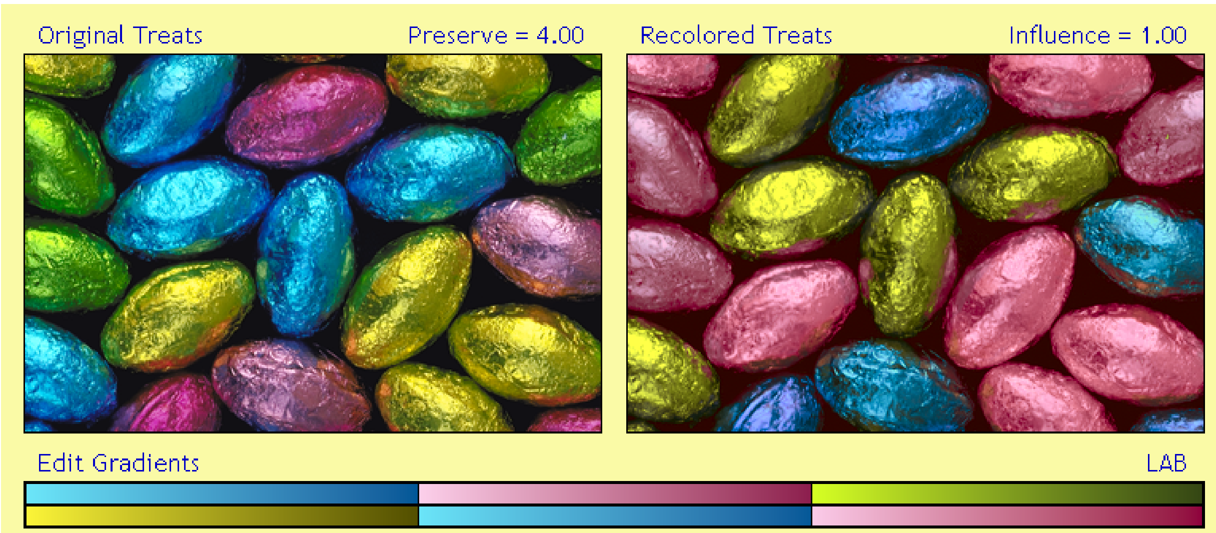


Color Gradient Mapping

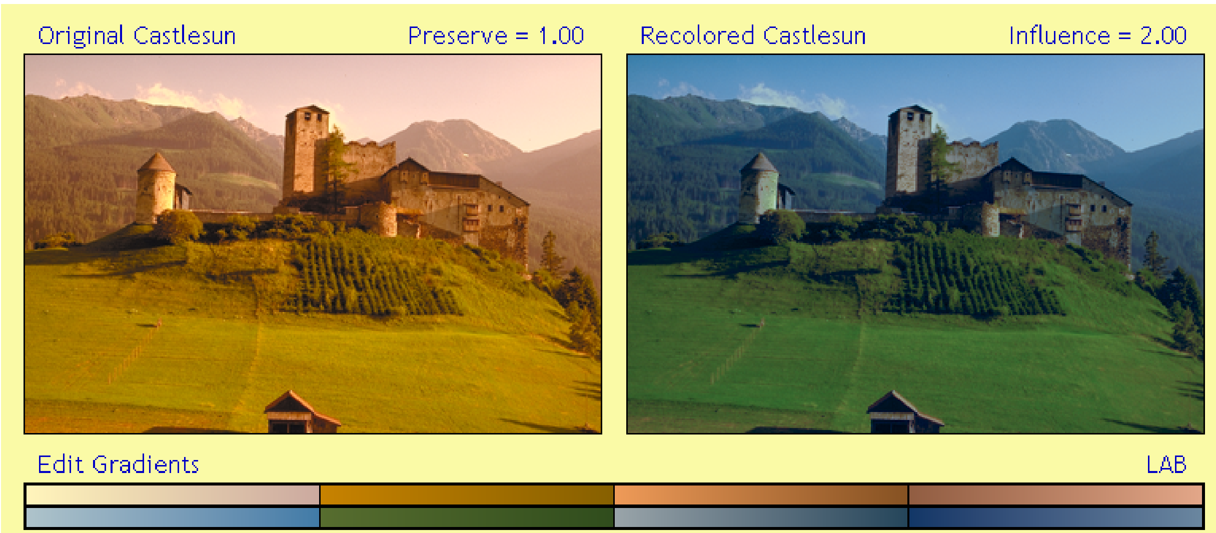
Apply a feature-based warping technique to calculate a nonlinear volumetric deformation of the color space.

- **For each gradient mapping, use Rodrigues' formula to derive the linear transformation P_i that maps its source colors to its target colors.**
- **For each gradient mapping, determine the relative weight of its influence on each pixel: $w_i = S_i / \max(\lambda, \sum S_i)$.**
- **Determine the portion of the original image T_0 that is unaffected by the influence of any of the color gradient mappings: $w_0 = 1 - \sum w_i$.**
- **The final transformation is the weighted sum: $P = w_0 P_0 + \sum w_i P_i$**
- **In effect, the resulting image can be seen as a composite of the original image and its color gradient transformations, with the mask of each layer determined by the region of influence of its color gradient.**
- **Compared with previous work, our approach benefits from operating on color spans rather than individual colors.**

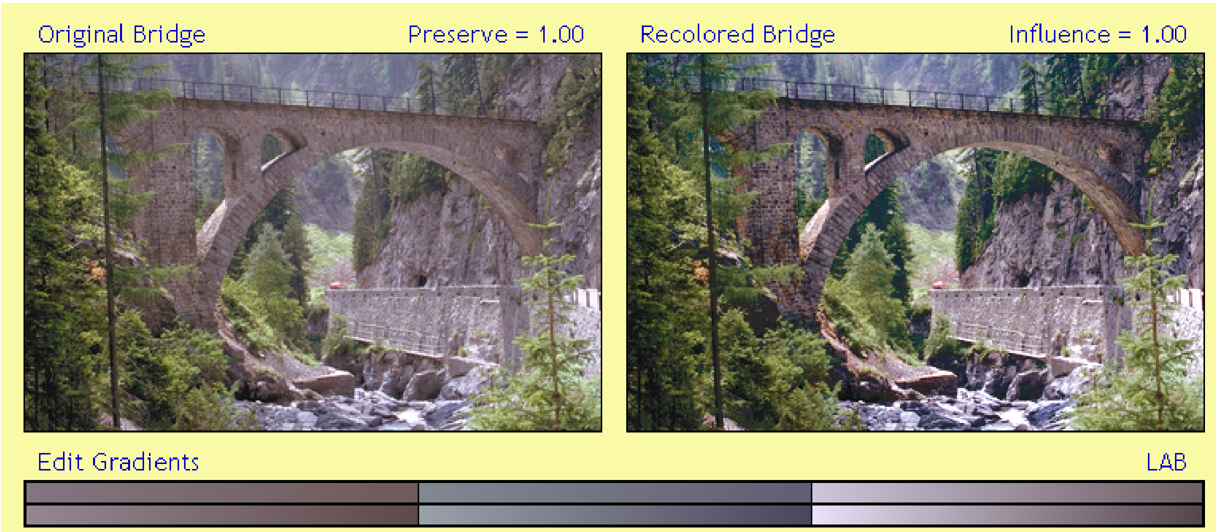
Application: Redecoration



Application: Relighting



Application: Contrast Adjustment



Application: Artistic Expression

UNIVERSITY OF CAMBRIDGE COMPUTER LABORATORY
RAINBOW RESEARCH GROUP