Nonlinear Multiresolution Image Blending

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A Detail Enhancement Technique for Image Compositing


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50%	50%	Interpolation

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50% **50%** **Our Method**

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Tools for Visual Expression

- **Stylized image representation (2005)**
  - **Non-photorealistic image compression and interpolation**
- **Color to grayscale conversion (2005)**
  - **Fast decolorization by rendering color contrasts in grayscale**
- **Color transfer (2005)**
  - **Color histogram specification by histogram warping**
- **Color correction (2005)**
  - **Image recoloring by finding and replacing color gradients**
- **Contrast adjustment (TBA)**
  - **Interactive contrast enhancement by contrast brushes**
- **Image compositing (2006)**
  - **Image blending by preserving of contrast, color, and salience**

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Linear Image Blending

20% Sunrise

40% Lake

40% Couple

Linear Image Blending

Contrast Preserving Image Blending

Color Preserving Image Blending

Salience Preserving Image Blending

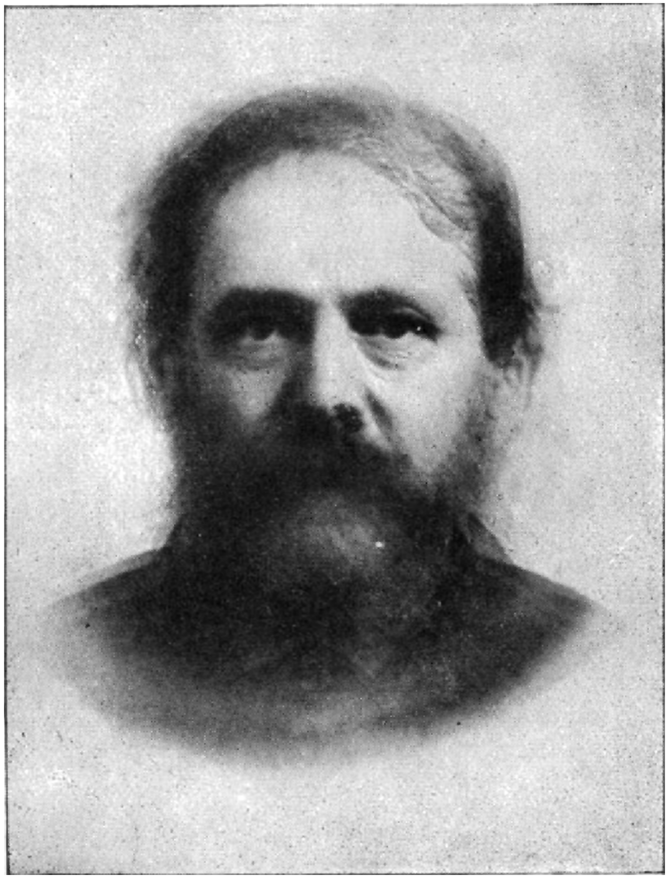
Linear Image Blending

Quadratic Image Blending

Quartic Image Blending

Selection Image Blending

Composite Photography:



31 Members of the Academy of Sciences

49 Students at Smith College

Composite portraits published in the journal *Science* in 1885-1886

Compositing Techniques:

- **Image Cloning** (Cut-and-Paste)
  - Occluded opaque objects: images placed on top of each other
  - Example: Image stitching
  - Accurate image mattes
  - Simple image blending
- **Image Mixing (Cut-and-Merge)**
  - Superimposed translucent objects: images combined with each other
  - Example: Cross dissolve
  - Simple image mattes
  - Perceptual image blending

Traditional Photomontage by Jerry Uelsmann

Compositing Goals

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Enable the artist to control the aesthetic appearance of the composite without the need to individually manipulate its components or their opacities

- **Image compositing:** (see the paper)
  - Multiple independent images with variable opacities
- **Cross dissolve:** (see the presentation)
  - Two independent images with constant opacities
- **Image stitching:**
  - Two independent images with binary opacities
- **Image fusion:**
  - Multiple dependent images with unknown opacities

Compositing Representations

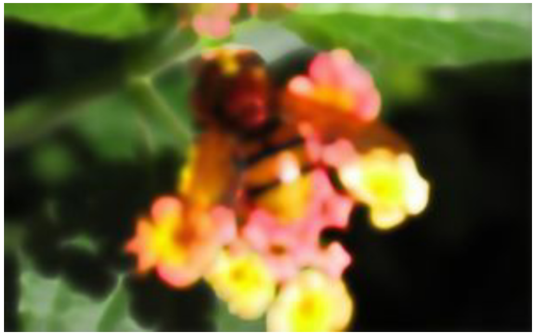
- Pixel values
  - Alpha channel (Smith & Catmull, 1977)
  - Blending modes (Porter & Duff, 1984)
  - Optimal image stitching (Milgram, 1977)
- Laplacian pyramids
  - Multiresolution splines (Burt & Adelson, 1983)
- Wavelet decompositions
  - Wavelet image stitching (Hsu & Wu, 1996)
  - Optimal wavelet image stitching (Su, Hwang, & Cheng, 2001)
- Gradient domain representations
  - Poisson image editing (Perez, Gangnet, & Blake, 2003)
  - Interactive digital photomontage (Agarwala et al., 2004)
  - Optimal gradient domain image stitching (Zomet et al., 2006)

Blending by Linear Interpolation

$$C = wA + (1 - w)B$$

- Linear cross dissolve of A and B, with constant opacity $0 \le w \le 1$
- Linear averaging reduces variation: $\sigma_C \le w\sigma_A + (1 - w)\sigma_B$
  - A nondegenerate linear combination of bounded, identically distributed signals, with nonzero mean, can not simultaneously maintain both their expected intensity μ and variation σ
- Linear blending averages coinciding pixels of different images: variation loss in the dynamic range reduces image contrast
- Linear smoothing averages adjacent pixels of the same image: variation loss in the frequency domain reduces image sharpness

Standard Linear Gaussian Smoothing



Our Color Preserving Gaussian Smoothing

Compositing Operators

- **Mathematical models:**
  - Linear weighted mean
    - Results in undesirable contrast loss (emphasizes gray)
  - Signed weighted power mean
    - User controlled contrast enhancement (emphasizes details)
  - Maximal absolute magnitude selection
    - Results in undesirable contrast gain (emphasizes noise)
- **Physical Models:**
  - Absorption of light
    - Results in undesirable darkening (emphasizes black)
  - Emission of light
    - Results in undesirable brightening (emphasizes white)
  - Mixture of pigments
    - Results undefined if pigment parameters are not available

Redefining Linear Interpolation

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$$C = wA + (1 - w)B$$

- **Operators:** $\oplus$ and $\otimes$
  - **Detail preserving image compositing**
    - Generalized means: enhances varied details over flat colors
  - **Color preserving image compositing**
    - Vector algebra: emphasizes vivid colors over shades of gray
- **Result:** C’
  - **Contrast preserving image compositing**
    - Statistical analysis: recovers contrast lost due to averaging
- **Weights:** w’
  - **Salience preserving image compositing**
    - Information theory: keeps what is deemed most informative

Standard Linear Image Blending

Detail Preserving Image Blending

Detail Preserving Blending

$$\mathbf{C} = \left\langle \mathbf{w}\langle \mathbf{A}\rangle^{\rho} + (1-\mathbf{w})\langle \mathbf{B}\rangle^{\rho} \right\rangle^{1/\rho} \quad \textbf{for} \quad \langle \mathbf{X}\rangle^{\rho} = \textbf{sign}(\mathbf{X})\,|\,\mathbf{X}\,|^{\rho}$$

- **Problem:** Linear blending obliterates fine details
- **Model:** Combine image values using a signed weighted power mean
- **Solution:** Emphasize variation over uniformity when compositing a heterogeneous image region with a homogenous image region
- **Parameter ρ :** User control over the degree of detail enhancement
- **Advantage:** Simple, efficient and continuous compositing technique to balance the effects of linear averaging and coefficient selection
- **Disadvantage:** May exaggerate image noise along with image detail

Signed Weighted Power Mean

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$$\mathbf{C} = \left\langle \mathbf{w}\langle \mathbf{A}\rangle^{\rho} + (1-\mathbf{w})\langle \mathbf{B}\rangle^{\rho} \right\rangle^{1/\rho} \quad \text{for} \quad \langle \mathbf{X}\rangle^{\rho} = \operatorname{sign}(\mathbf{X})\,|\,\mathbf{X}\,|^{\rho}$$

- **Intermediate Value: Bounded contrast**
  - **For** $0 \le \rho \le \infty$: $\min(\mathbf{A},\mathbf{B}) \le \mathbf{C} \le \max(\mathbf{A},\mathbf{B})$
- **Geometric Mean: Minimal contrast**
  - **For** $\rho \to 0$: $\mathbf{C} = \frac{1}{2}\left(\operatorname{sign}(\mathbf{A}) + \operatorname{sign}(\mathbf{B})\right)|\,\mathbf{A}\,|^{\mathbf{w}}\,|\,\mathbf{B}\,|^{1-\mathbf{w}}$
- **Linear Mean: Reduced contrast**
  - **For** $\rho = 1$: $\mathbf{C} = \mathbf{w}\mathbf{A} + (1-\mathbf{w})\mathbf{B}$
- **Power Mean: Enhanced contrast**
  - **For** $\rho \in \mathbb{N}$ **odd**: $\mathbf{C} = \sqrt[\rho]{\mathbf{w}\mathbf{A}^{\rho} + (1-\mathbf{w})\mathbf{B}^{\rho}}$
- **Coefficient Selection: Maximal contrast**
  - **For** $\rho \to \infty$: $\mathbf{C} = \mathbf{A}$ **when** $|\,\mathbf{A}\,| \ge |\,\mathbf{B}\,|$ **or** $\mathbf{C} = \mathbf{B}$ **when** $|\,\mathbf{B}\,| \ge |\,\mathbf{A}\,|$

Signed Weighted Power Mean

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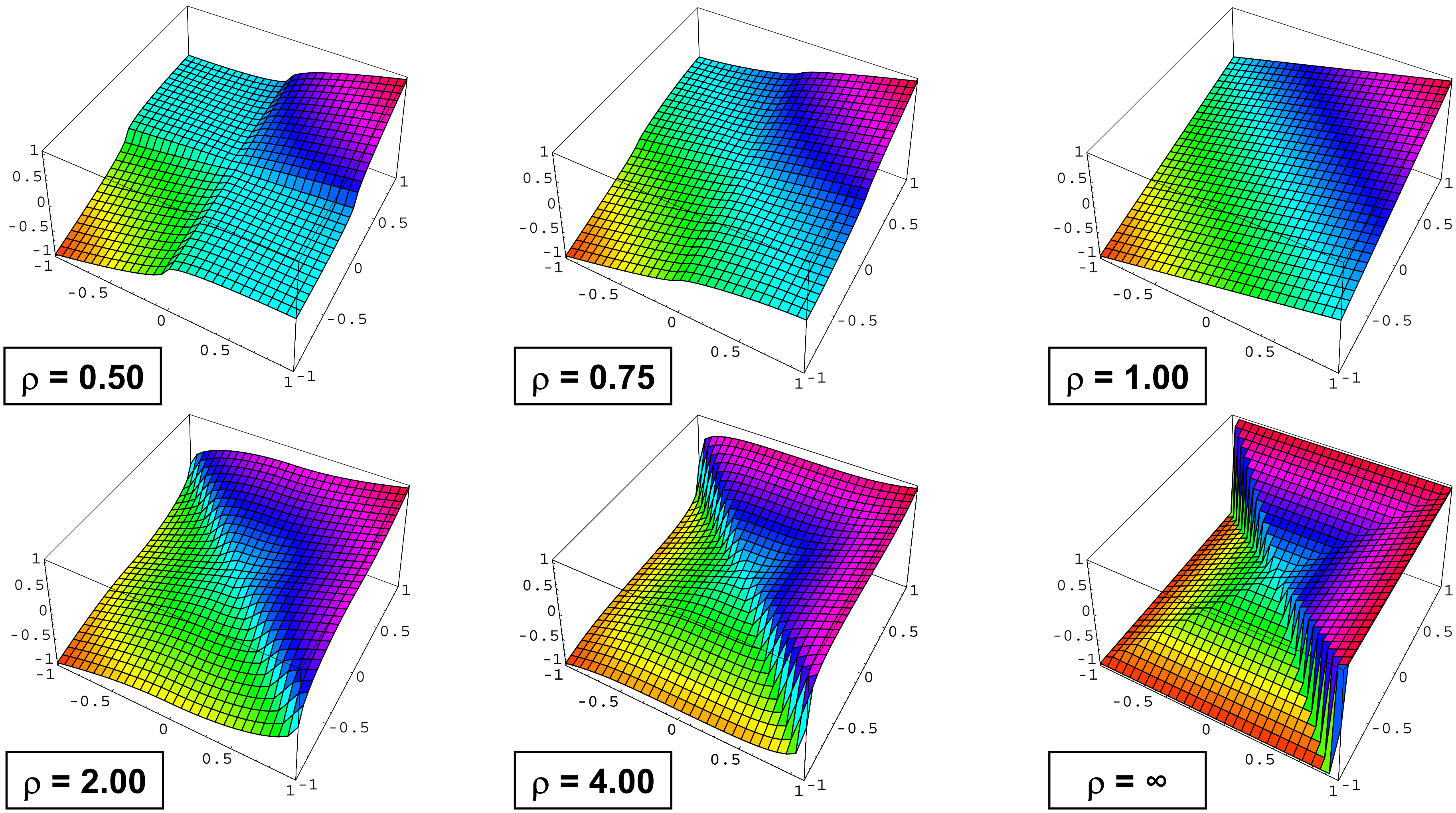


$\rho = 0.5$

$\rho = 1.0$

$\rho = 2.0$

$\rho = 4.0$

$\rho = \infty$

Contrast Preserving

ρ = 0.5
Nonlinear
Cross Dissolve

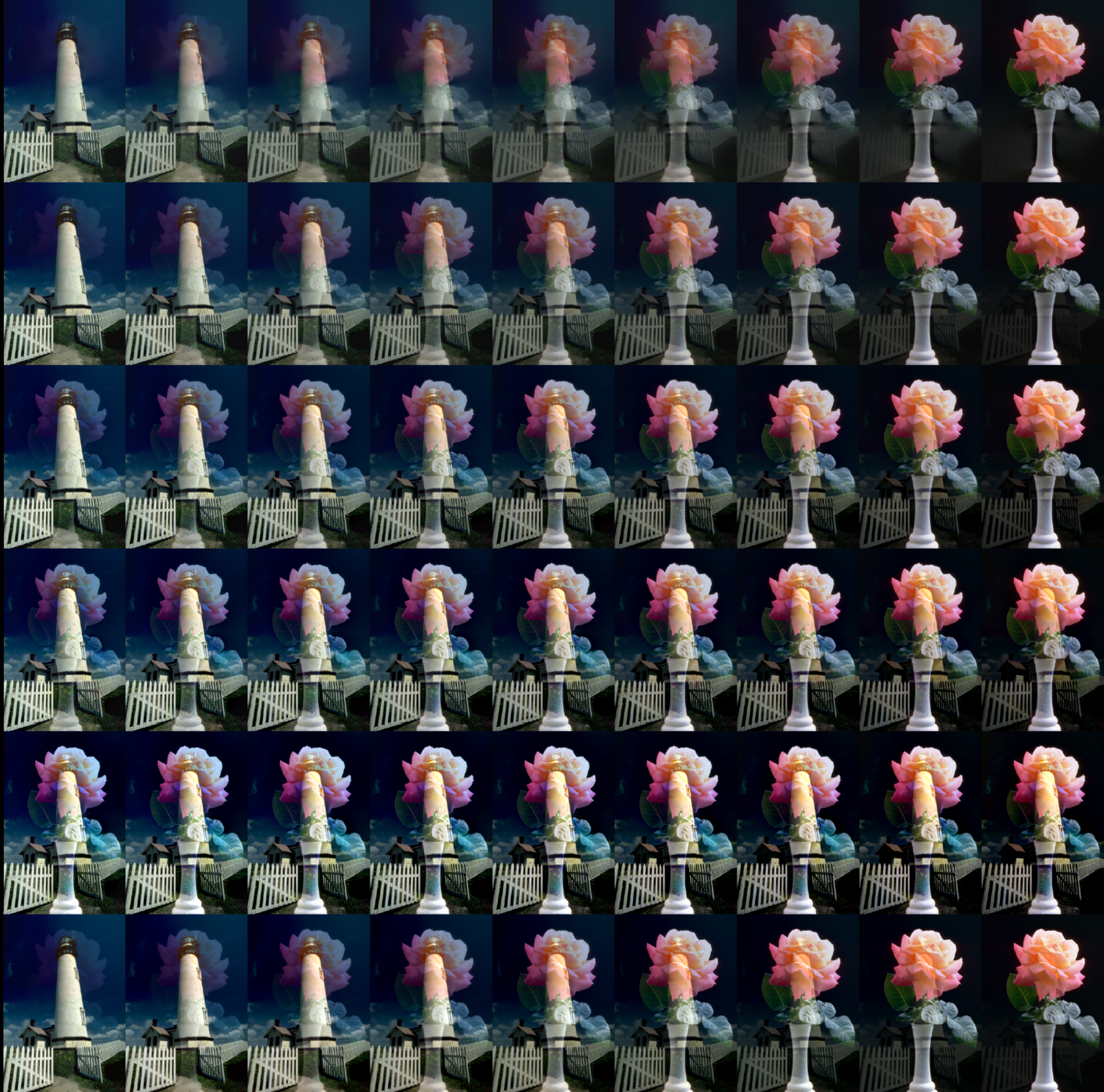
ρ = 1.0
Linear
Cross Dissolve

ρ = 2.0
Nonlinear
Cross Dissolve

ρ = 4.0
Nonlinear
Cross Dissolve

ρ = ∞
Selection
Cross Dissolve

Contrast
Preserving
Cross Dissolve



ρ = 0.5
Nonlinear
Cross Dissolve

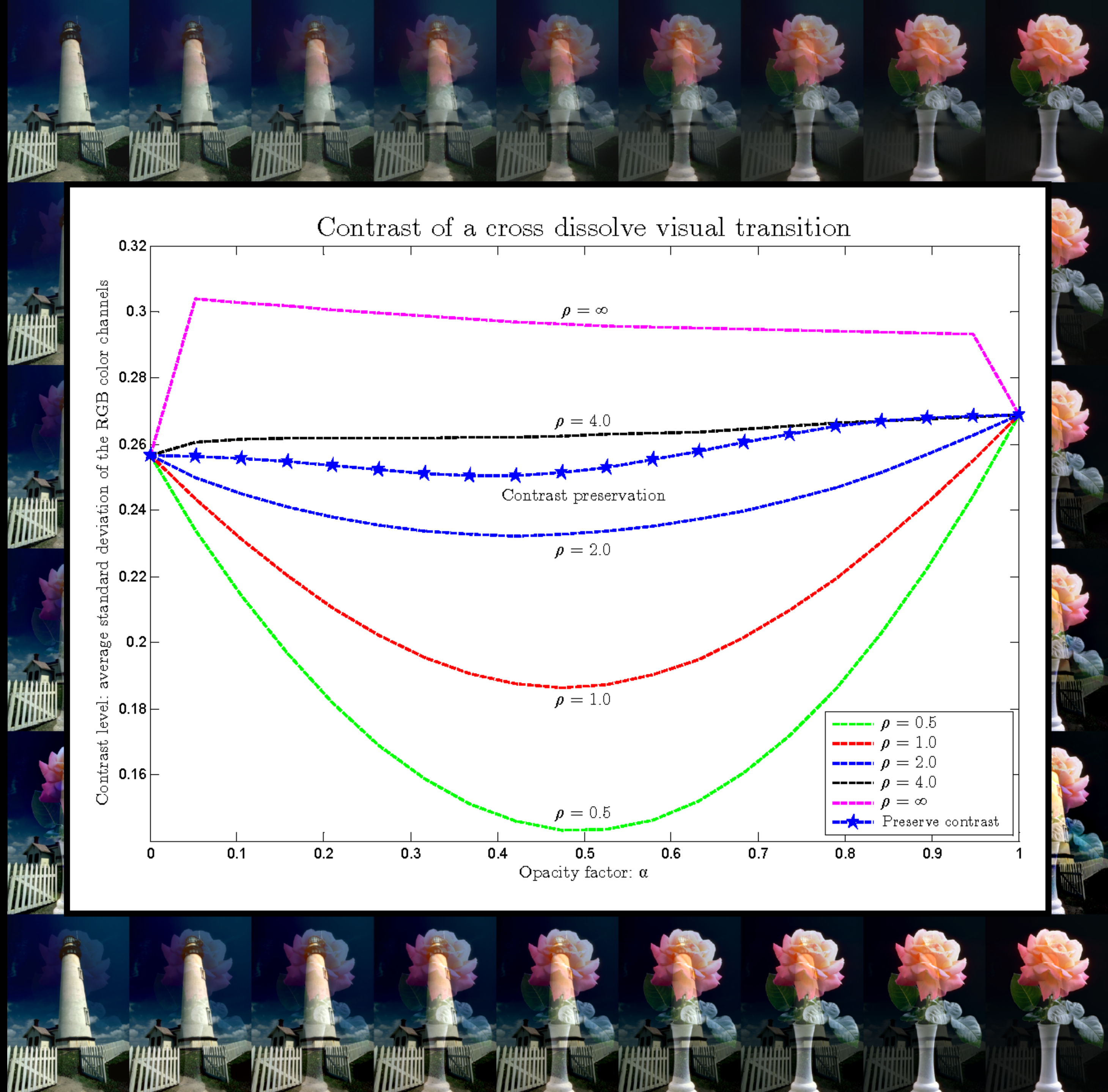
ρ = 1.0
Linear
Cross Dissolve

ρ = 2.0
Nonlinear
Cross Dissolve

ρ = 4.0
Nonlinear
Cross Dissolve

ρ = ∞
Selection
Cross Dissolve

Contrast
Preserving
Cross Dissolve



Linear Image Blending

Church

Forest

Opacity

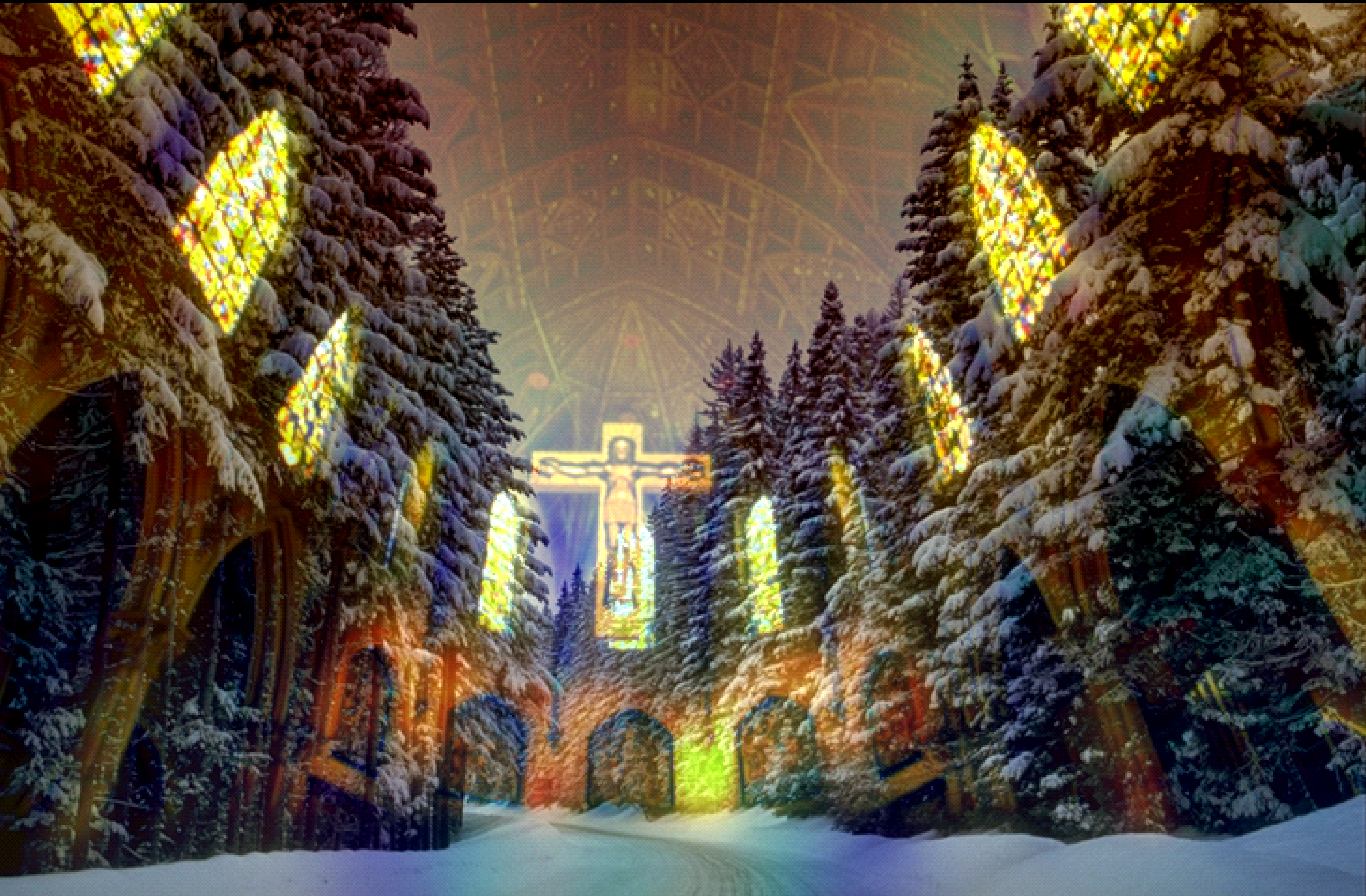
Square Root Image Blending: $\rho = 0.5$

Linear Image Blending: $\rho = 1.0$

Quadratic Image Blending: $\rho = 2.0$

Quartic Image Blending: ρ = 4.0

Selection Image Blending: $\rho = \infty$

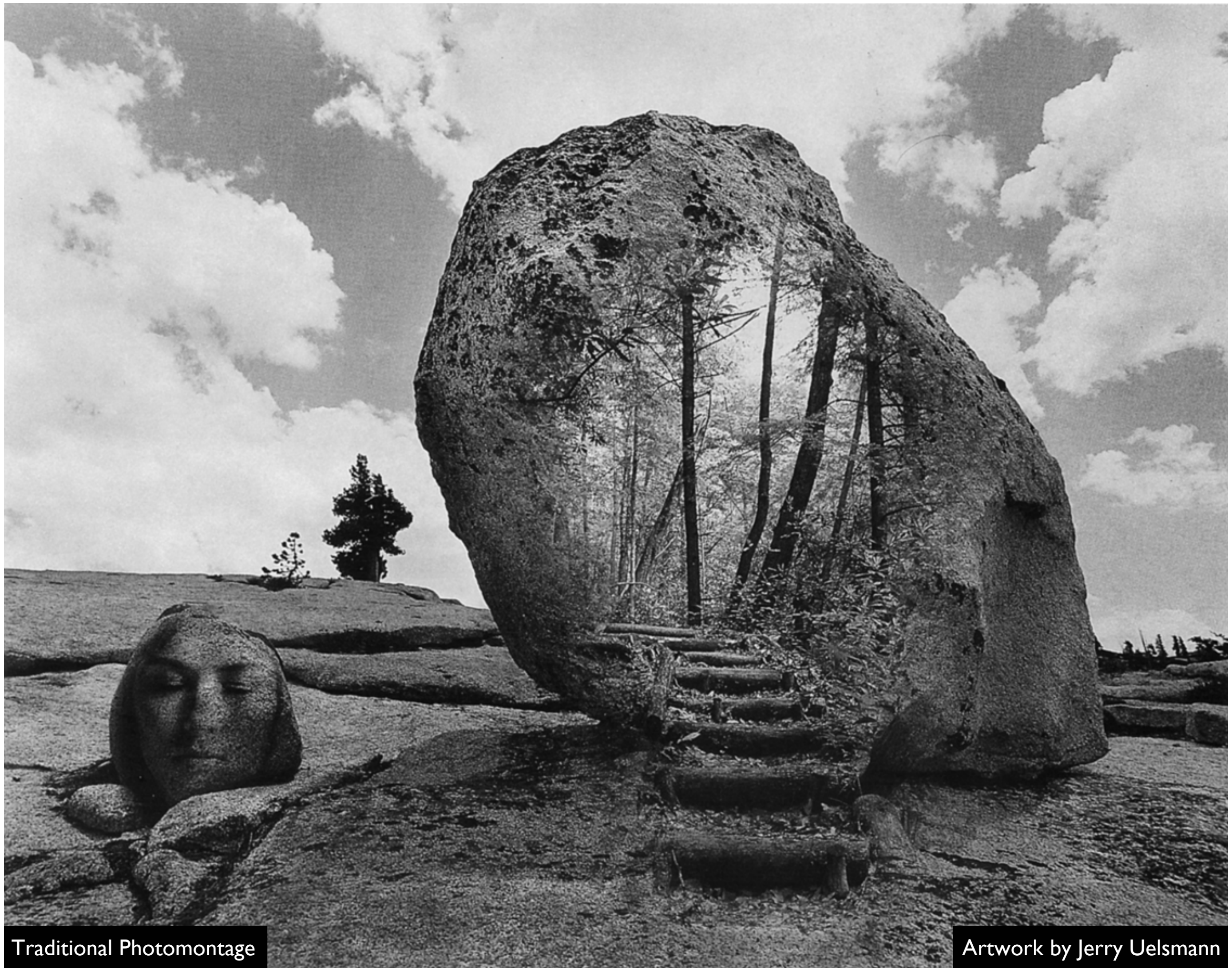


Color Preserving Image Blending

Contrast Preserving Image Blending

Salience Preserving Image Blending

Questions?



Traditional Photomontage

Artwork by Jerry Uelsmann