Non-Photorealistic Rendering

Photorealistic Rendering

Battlefield 4

Non-Photorealistic Rendering

Street Fighter VI

NPR

What is NPR?

Why might we use it?

NPR Uses

Convey numerous artistic styles

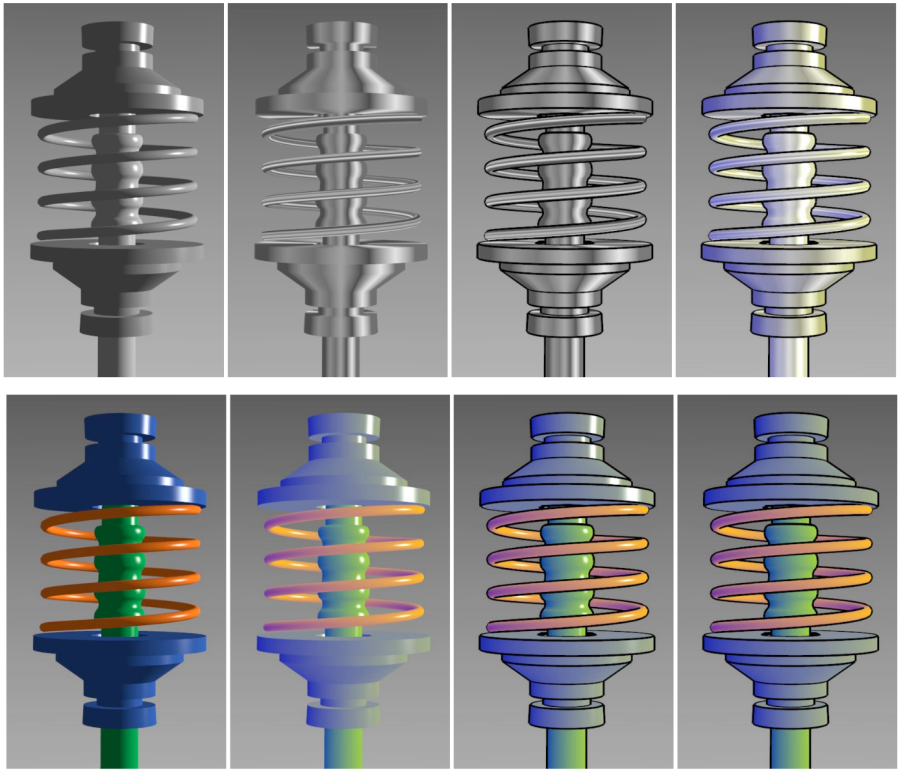
- Painting
- Drawing
- Technical Illustration

Succinctly convey important information

Convey a wider range of emotion

Technical Illustration

- Programmatically extract “important” lines
- Incorporate artistic techniques (e.g. tone shifts) into lighting models
- Convey object’s form



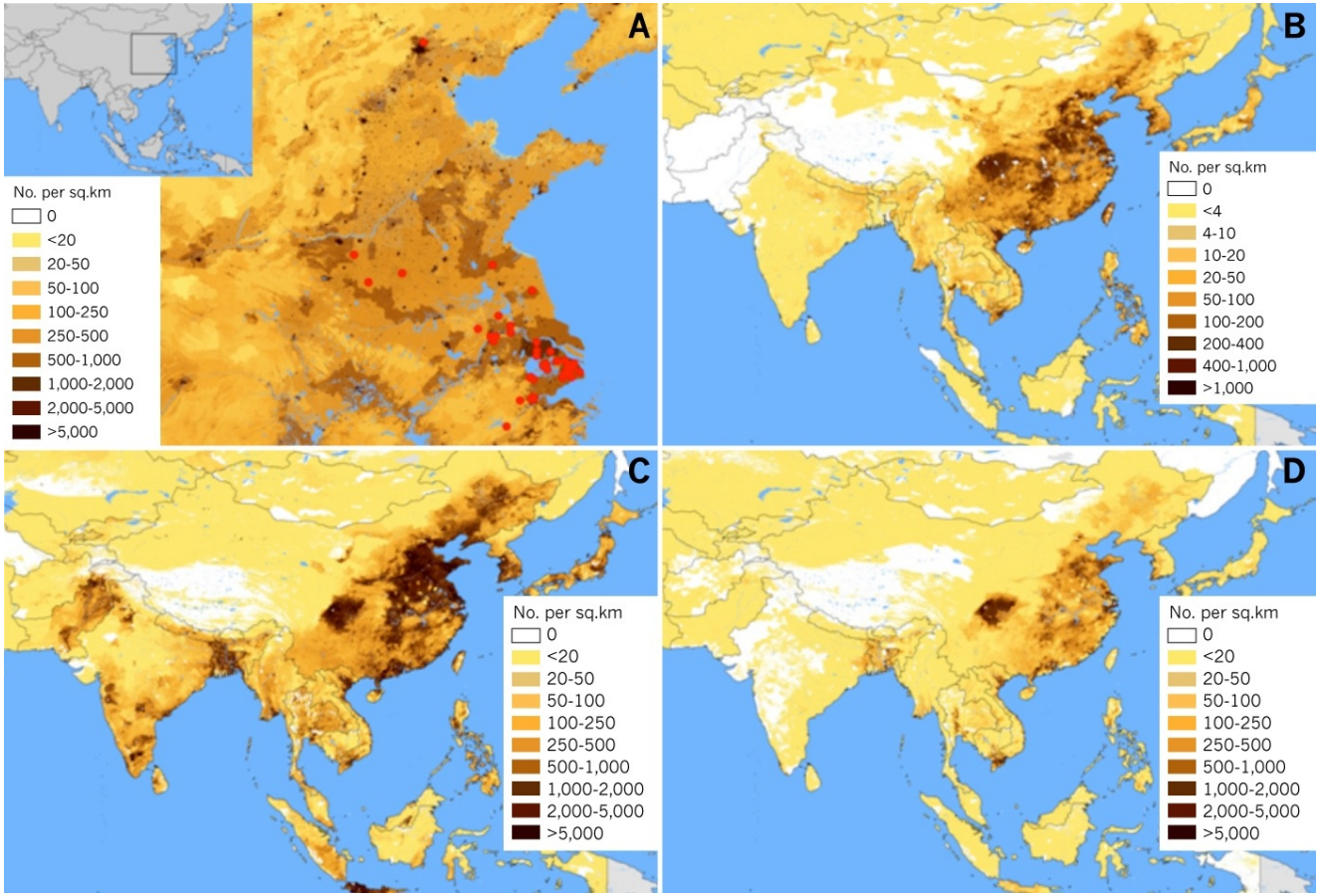
A Non-Photorealistic Lighting Model For Automatic Technical Illustration (Gooch et al ’98)

Data Visualization

Combines graphics, HCI, cognitive science, psychology, and big data

Provides concise, meaningful view of information

Data Visualization



H7N9 outbreaks and human/animal population densities (Nature)

Unique Styles

OverCoat: An Implicit Canvas for 3D Painting (Schmid et al ’11)

- Give computer graphics a traditional look and feel
- Procedural assistance reduces artist work

Okami

https://www.youtube.com/watch?v=lkVt1s_ZFbw Zelda: Wind Waker

Painterly Effects

Paint by Numbers (Haeberli '90)

Recreate effects of traditional media

Encapsulate "style" via stroke properties

What Is Style?

Ori and the Blind Forest

Creating a Style

Style is shaped by:

- Strokes
- Textures
- Lighting
- Simulation

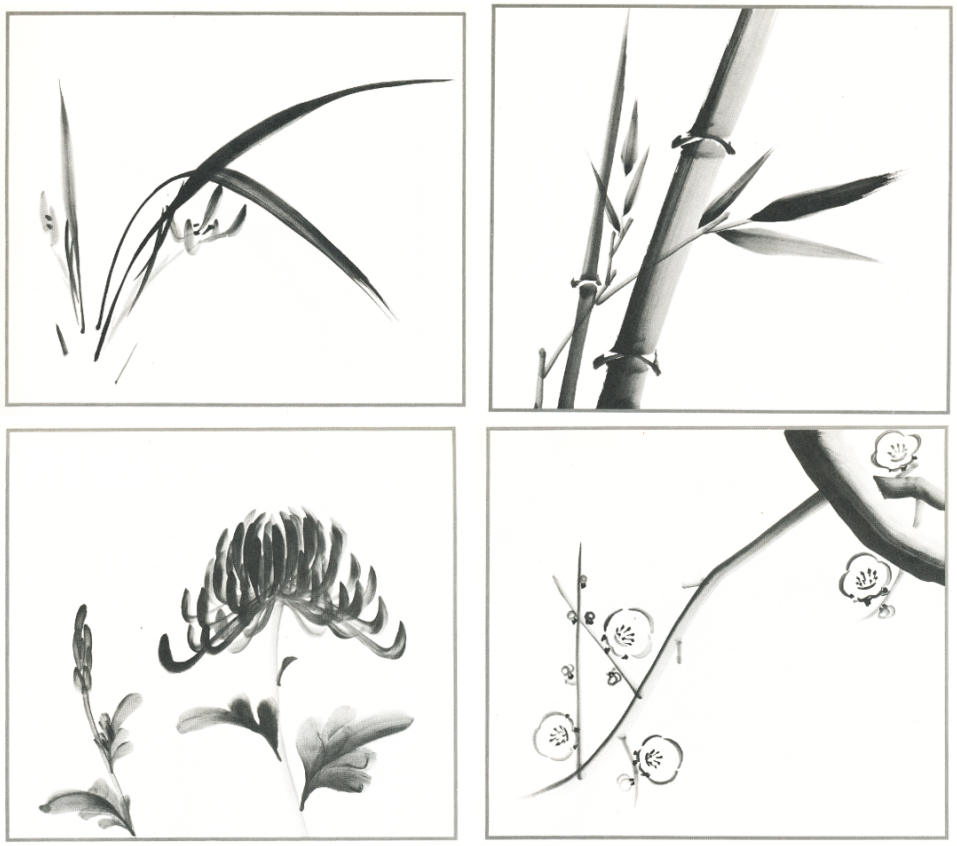
Creating Strokes

Strokes can define:

- Depth (e.g. line thickness, line visibility)
- Edges (e.g. silhouettes, boundaries, creases)
- Shading (e.g. hatching, line density)
- Stylization (e.g. Impressionism, Pointillism, sumi-e)

Stroke Properties

- Width
- Density
- Orientation
- Color
- Opacity
- Texture



Four Gentlemen (sumi-e ink painting)

Stroke Appearance

Stroke appearance controlled by:

- Choices in curve
  - Splines versus cubic interpolation
  - Continuity
- Shaders
  - Translucency and pigment density
  - Lighting interaction with stroke material

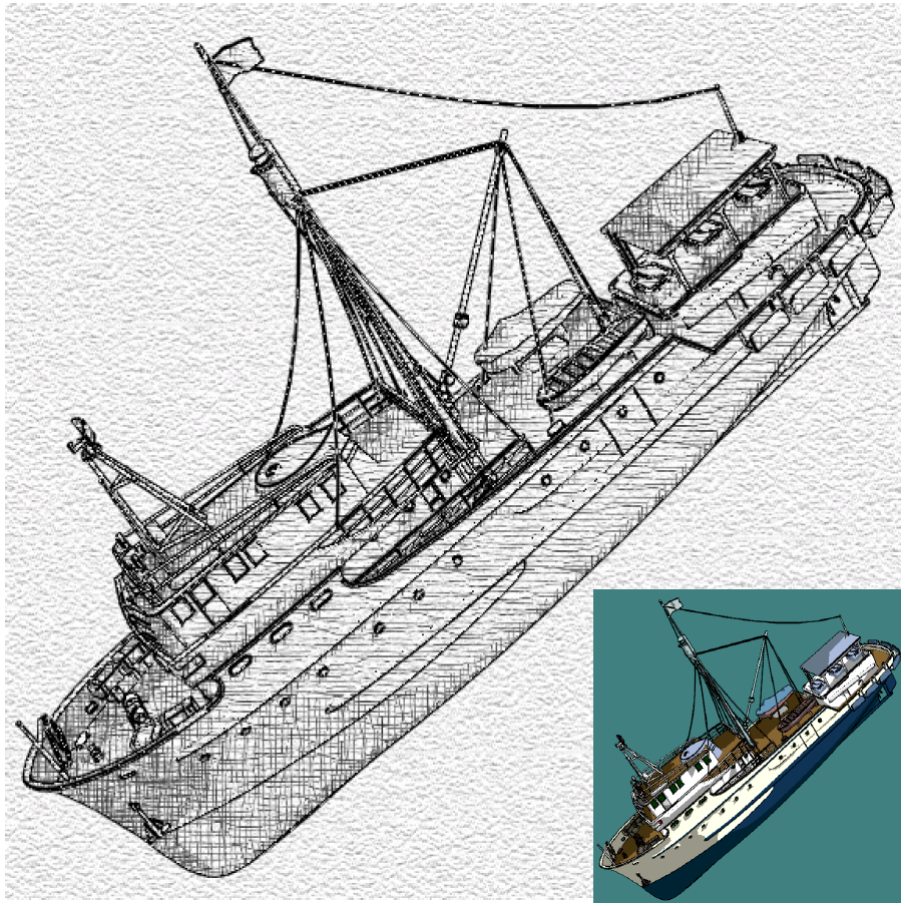
Textures

Textures used in:

- Strokes
- Backgrounds

Convey material properties

Also can be created using simulation or noise functions



Stylized Rendering Techniques For Scalable Real-Time 3D Animation (Lake et al ’00)

Lighting

NPR still requires standard lighting techniques:

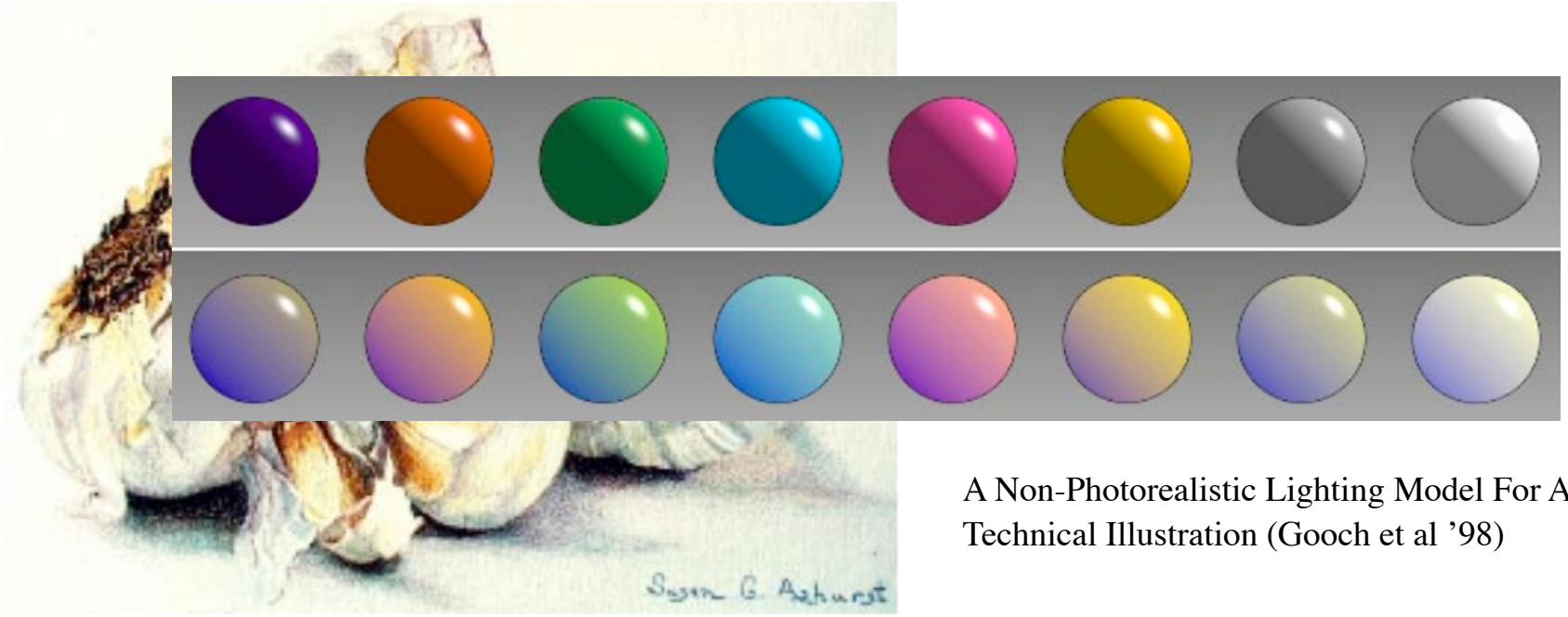
- Diffuse, specular, ambient, etc
- Environment mapping/BRDFs for reflectance

Use of luminance (intensity) and hue (color) shift to change object appearance

- Accentuates form, silhouette, and lighting

Luminance and Hue Shifts

Linear shift from warm to cool tones based on object normals



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Simulation

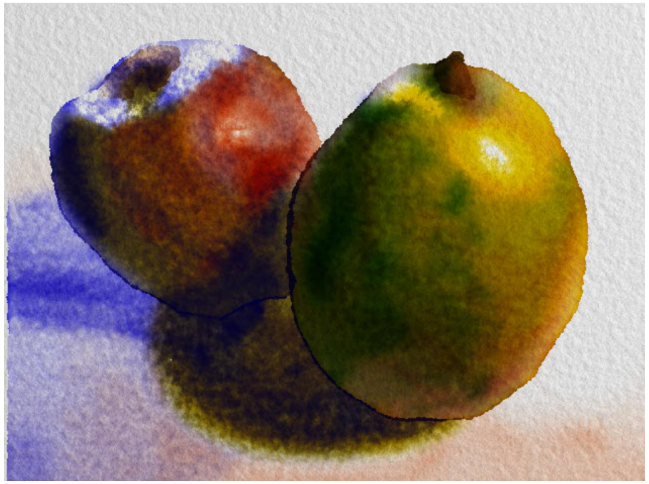
Reconstruct fluid dynamics of painting

- Brush disperses paint pigment and binder on canvas surface
- Pigment and binder diffuse with solvent

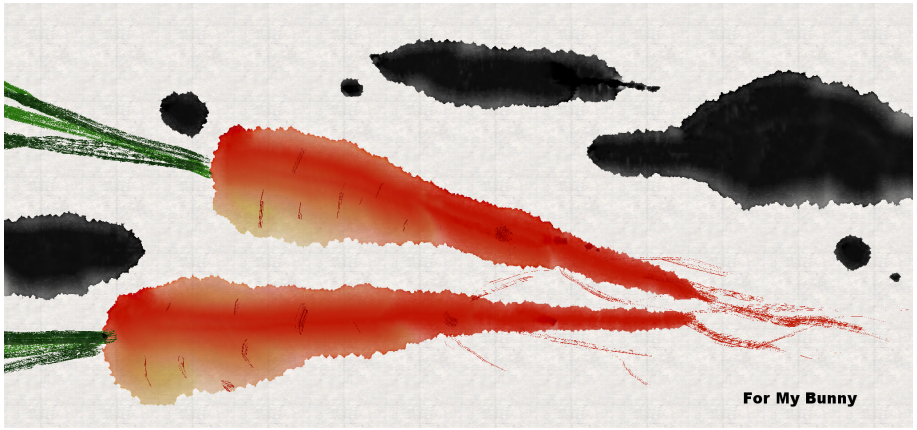
What needs to be simulated?

Simulation

1. Surface material dictates fluid flow and paint absorption
2. Pigment and binder are advected along solvent
3. Brush material and structure affects density and motion of paint along surface



Computer-Generated Watercolor (Curtis et al ’97)



MoXi: Real-Time Ink Dispersion in Absorbent Paper (Chu and Tai ‘05)

https://www.youtube.com/watch?v=ecf7y9kqbto

Edges: Silhouettes

- Between back-facing and front-facing polygons
- Polygon surface normal is perpendicular to view vector
- Calculated in world-space or screen-space

Edges: Boundaries and Creases

Boundaries

- Edge between intersecting mesh models
- Can be calculated in advance

Creases

- Edge between poly-faces with distinct normal values
- Can be calculated in advance

Edge Detection

Automatic extraction of object boundaries

World space techniques compare view angle to surface normal (determines if back-facing or front-facing)

Screen space techniques locate discontinuities in brightness

Image Kernels

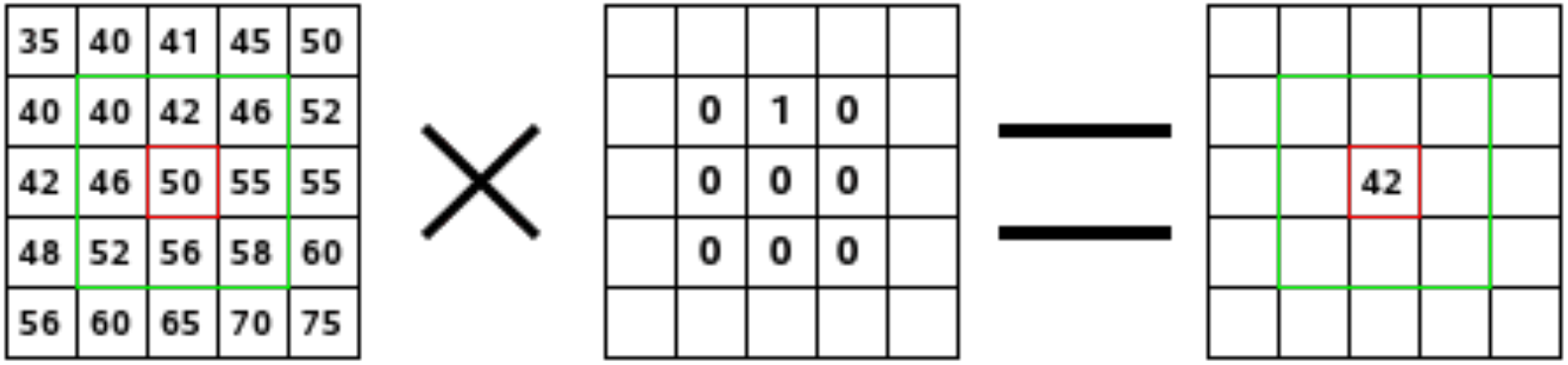
- Also called a convolution matrix or mask
- Matrix convolves kernel values with image values
  - Square and small kernels (3x3, 5x5, etc)
  - Larger matrices lose more local information
- Allows for “neighborhood” effects such as blur, sharpening, and edge-detection

Convolution

Convolution matrix applied to each pixel

- Multiply corresponding cells then sum

Value stored at corresponding location



Sobel Operators

Two 3x3 kernels that approximate horizontal and vertical derivatives (i.e. changes in light intensity)

$$\mathbf{G}_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} * \mathbf{A} \quad \text{and} \quad \mathbf{G}_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} * \mathbf{A}$$

Horizontal and vertical convolutions performed independently

Gradient magnitude calculated from results

Prince of Persia 2008

Toon Shading

Color simplification of highlights and shadow to create a cel-shaded (classic animation) look

Easy to do in shaders!

Creating a Toon Shader

1. Choose colors for surfaces (base, shadow, highlight color, etc) and store in 1D texture map
2. Set threshold between these colors based on light intensity
3. Calculate light intensity (L·N) at each vertex

Sakuna: Of Rice and Ruin