Non-Photorealistic Rendering

Goals of Computer Graphics:

- Traditional: Photorealism
- Sometimes, we want more
  - Cartoons
  - Artistic expression in paint, pen-and-ink
  - Technical illustrations
  - Scientific visualization
  [Lecture next week]

Pen-and-ink Illustrations
Painterly Rendering
Cartoon Shading
Technical Illustrations

Non-Photorealistic Rendering

“A means of creating imagery that does not aspire to realism” - Stuart Green

Some NPR Categories

- Pen-and-Ink illustration
  - Techniques: cross-hatching, outlines, line art, etc.
- Painterly rendering
  - Styles: impressionist, expressionist, pointillist, etc.
- Cartoons
  - Effects: cartoon shading, distortion, etc.
- Technical illustrations
  - Characteristics: Matte shading, edge lines, etc.
- Scientific visualization
  - Methods: splatting, hedgehogs, etc.

Outline

- Pen-and-Ink Illustrations
- Painterly Rendering
- Cartoon Shading
- Technical Illustrations
**Hue**
- Perception of “distinct” colors by humans
- Red
- Blue

![Hue Scale](Source: Wikipedia)

**Tone**
- Perception of “brightness” of a color by humans
- Also called lightness
- Important in NPR

![Tone Scale](Source: Wikipedia)

**Pen-and-Ink Illustrations**
Winkenbach and Salesin 1994

- Strokes
  - Curved lines of varying thickness and density
- Texture
  - Conveyed by collection of strokes
- Tone
  - Perceived gray level across image or segment
- Outline
  - Boundary lines that disambiguate structure

![Pen-and-Ink Illustrations](Source: Winkenbach and Salesin 1994)

**Rendering Pipeline: Polygonal Surfaces with NPR**

- Stroke generated by moving along straight path
- Stroke perturbed by
  - Waviness function (straightness)
  - Pressure function (thickness)
- Collected in stroke textures
  - Tone dependent
  - Resolution dependent
  - Orientation dependent
- How automatic are stroke textures?
Stroke Texture Examples

Winkenbach and Salesin 1994

Stroke Texture Operations

Scaling

Changing Viewing Direction (Anisotropic)

Indication

• Selective addition of detail
• Difficult to automate
• User places detail segments interactively

Indication Example

Input without detail

With indication

Without indication

Outlines

• Boundary or interior outlines
• Accented outlines for shadowing and relief
• Dependence on viewing direction
• Suggest shadow direction

Rendering Parametric Surfaces

• Stroke orientation and density
  – Place strokes along isoparametric lines
  – Choose density for desired tone
  – tone = spacing / width

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Parametric Surface Example

Winkenbach and Salesin 1996

Hatching + standard rendering

Constant-density hatching
Longer smoother strokes for glass
Varying reflection coefficient

Smooth shading with single light
Environment mapping

Standard rendering techniques are still important!

Orientable Textures

- Inputs
  - Grayscale image to specify desired tone
  - Direction field
  - Stroke character
- Output
  - Stroke shaded image

Salisbury et al. 1997

Outline

- Pen-and-Ink Illustrations
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Painterly Rendering

- Physical simulation
  - User applies brushstrokes
  - Computer simulates media (paper + ink)
- Automatic painting
  - User provides input image or 3D model
  - User specifies painting parameters
  - Computer generates all strokes
Physical Simulation Example

Curtis et al. 1997, Computer Generated Watercolor

Computer-Generated Watercolor

- Complex physical phenomena for artistic effect
- Build simple approximations
- Paper generation as random height field
- Simulated effects

Fluid Dynamic Simulation

- Use water velocity, viscosity, drag, pressure, pigment concentration, paper gradient
- Paper saturation and capacity
- Discretize and use cellular automata

Interactive Painting

User input
Simulation in progress
Finished painting

Automatic Painting Example

Hertzmann 1997

Automatic Painting from Images

- Start from color image: no 3D information
- Paint in resolution-based layers
  - Blur to current resolution
  - Select brush based on current resolution
  - Find area of largest error compared to real image
  - Place stroke
  - Increase resolution and repeat
- Layers are painted coarse-to-fine
- Styles controlled by parameters
Layered Painting

- Blurring
- Adding detail with smaller strokes

Painting Styles

- Style determined by parameters
  - Approximation thresholds
  - Brush sizes
  - Curvature filter
  - Blur factor
  - Minimum and maximum stroke lengths
  - Opacity
  - Grid size
  - Color jitter
- Encapsulate parameter settings as style

Style Examples

- "Impressionist"
  - No random color, 4 ≤ stroke length ≤ 16
  - Brush sizes 8, 4, 2; approximation threshold 100
- "Expressionist"
  - Random factor 0.5, 10 ≤ stroke length ≤ 16
  - Brush sizes 8, 4, 2; approximation threshold 50
- "Pointilist"
  - Random factor ~0.75, 0 ≤ stroke length ≤ 0
  - Brush sizes 4, 2; approximation threshold 100
  - Not completely convincing to artists (yet?)

Outline

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Cartoon Shading

- Shading model in 2D cartoons
  - Use material color and shadow color
  - Present lighting cues, shape, and context
- Stylistic
- Used in many animated movies
- Real-time techniques for games
**Cartoon Shading as Texture Map**
- Apply shading as 1D texture map
- Two-pass technique:
  - Pass 1: standard shader
  - Pass 2: use result from 1 as texture coordinates

**Shading Variations**
- Gouraud
- 1 texel: flat shading
- 2 texels: shadow
- 8 texels: shadow + highlight

**Outline**
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**Technical Illustrations**
- Level of abstraction
  - Accent important 3D properties
  - Diminish or eliminate extraneous details
  - Do not represent reality
  - Photo
  - Ruppel 1995

**Conventions in Technical Illustrations**
- Black edge lines
- Cool to warm shading colors
- Single light source; shadows rarely used

**Technical Illustration Example**
- Phong shading
- Metal shading (anisotropic)
- Edge lines
- Gooch shading (cool to warm shift gives better depth perception)
  - Source: Bruce Gooch
The Future

- Smart graphics
  - Design from the user’s perspective
  - HCI, AI, Perception
- Artistic graphics
  - More tools for the creative artist
  - New styles and ideas

Summary

- Beyond photorealism
  - Artistic appeal
  - Technical explanation and illustration
  - Scientific visualization
- Use all traditional computer graphics tools
- Employ them in novel ways
- Have fun!