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.

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]

Outline

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

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

### Pen-and-Ink Illustrations
- 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

### Rendering Pipeline: Polygonal Surfaces with NPR
- 3D Model
- Lighting
- Visible Polygons
- Procedural Stroke Texture
- Stroke Clipping
- Outline Drawing
- Camera

### Strokes and Stroke Textures
- 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

Stroke Texture Operations

Indication

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

Indication Example

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
Parametric Surface Example

Hatching + standard rendering

Standard rendering techniques are still important!

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

Orientable Stroke Texture Example

Salisbury et al. 1997

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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

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

Layered Painting

Adding detail with smaller strokes

Blurring

Style Examples

Some Styles

• “Impressionist”
  – No random color, \(4 \leq \text{stroke length} \leq 16\)
  – Brush sizes 8, 4, 2; approximation threshold 100
• “Expressionist”
  – Random factor 0.5, \(10 \leq \text{stroke length} \leq 16\)
  – Brush sizes 8, 4, 2; approximation threshold 50
• “Pointilist”
  – Random factor \(~0.75, 0 \leq \text{stroke length} \leq 0\)
  – Brush sizes 4, 2; approximation threshold 100
• Not completely convincing to artists (yet?)

Outline

• Pen-and-Ink Illustrations
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• Cartoon Shading
• Technical Illustrations

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

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Technical Illustrations

- Level of abstraction
  - Accent important 3D properties
  - Dimish or eliminate extraneous details
- Do not represent reality

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)
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!