Non-Photorealistic Rendering

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

Apr 24, 2013
Jernej Barbic
University of Southern California

http://www-bcf.usc.edu/~jbarbic/cs480-s13/
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]
Non-Photorealistic Rendering

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

Cassidy Curtis 1998

David Gainey
Non-photorealistic Rendering

Also called:
- Expressive graphics
- Artistic rendering
- Non-realistic graphics
- Art-based rendering
- Psychographics

Source: ATI
Some NPR Categories

• Pen-and-Ink illustration
  – Techniques: cross-hatching, outlines, line art, etc.
• Painterly rendering
  – Styles: impressionist, expressionist, pointilist, 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

• Green

• Yellow

Hue Scale

0  60  120  180  240  300  360

Tone

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

Pen-and-Ink Illustrations

Winkenbach and Salesin 1994
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

Winkenbach and Salesin 1994
Rendering Pipeline: Polygonal Surfaces with NPR

3D Model → Lighting → Visible Polygons → Procedural Stroke Texture → Stroke Clipping → Outline Drawing → Camera

How much 3D information do we preserve?
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

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 = width / spacing
Parametric Surface Example

Winkenbach and Salesin 1996
Hatching + standard rendering

Constant-density hatching
Smooth shading with single light

Longer smoother strokes for glass

Varying reflection coefficient
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
Orientable Stroke Texture Example

Salisbury et al. 1997
Outline

- Pen-and-Ink Illustrations
- Painterly Rendering
- Cartoon Shading
- Technical Illustrations
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 controled 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

Source image

“Impressionist”

“Expressionist”

“Pointillist”
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 $\sim0.75$, $0 \leq \text{stroke length} \leq 0$
  – Brush sizes 4, 2; approximation threshold 100
• Not completely convincing to artists (yet?)
Outline

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

- Shading model in 2D cartoon
  - Use material color and shadow color
  - Present lighting cues, shape, and context
- Stylistic
- Used in many animated movies
- Real-time techniques for games

Source: Alec Rivers
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

\[ u = N \cdot L \]
Shading Variations

Gouraud
Flat shading

1 texel
Shadow

2 texels

8 texels
Shadow + highlight
Outline

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

- Level of abstraction
  - Accent important 3D properties
  - Dimish 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!