Non-Photorealistic Rendering

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

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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

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 = spacing / width
Parametric Surface Example

Winkenbach and Salesin 1996
Hatching + standard rendering

Constant-density hatching
Smooth shading with single light
Longer smoother strokes for glass
Environment mapping
Varying reflection coefficient

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 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

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 \(~0.75\), \( 0 \leq \text{stroke length} \leq 0 \)
  – Brush sizes 4, 2; approximation threshold 100

• Not completely convincing to artists (yet?)
Outline

• Pen-and-Ink Illustrations
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• 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

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

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Shading Variations

Gouraud 1 texel 2 texels 8 texels
Flat shading Shadow Shadow + highlight
Outline

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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!