CSCI 480 Computer Graphics
Lecture 23

Non-Photorealistic Rendering

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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

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
  - Green
  - Blue
  - Yellow

**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

**Pen-and-Ink Illustrations**
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

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 = width / spacing
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

Orientable Stroke Texture Example

Salisbury et al. 1997

Outline

• Pen-and-Ink Illustrations
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• 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

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

- 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?)

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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

Outlining

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Technical Illustrations

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