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

Pen-and-ink Illustrations
- 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

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

Pen-and-Ink Illustrations

Winkenbach and Salesin 1994

Rendering Pipeline:
Polygonal Surfaces with NPR

3D Model → Lighting → Camera

Visible Polygons

Procedural Stroke Texture

Stroke Clipping

Outline Drawing

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
- 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
- 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

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

Some Styles

• “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

• 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
**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
- Flat shading
- 1 texel
- 2 texels
- 8 texels
- Shadow + highlight

**Outline**

- Pen-and-Ink Illustrations
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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)
- Gouraud 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!