Goals of Computer Graphics

- Traditional: Photorealism
- Sometimes, we want more
  - Cartoons
  - Artistic expression in paint, pen-and-ink
  - Technical illustrations
  - Scientific visualization [Lecture 21]

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
Pen-and-Ink Illustrations

- Strokes
  - Curved lines of varying thickness and density
- Texture
  - Character conveyed by collection of strokes
- Tone
  - Perceived gray level across image or segment
- Outline
  - Boundary lines that disambiguate structure

Pen-and-Ink Examples

- Winkenbach and Salesin 1994

Rendering Polygonal Surfaces

- 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

Prioritized Stroke Textures

- Technique for limiting human intervention
- Collection of strokes with associated priority
- When rendering
  - First draw highest priority only
  - If too light, draw next highest priority, etc.
  - Stop if proper tone is achieved
- Procedural stroke textures
- Support scaling
- Also applies to non-procedural 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

Bold strokes indicate detail segments

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 isoparameter lines
  - Choose density for desired tone
  - \( \text{tone} = \frac{\text{width}}{\text{spacing}} \)

Stroke Width

- Adjust stroke width retain uniform tone

Winkenbach and Salesin 1996
Parametric Surface Example

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

Outline

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

Painterly Rendering

- Physical simulation
  - User applies brushstrokes
  - Computer simulates media
- Automatic painting
  - User provides input image or 3D model
  - User specifies painting parameters
  - Computer generates all strokes
- Subject to controversy
**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

Brush Strokes

• Start at point of maximal error
  – Calculate difference between original image and image painted so far
• Direction perpendicular to gradient
  – Stroke tends to follow equally shaded area
• Stopping criteria
  – Difference between brush color and original image color exceeds threshold
  – Maximal stroke length reached

Longer Brush Strokes

• For longer, curved brush strokes
  – Repeat straight line algorithm
  – Stop, again on length or difference threshold
• Use anti-aliased cubic B-spline

Painting Styles

• Style determined by parameters
  – Approximation threshold
  – Brush sizes
  – Curvature filter
  – Blur factor
  – Minimum and maximum stroke lengths
  – Opacity
  – Grid size
  – Color jitter
• Encapsulate parameter settings as style

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 convincing to artists

Style Examples
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
- Developing real-time techniques for games

Cartoon Shading as Texture Map

- Apply shading as 1D texture map

Shading Variations

- Gouraud
  - 1 texel
  - 2 texels
  - 8 texels
- Flat shading
- Shadow
- 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

![Technical Illustration Example](image)

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

Movies

- Baxter et al., DAB: Interactive Haptic Painting with 3D Virtual Brushes, SIGGRAPH'01
- Kowalski et al., Art-based Rendering of Fur, Grass and Trees, SIGGRAPH'99

Summary

- Beyond photorealism
  - Artistic appeal
  - Technical explanation and illustration
  - Scientific visualization
- Use all traditional computer graphics tools
- Employ them in novel ways
- Have fun!

Preview

- Assignment 7 due tonight
- Tuesday Guest Lecture
  - Wayne Wooten, Pixar
- Thursday
  - Assignment 7 images and movies
  - Assignment 8 due before class
  - 2nd half review for final