

Non-Photorealistic Rendering

Pen-and-Ink Illustrations
Painterly Rendering
Cartoon Shading
Technical Illustrations
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<http://www.cs.cmu.edu/~fp/courses/graphics/>

Goals of Computer Graphics

- Traditional: Photorealism
- Sometimes, we want more
 - Cartoons
 - Artistic expression in paint, pen-and-ink
 - Technical illustrations
 - Scientific visualization [Lecture 20]

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Non-Photorealistic Rendering

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



Cassidy Curtis 1998



David Gainey

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Some NPR Categories

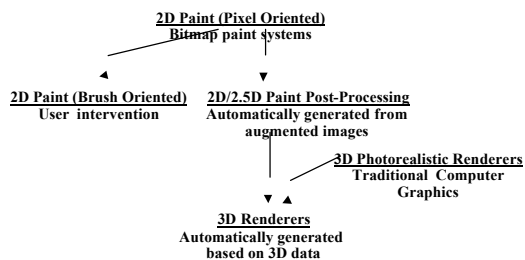
- Pen-and-Ink illustration
 - Techniques: cross-hatching, outlines, line art, etc.
- Painterly rendering
 - Styles: impressionist, expressionist, pointilist, etc.
- Cartoons
 - Effects: cartoon shading, distortion, etc.
- Technical illustrations
 - Characteristics: Matte shading, edge lines, etc.
- Scientific visualization
 - Methods: splatting, hedgehogs, etc.

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Emergence of NPR



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Outline

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

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Pen-and-Ink Illustrations

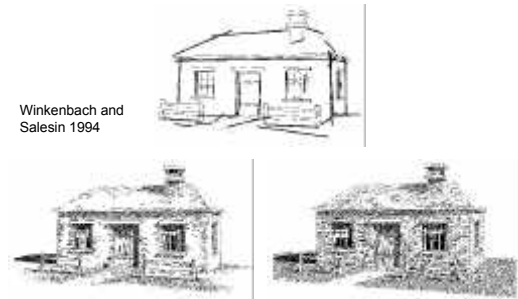
- Strokes
 - Curved lines of varying thickness and density
- Texture
 - Character conveyed by collection of strokes
- Tone
 - Perceived gray level across image or segment
- Outline
 - Boundary lines that disambiguate structure

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Pen-and-Ink Examples

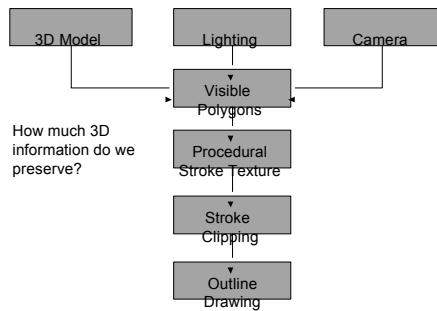


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Rendering Polygonal Surfaces



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Strokes and Stroke Textures

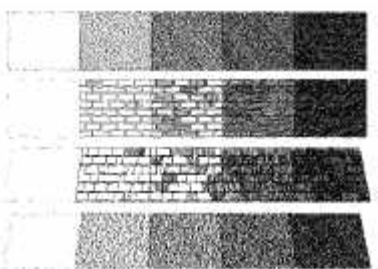
- Stroke generated by moving along straight path
- Stroke perturbed by
 - Waviness function (straightness)
 - Pressure function (thickness)
- Collected in stroke textures
 - Tone dependent
 - Resolution dependent
 - Orientation dependent
- How automatic are stroke textures

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Stroke Texture Examples



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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

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Stroke Texture Operations

Scaling



Changing Viewing Direction
(Anisotropic)

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Indication

- Selective addition of detail
- Difficult to automate
- User places detail segments interactively

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Indication Example



Bold strokes
indicate detail
segments

With indication



Without indication



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Outlines

- Boundary or interior outlines
- Accented outlines for shadowing and relief
- Dependence on viewing direction
- Suggest shadow direction

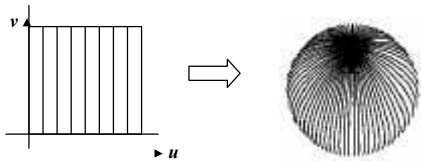
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Rendering Parametric Surfaces

- Stroke orientation and density
 - Place strokes along isoparameter lines
 - Choose density for desired tone
 - tone = width / spacing



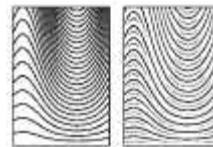
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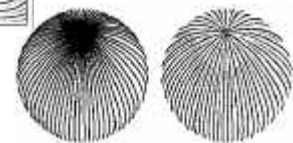
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Stroke Width

- Adjust stroke width retain uniform tone



Winkenbach and
Salesin 1996



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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!

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Parametric Surface Example



Winkenbach and Salesin 1996

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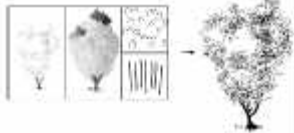
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Orientable Textures

- Inputs
 - Grayscale image to specify desired tone
 - Direction field
 - Stroke character
- Output
 - Stroke shaded image

Salisbury et al. 1997

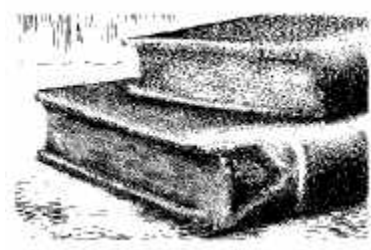


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Orientable Stroke Texture Example



Salisbury et al. 1997

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Outline

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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

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Physical Simulation Example



Curtis et al. 1997, *Computer Generated Watercolor*

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Computer-Generated Watercolor

- Complex physical phenomena for artistic effect
- Build simple approximations
- Paper generation as random height field



- Simulated effects



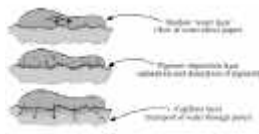
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Fluid Dynamic Simulation

- Use water velocity, viscosity, drag, pressure, pigment concentration, paper gradient
- Paper saturation and capacity



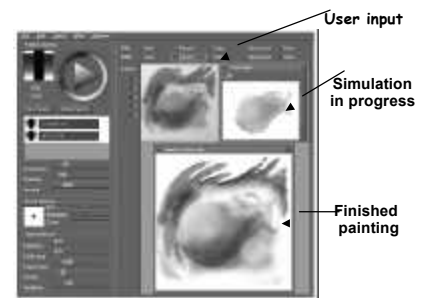
- Discretize and use cellular automata

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Interactive Painting



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Automatic Painting Example



Hertzmann 1997

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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

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Layered Painting



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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

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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



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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

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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 convincing to artists

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Style Examples



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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
- Developing real-time techniques for games

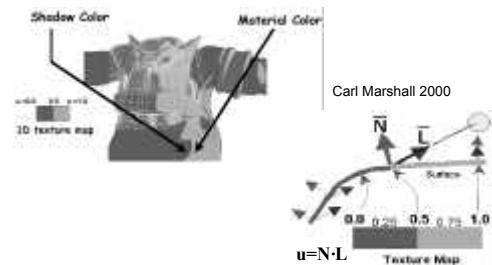
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Cartoon Shading as Texture Map

- Apply shading as 1D texture map

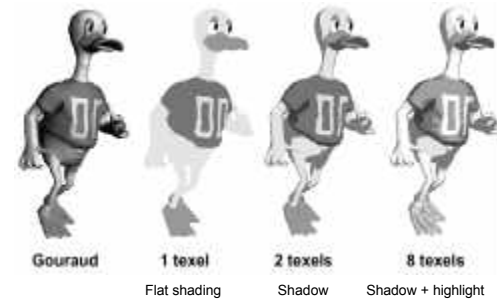


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Shading Variations



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Technical Illustrations

- Level of abstraction
 - Accent important 3D properties
 - Dimish or eliminate extraneous details
- Do not represent reality



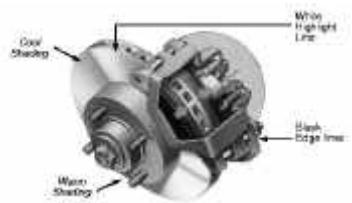
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Conventions in Technical Illustrations

- Black edge lines
- Cool to warm shading colors
- Single light source; shadows rarely used



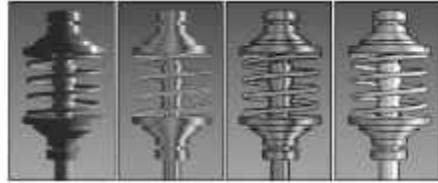
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Technical Illustration Example

Phong shading Metal shading (anisotropic) Edge lines Tone shading (cool to warm shift)



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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

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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

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Summary

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

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Preview

- Assignment 7 due next Thursday
- Assignment 8 out today, due in 2 weeks
- No late days on Assignment 8
- Tuesday: TBA
- Thursday: Advanced Global Illumination
- Tuesday: Guest Lecture/Games [Kuffner]
- Thursday: Final Review

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