CSCI 420 Computer Graphics
Lecture 24

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]

cartoon shading

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

Source: Bosch (2010)

Some NPR Categories

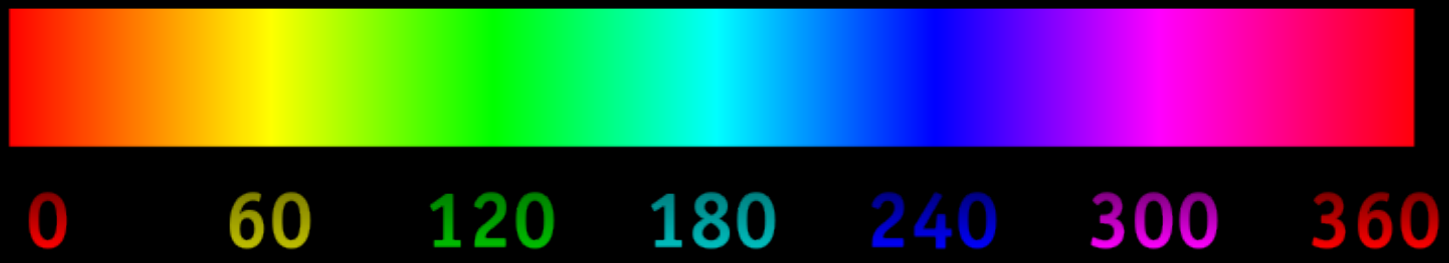
- Pen-and-Ink illustration
  - Techniques: cross-hatching, outlines, line art, etc.
- Painterly rendering
  - Styles: impressionist, expressionist, pointilist, etc.
- Cartoons
  - Effects: cartoon shading, distortion, etc.
- Technical illustrations
  - Characteristics: Matte shading, edge lines, etc.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

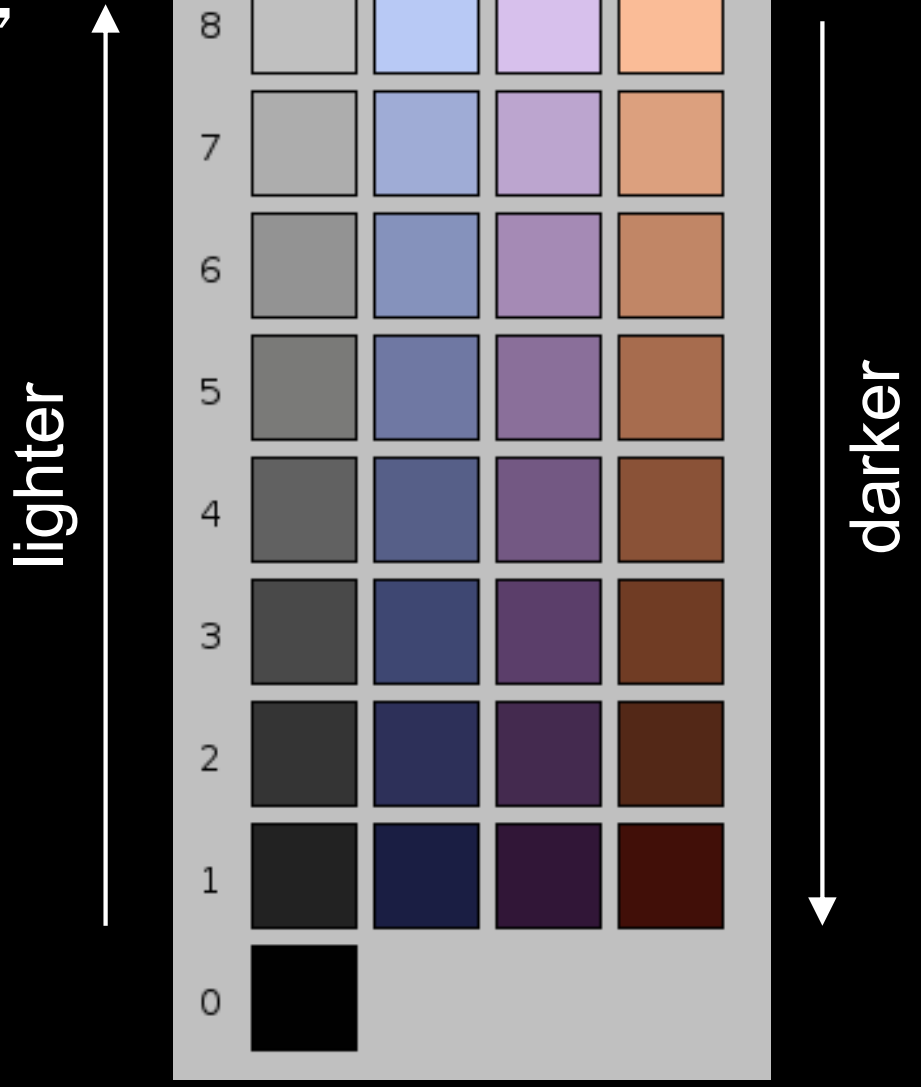


Hue Scale

Source: Wikipedia

Tone

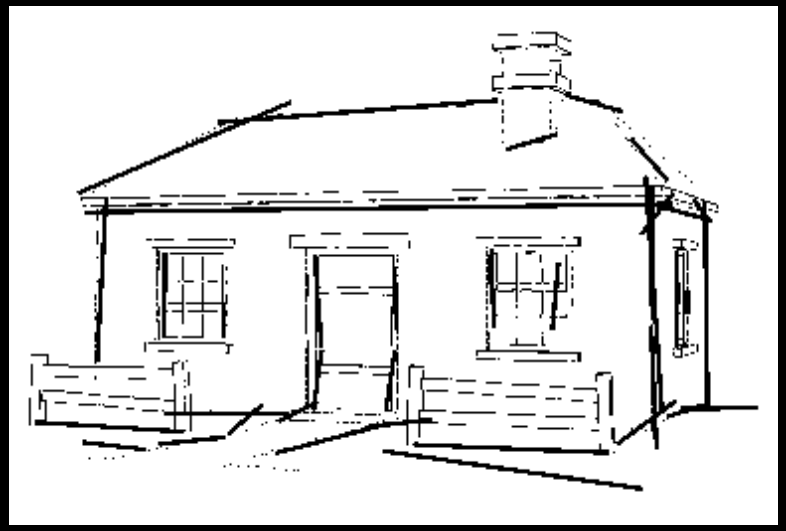
- Perception of “brightness” of a color by humans
- Also called lightness
- Important in NPR

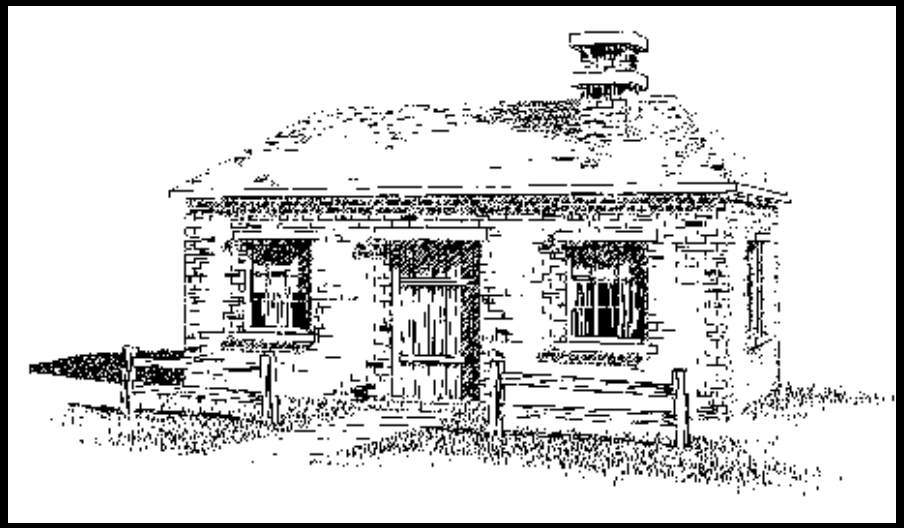


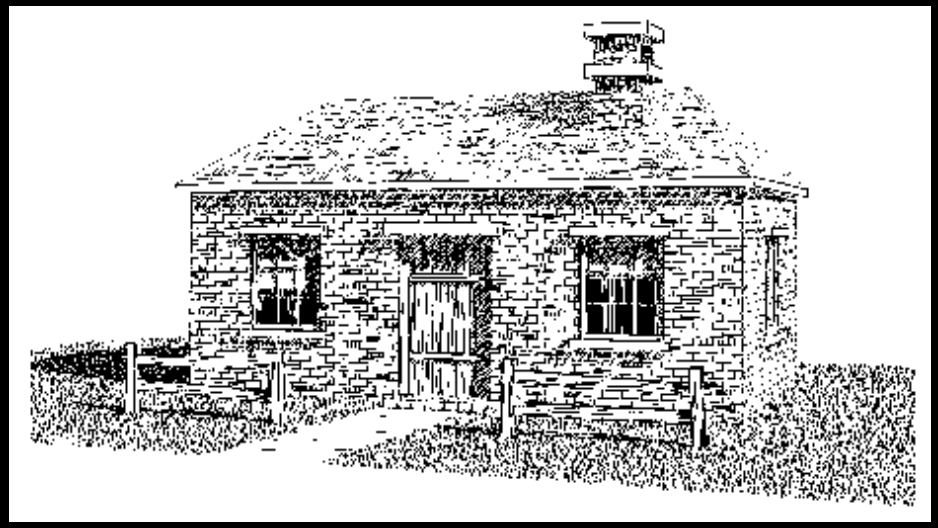
Source: Wikipedia

Pen-and-Ink Illustrations

Winkenbach and Salesin 1994

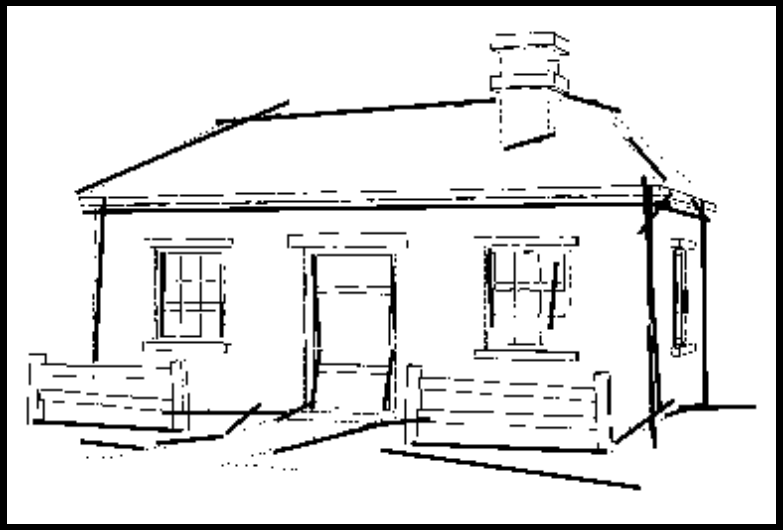


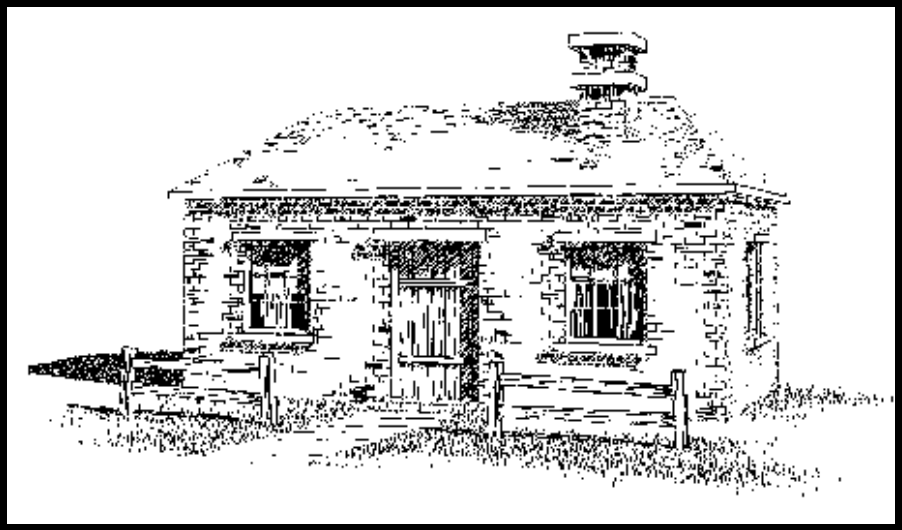




Pen-and-Ink Illustrations

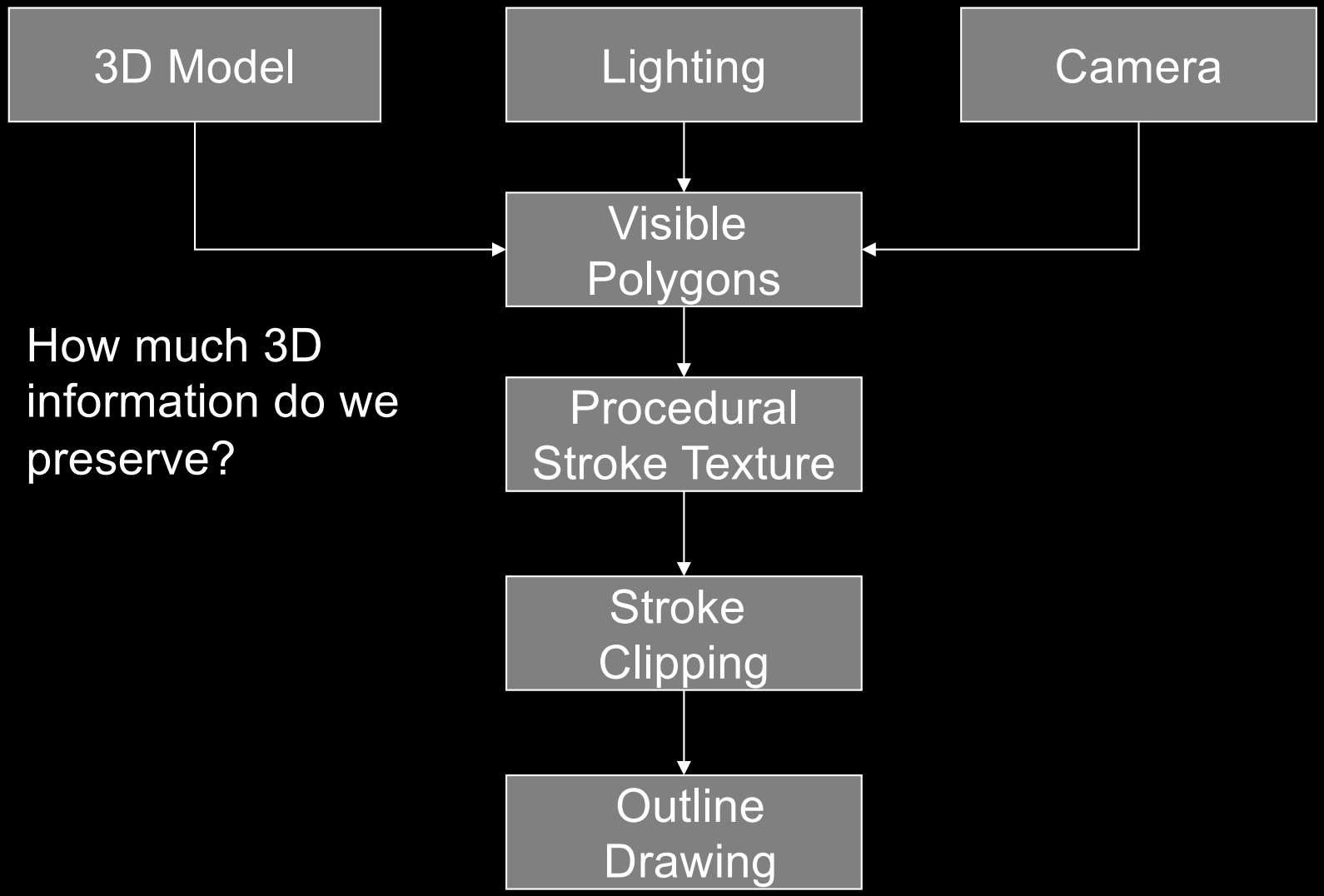
- Strokes
  - Curved lines of varying thickness and density
- Texture
  - Conveyed by collection of strokes
- Tone
  - Perceived gray level across image or segment
- Outline
  - Boundary lines that disambiguate structure





Winkenbach and Salesin 1994

Rendering Pipeline: Polygonal Surfaces with NPR

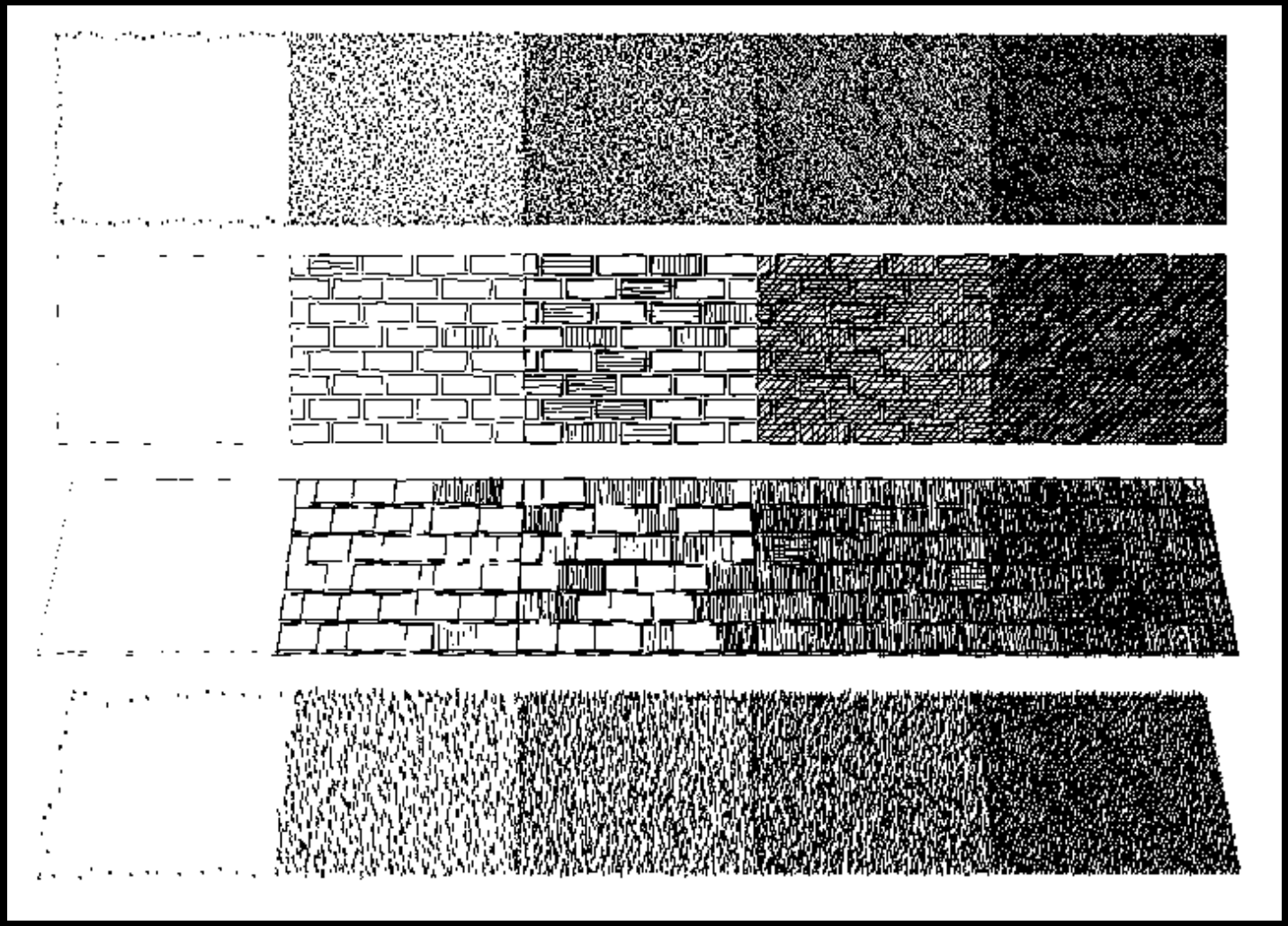


How much 3D information do we preserve?

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?

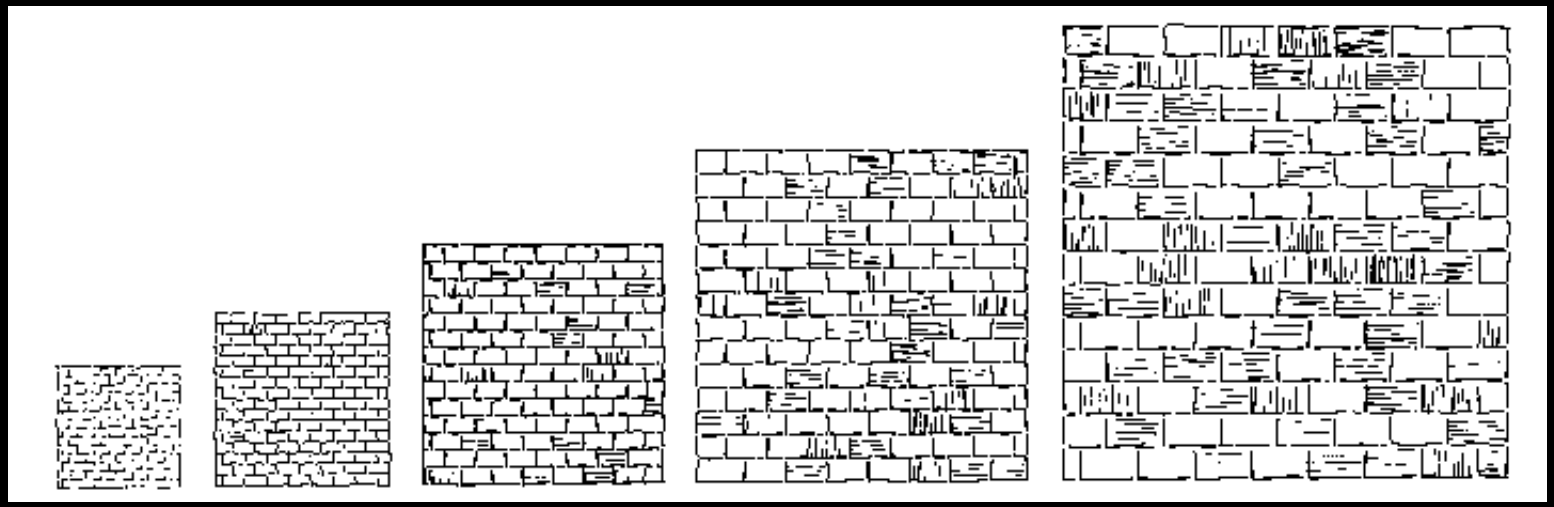
Stroke Texture Examples

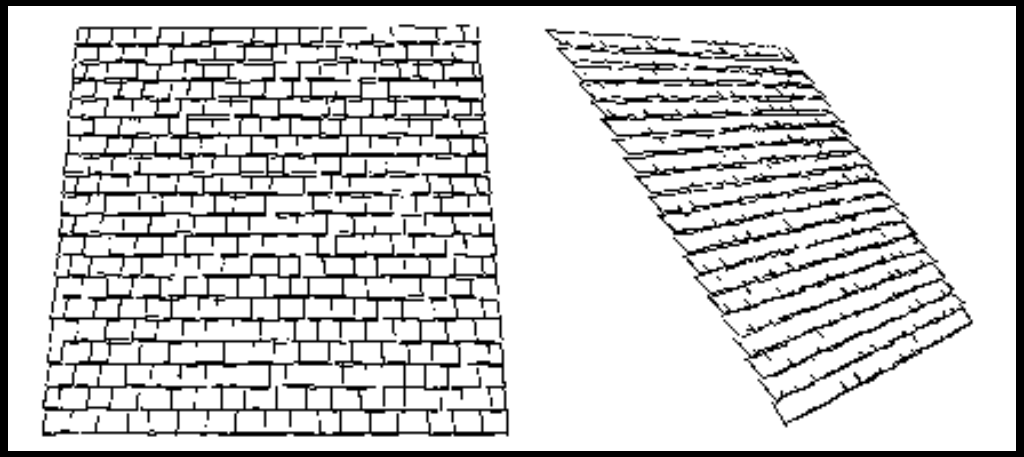


Winkenbach and Salesin 1994

Stroke Texture Operations

Scaling



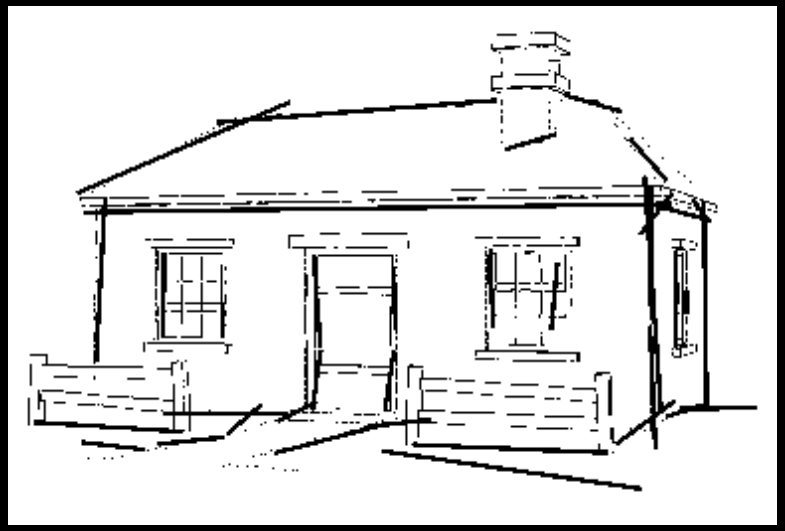


Changing Viewing Direction (Anisotropic)

Indication

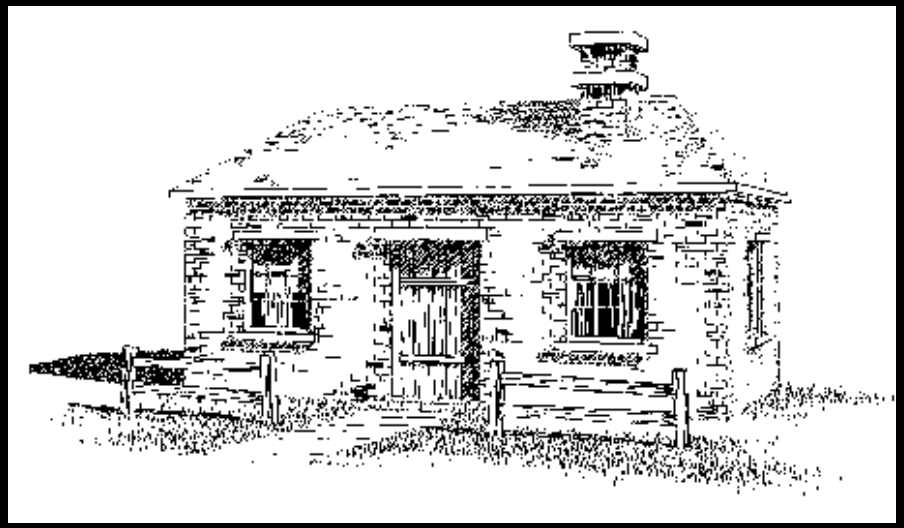
- Selective addition of detail
- Difficult to automate
- User places detail segments interactively

Indication Example

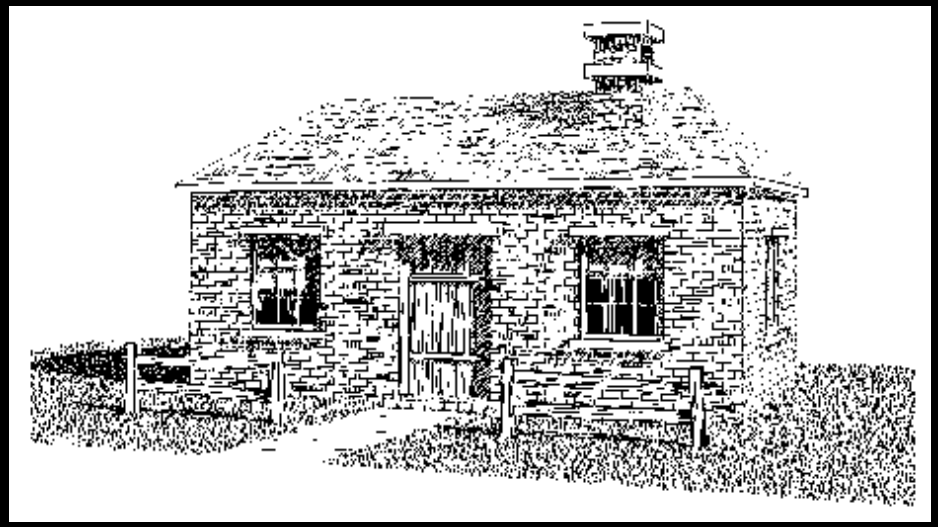


Input without detail

With indication



Without indication

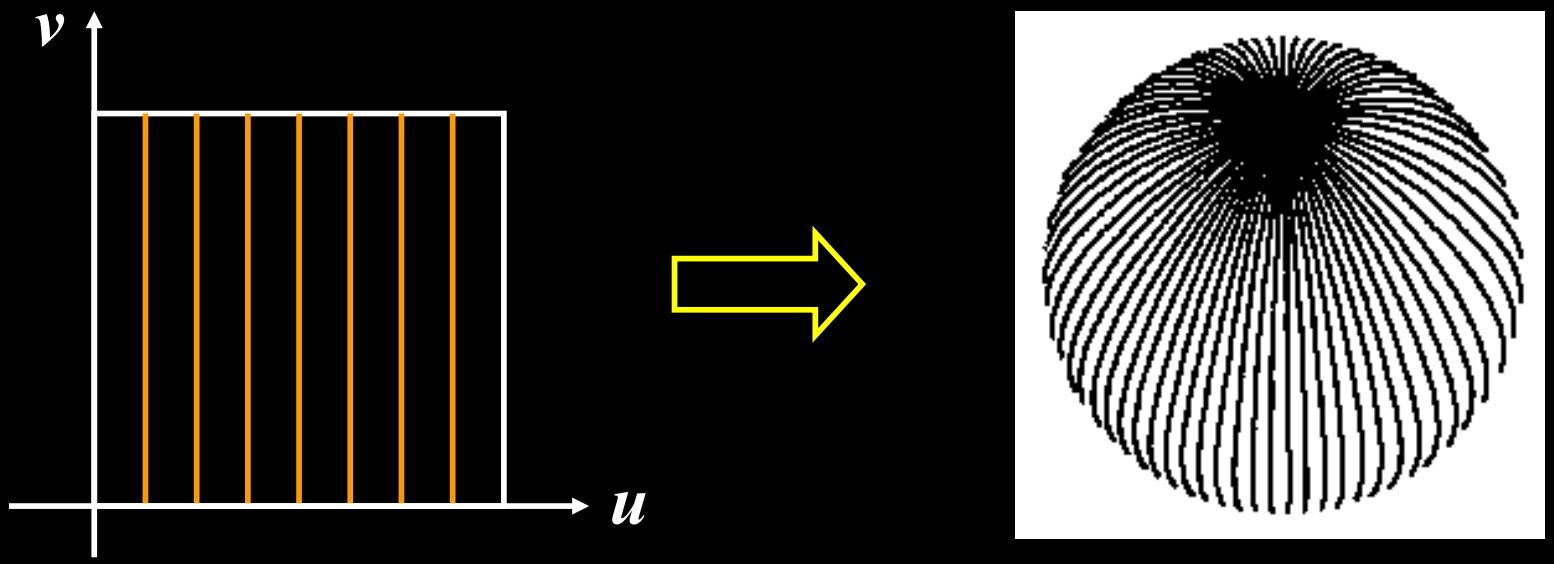


Outlines

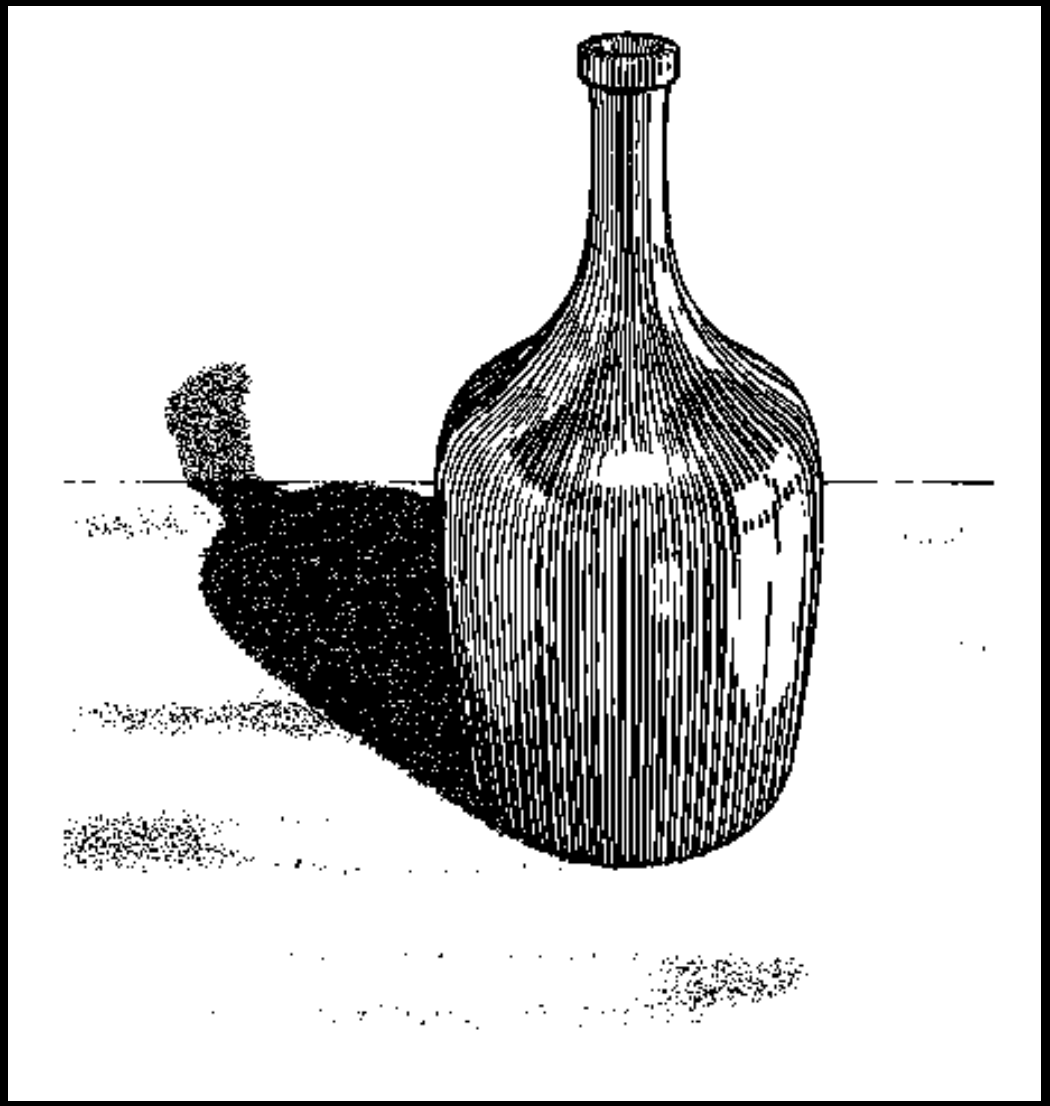
- Boundary or interior outlines
- Accented outlines for shadowing and relief
- Dependence on viewing direction
- Suggest shadow direction

Rendering Parametric Surfaces

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

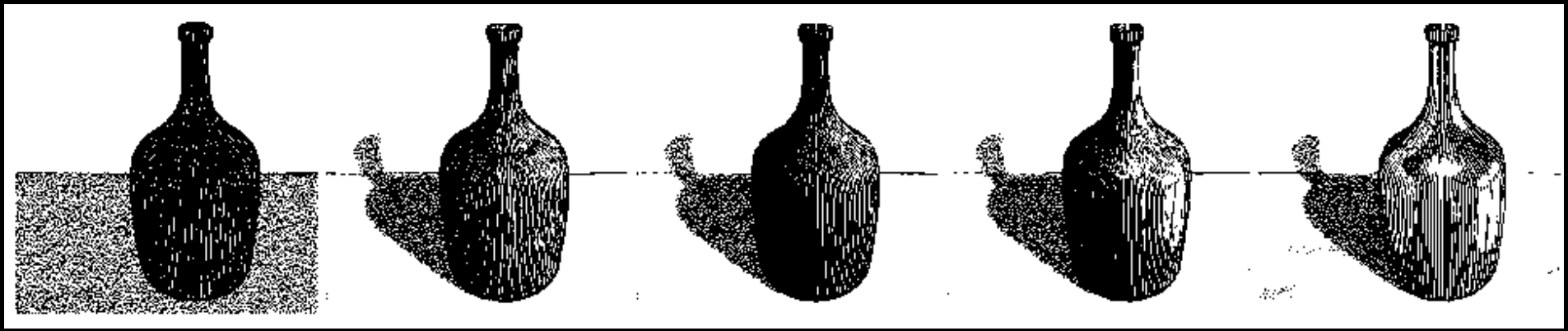


Parametric Surface Example



Winkenbach and Salesin 1996

Hatching + standard rendering



Constant-density hatching

Smooth shading with single light

Longer smoother strokes for glass

Environment mapping

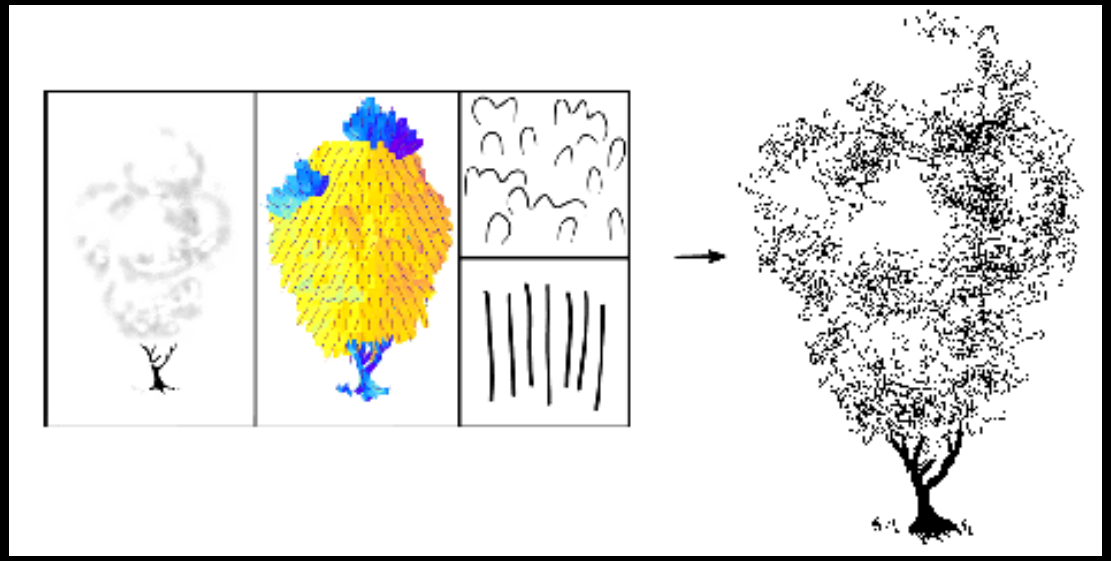
Varying reflection coefficient

Standard rendering techniques are still important!

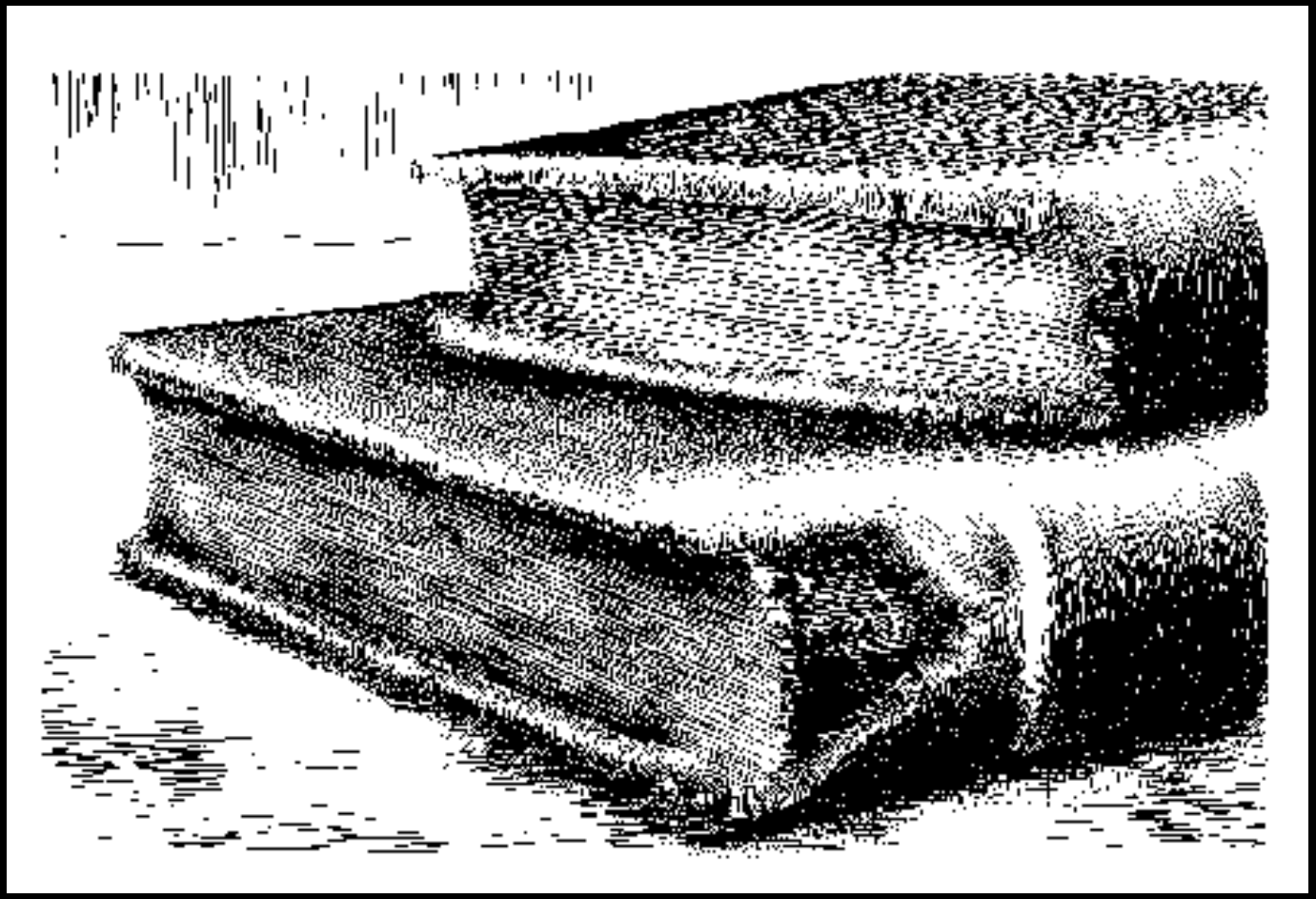
Orientable Textures

- 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

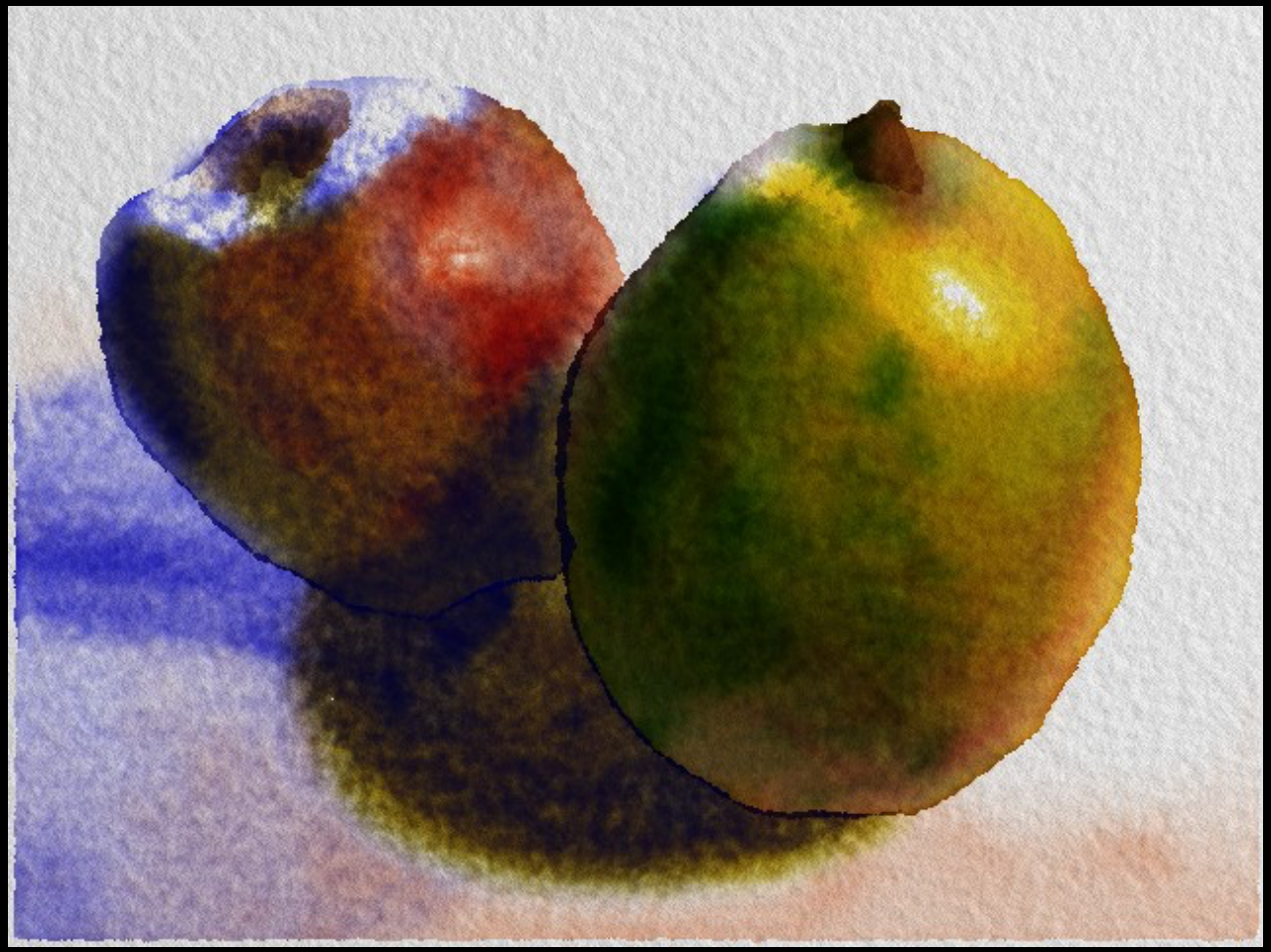
Outline

- 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

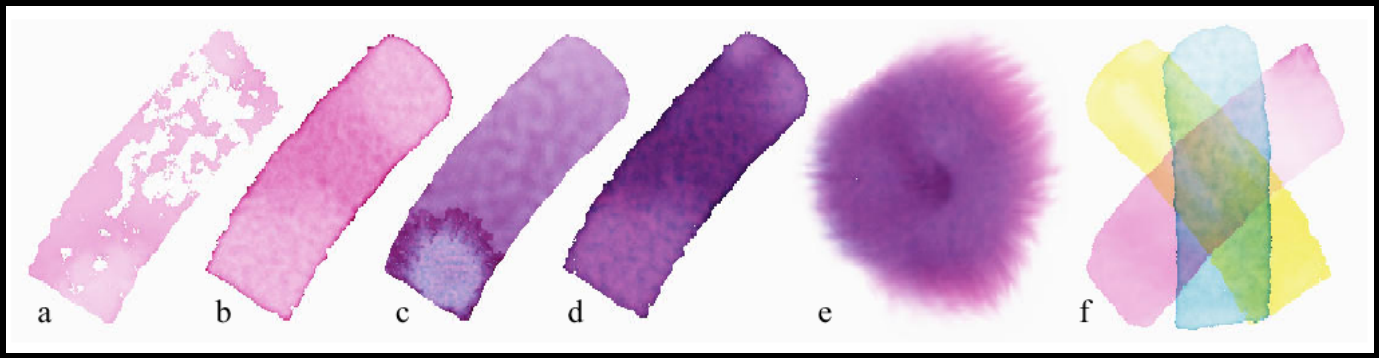


Curtis et al. 1997, *Computer Generated Watercolor*

Computer-Generated Watercolor

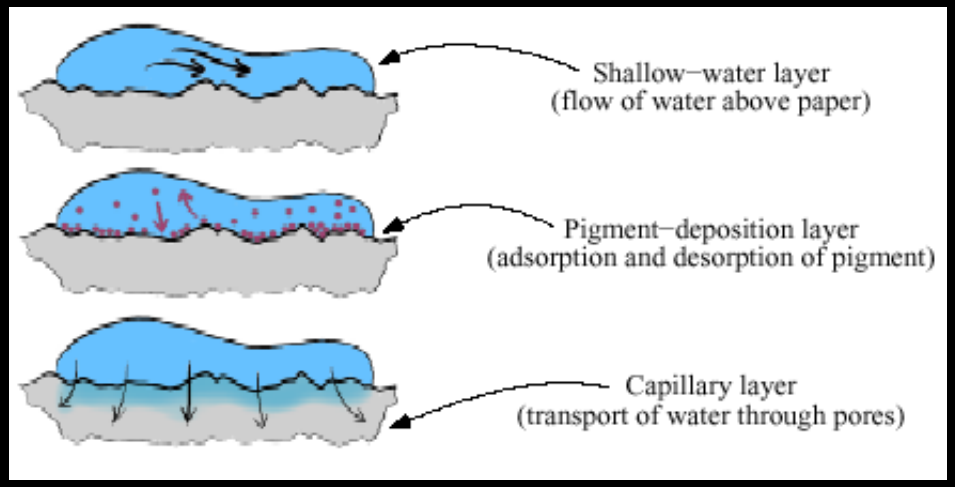
- Complex physical phenomena for artistic effect
- Build simple approximations
- Paper generation as random height field

- Simulated effects



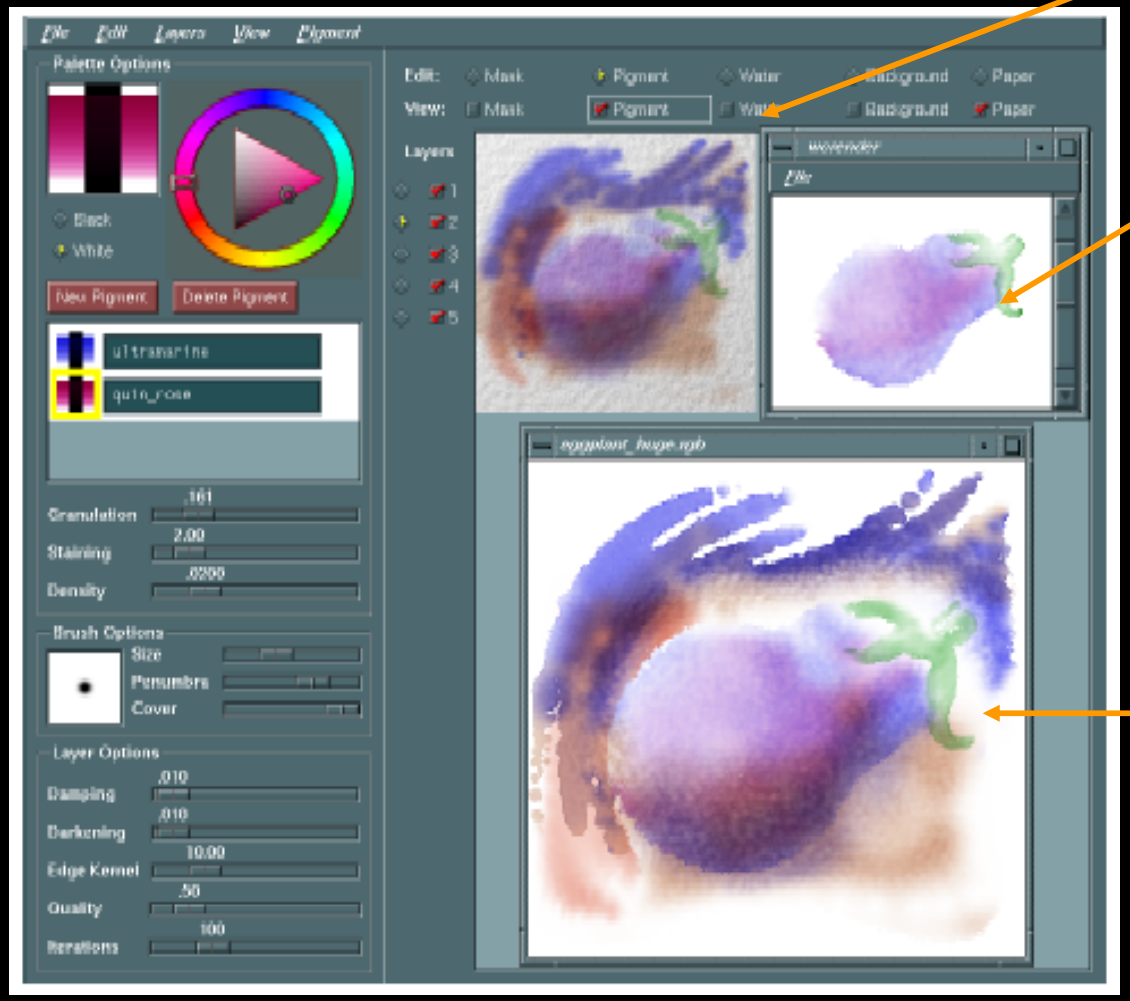
Fluid Dynamic Simulation

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



- Discretize and use cellular automata

Interactive Painting



Automatic Painting Example

Hertzmann 1998

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

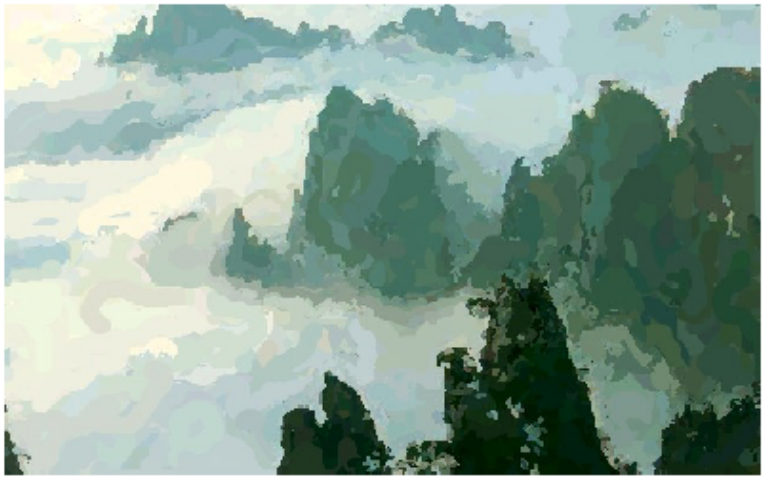
Adding detail with smaller strokes

Painting Styles

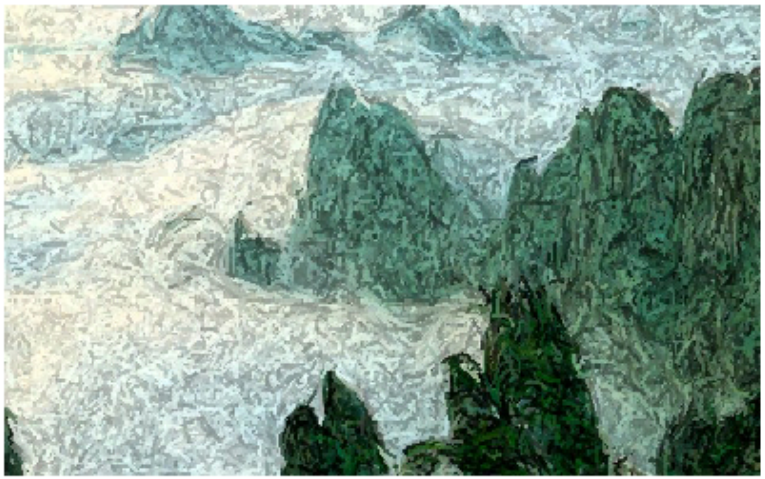
- Style determined by parameters
  - Approximation thresholds
  - Brush sizes
  - Curvature filter
  - Blur factor
  - Minimum and maximum stroke lengths
  - Opacity
  - Grid size
  - Color jitter
- Encapsulate parameter settings as style

Style Examples

Source image



“Impressionist”



“Expressionist”

“Pointillist”

Some Styles

- “Impressionist”
  - No random color, 4 ≤ 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?)

Automatic Painting Using Neural Networks

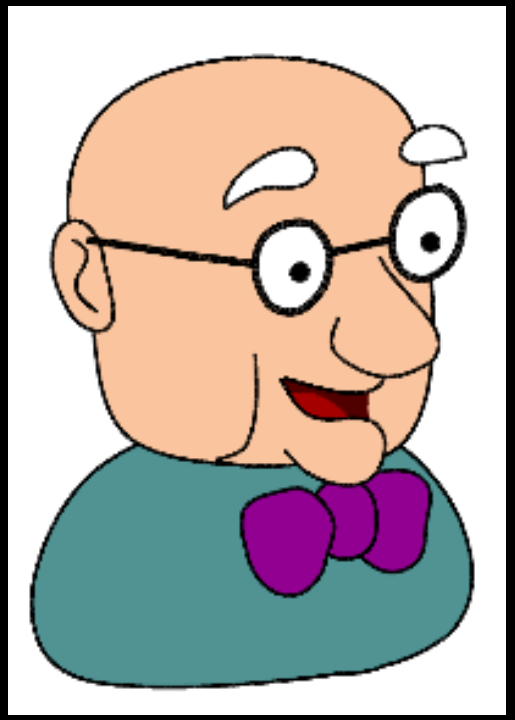
Wu et al. 2018

Outline

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

Cartoon Shading

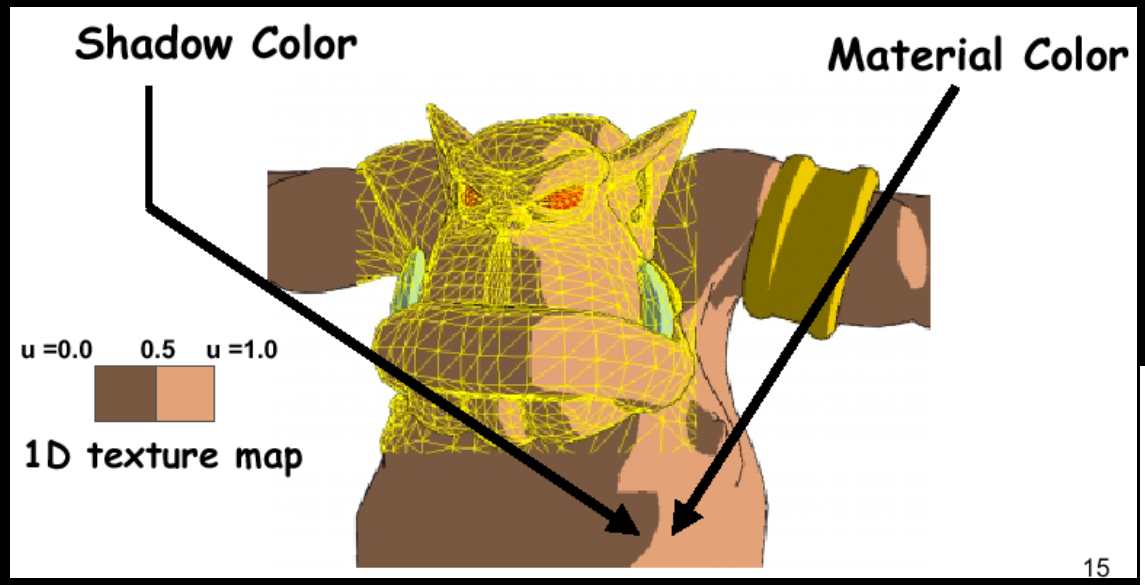
- Shading model in 2D cartoons
  - Use material color and shadow color
  - Present lighting cues, shape, and context
- Stylistic
- Used in many animated movies
- Real-time techniques for games



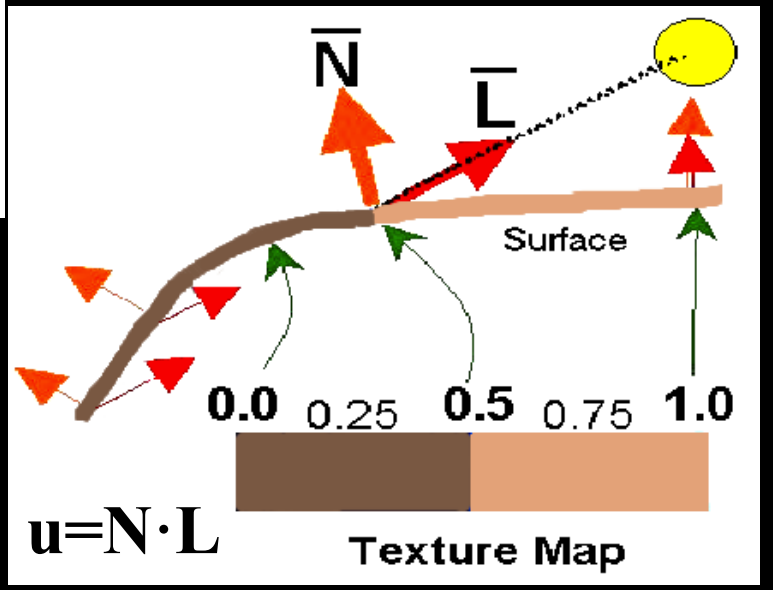
Rivers et al. 2010

Cartoon Shading as Texture Map

- Apply shading as 1D texture map

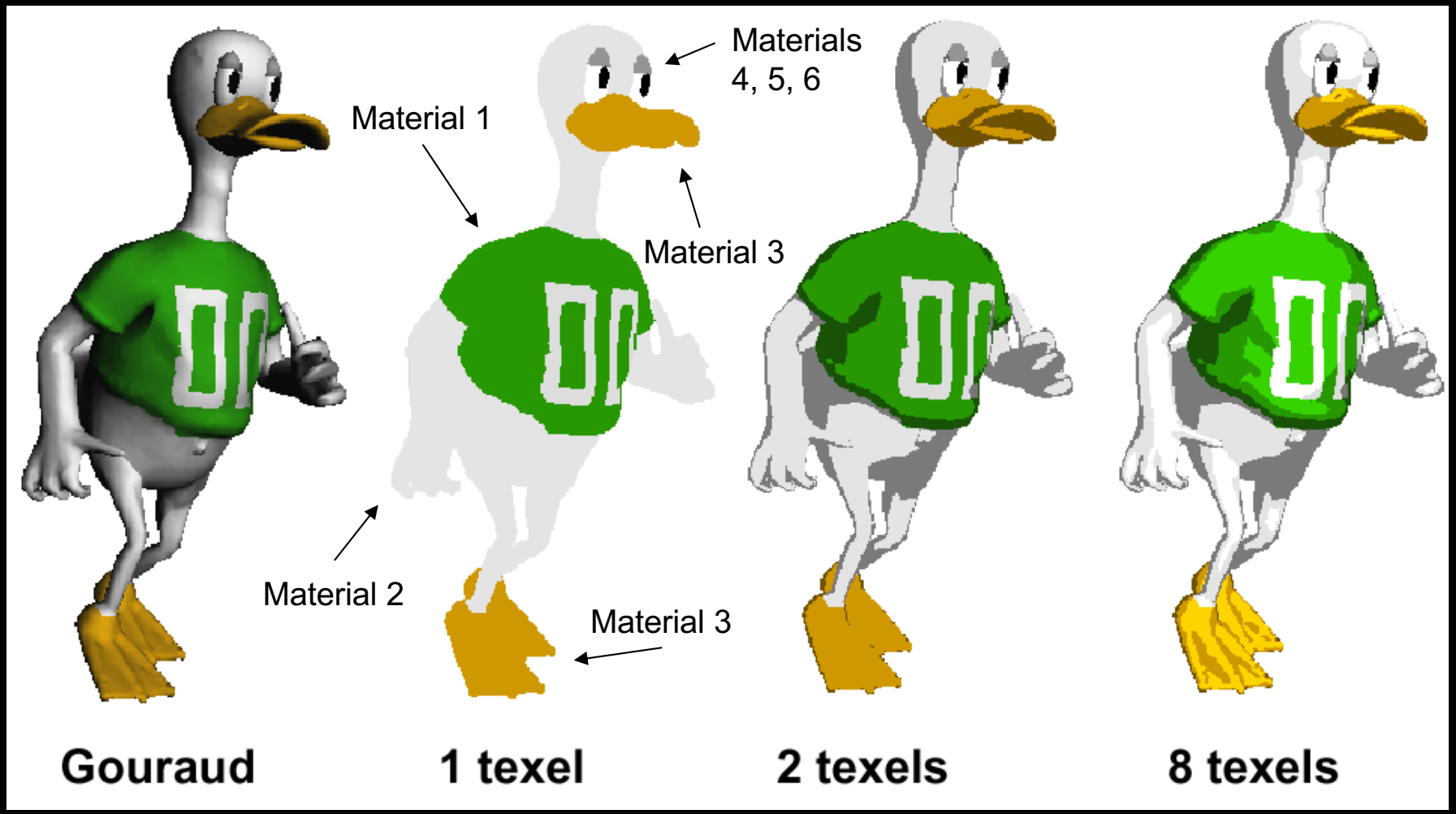


Carl Marshall 2000



- Two-pass technique:
  Pass 1: standard shader
  Pass 2: use result from 1 as texture coordinates

Shading Variations



Flat shading Shadow Shadow + highlight

Outline

- Pen-and-Ink Illustrations
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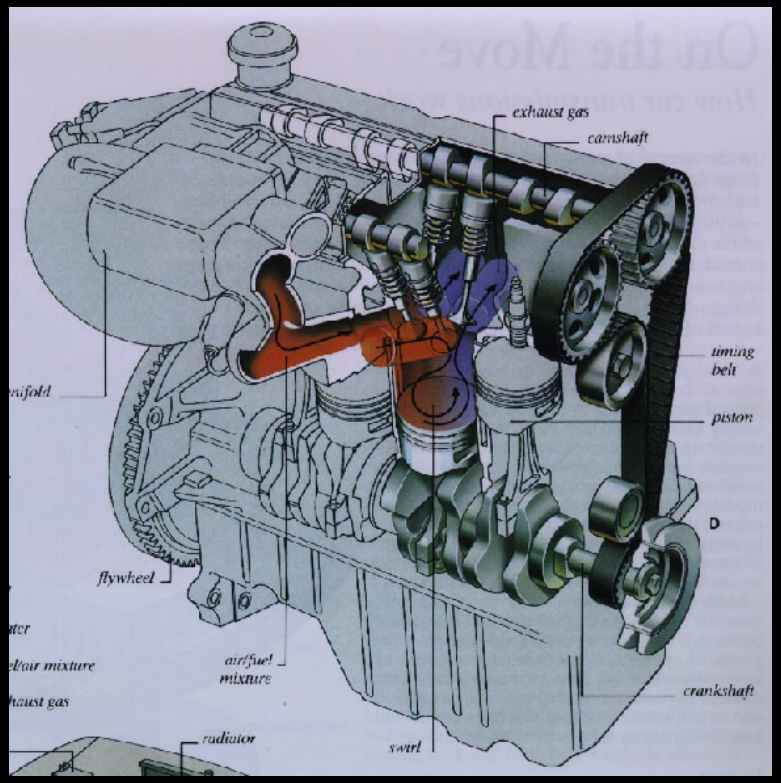
Technical Illustrations

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

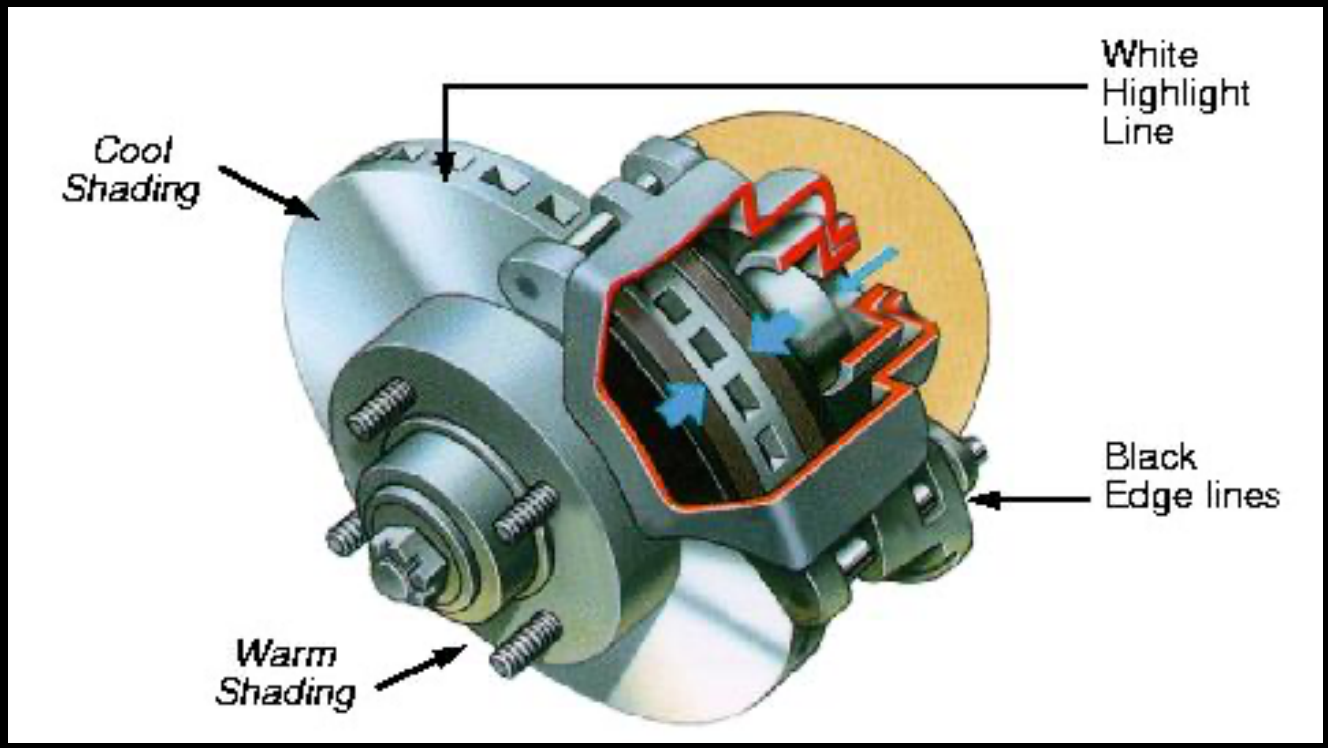
Ruppel 1995



Photo

Conventions in Technical Illustrations

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



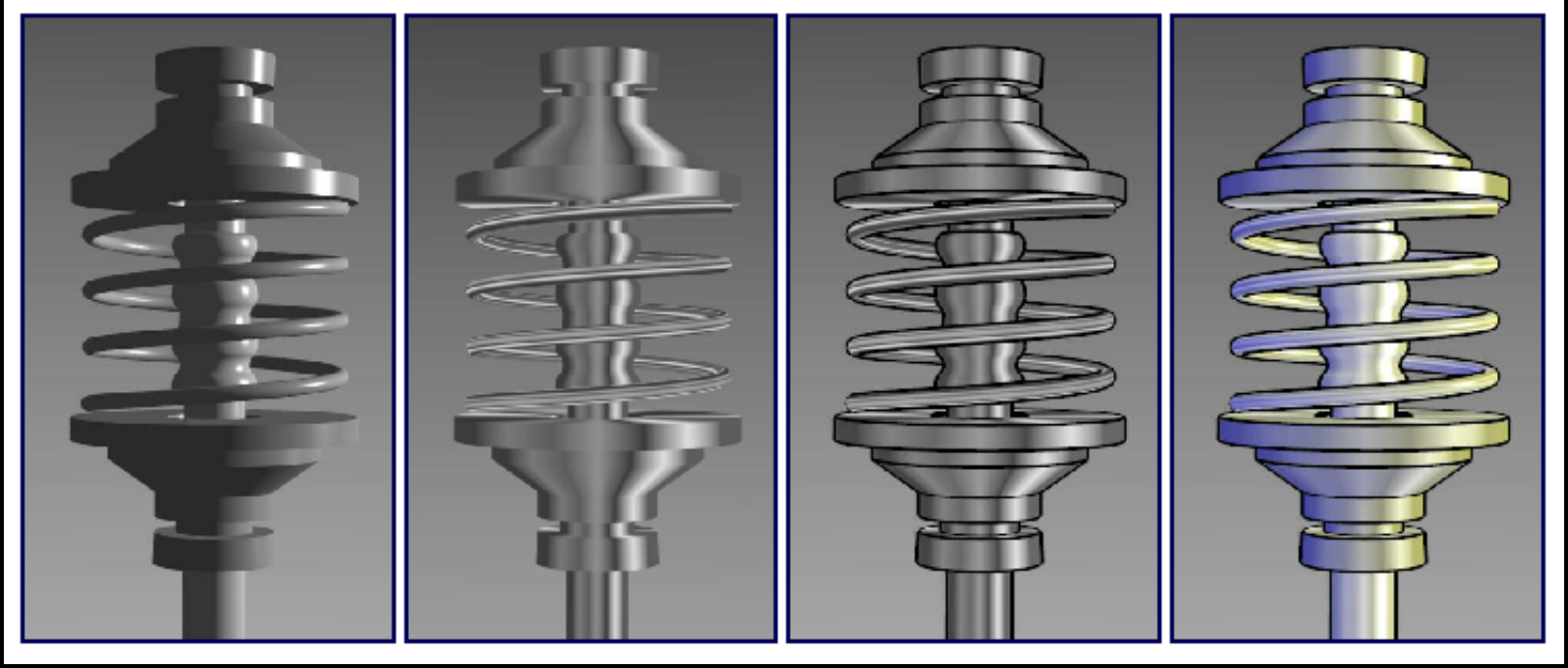
Technical Illustration Example

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!