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

Source: ATI

- Art-based rendering

- Psychographics

4

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
- Blue

- Green
- Yellow

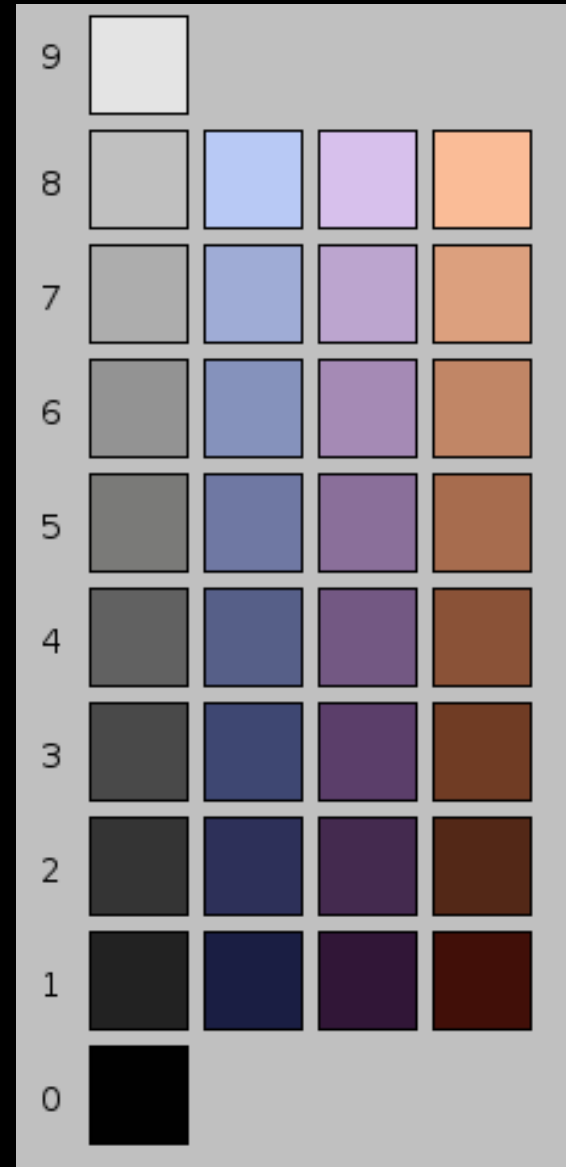0   60   120   180   240   300   360

Hue Scale

Source: Wikipedia

Tone

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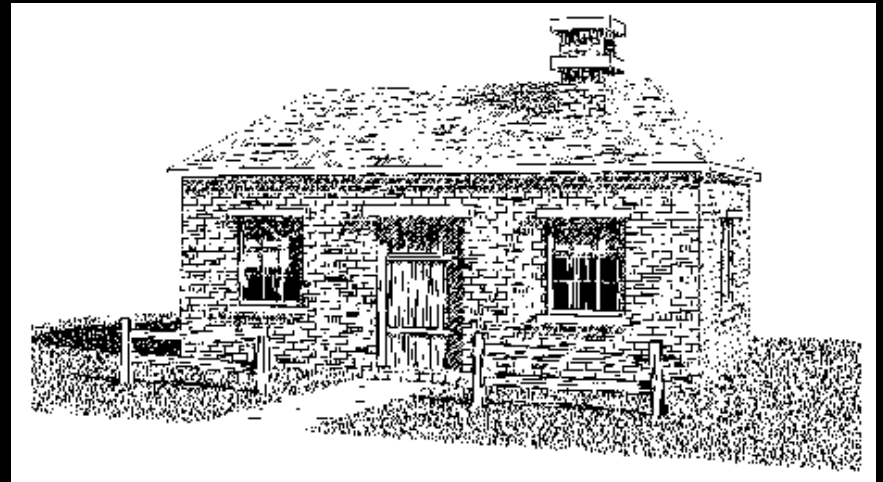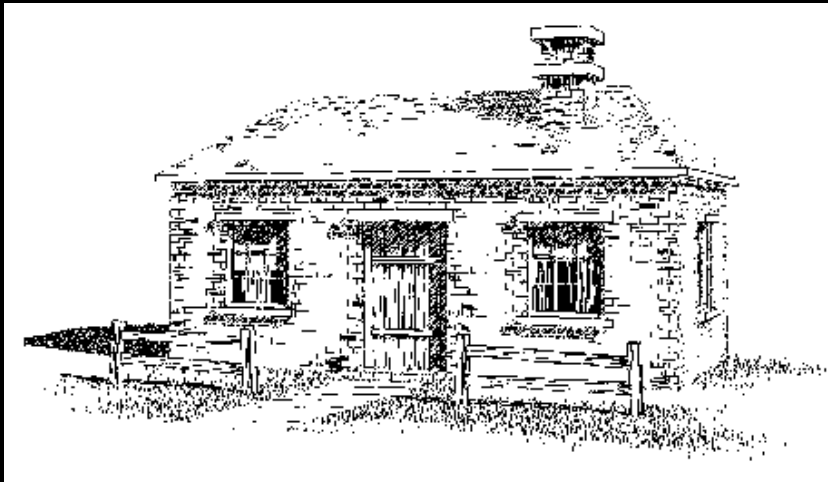
- Also called lightness
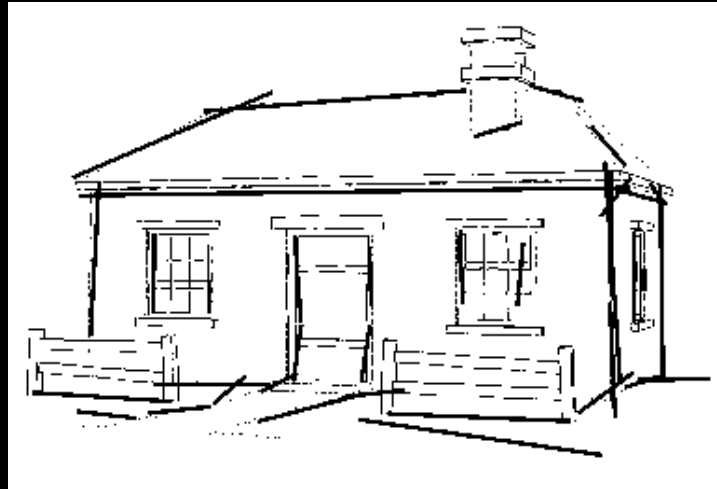
- Important in NPR

lighter

darker

Source: Wikipedia

Pen-and-Ink Illustrations

Winkenbach and
Salesin 1994

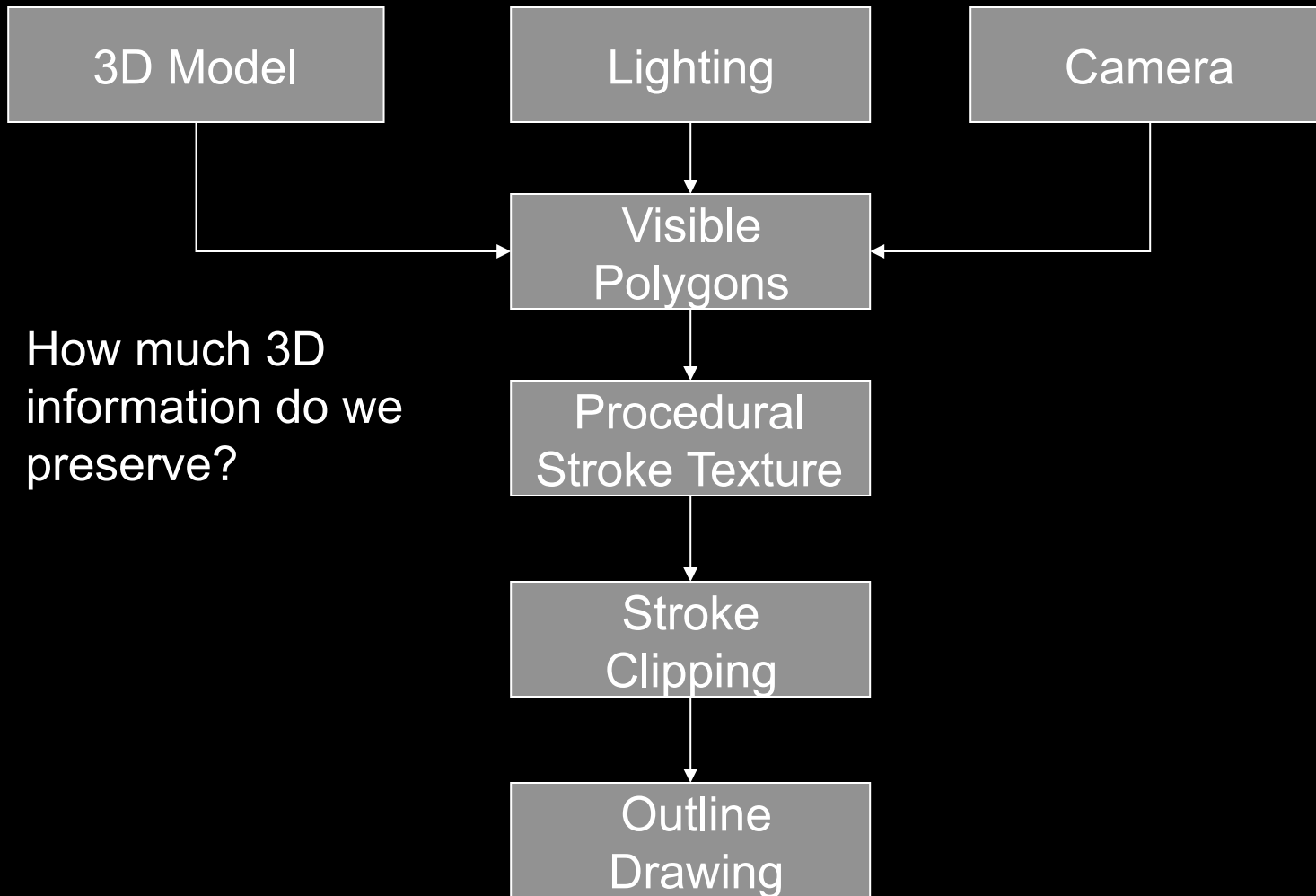# Pen-and-Ink Illustrations

- ## Strokes
  - Curved lines of varying thickness and density

- ## Texture
  - Conveyed by collection of strokes

- ## Tone
  - Perceived gray level across image or segment

- ## Outline
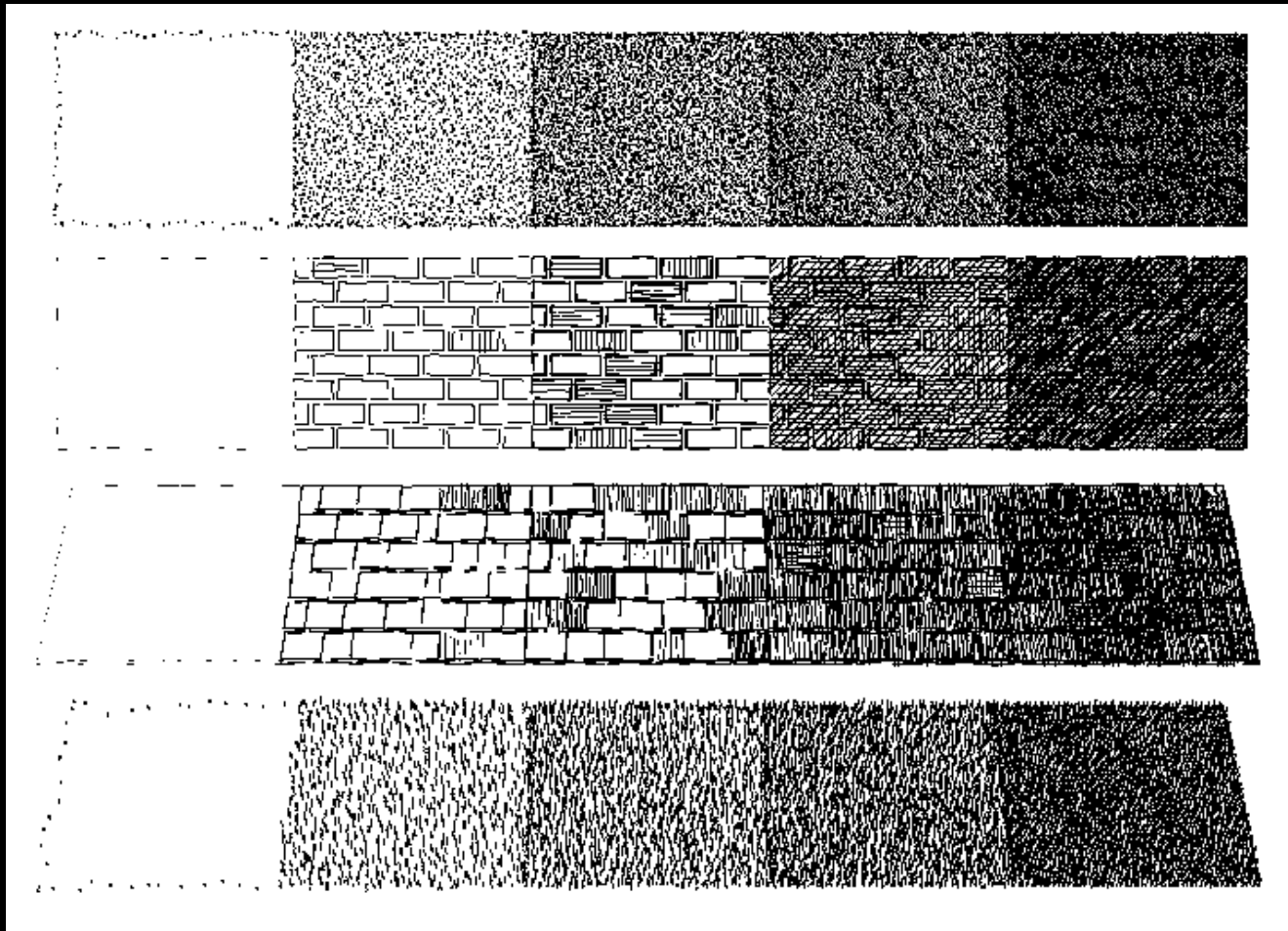 - Boundary lines that disambiguate structure

Winkenbach and
Salesin 1994

Rendering Pipeline: Polygonal Surfaces with NPR

```
┌─────────────┐      ┌─────────────┐      ┌─────────────┐
│  3D Model   │      │  Lighting   │      │   Camera    │
└──────┬──────┘      └──────┬──────┘      └──────┬──────┘
       │                    │                    │
       │             ┌──────▼──────┐             │
       └────────────▶│   Visible   │◀────────────┘
                     │  Polygons   │
                     └──────┬──────┘
                            │
                     ┌──────▼──────┐
                     │ Procedural  │
                     │Stroke Texture│
                     └──────┬──────┘
                            │
                     ┌──────▼──────┐
                     │   Stroke    │
                     │  Clipping   │
                     └──────┬──────┘
                            │
                     ┌──────▼──────┐
                     │   Outline   │
                     │   Drawing   │
                     └─────────────┘
```

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
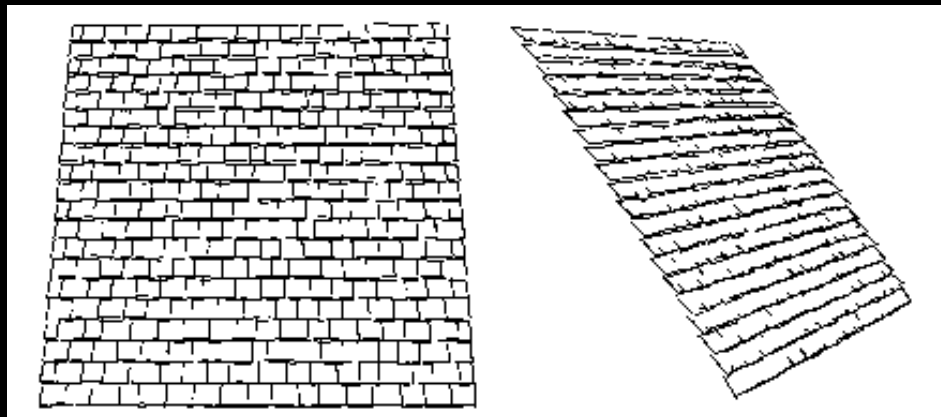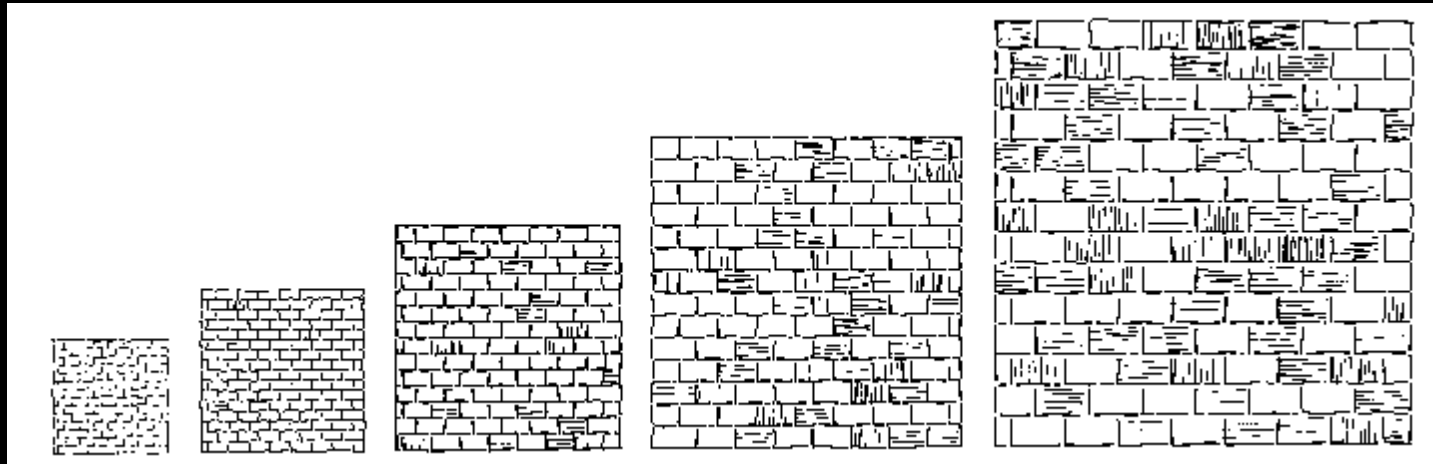 - Orientation dependent
- How automatic are stroke textures?

Stroke Texture Examples

Winkenbach and Salesin 1994
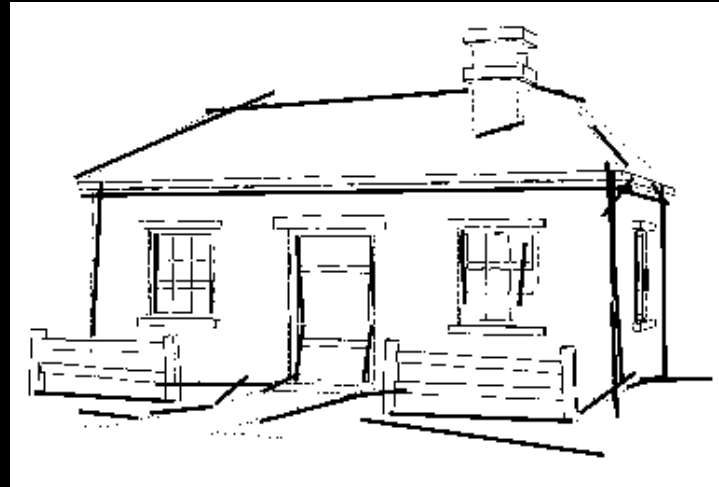
Stroke Texture Operations

Scaling

Changing Viewing
Direction
(Anisotropic)

Indication

- Selective addition of detail

- Difficult to automate

- User places detail segments interactively

Indication Example
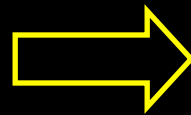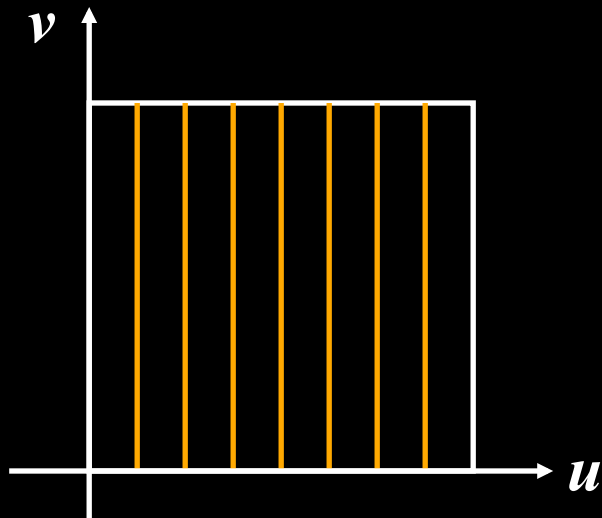

Input without detail

With indication

Without indication

16

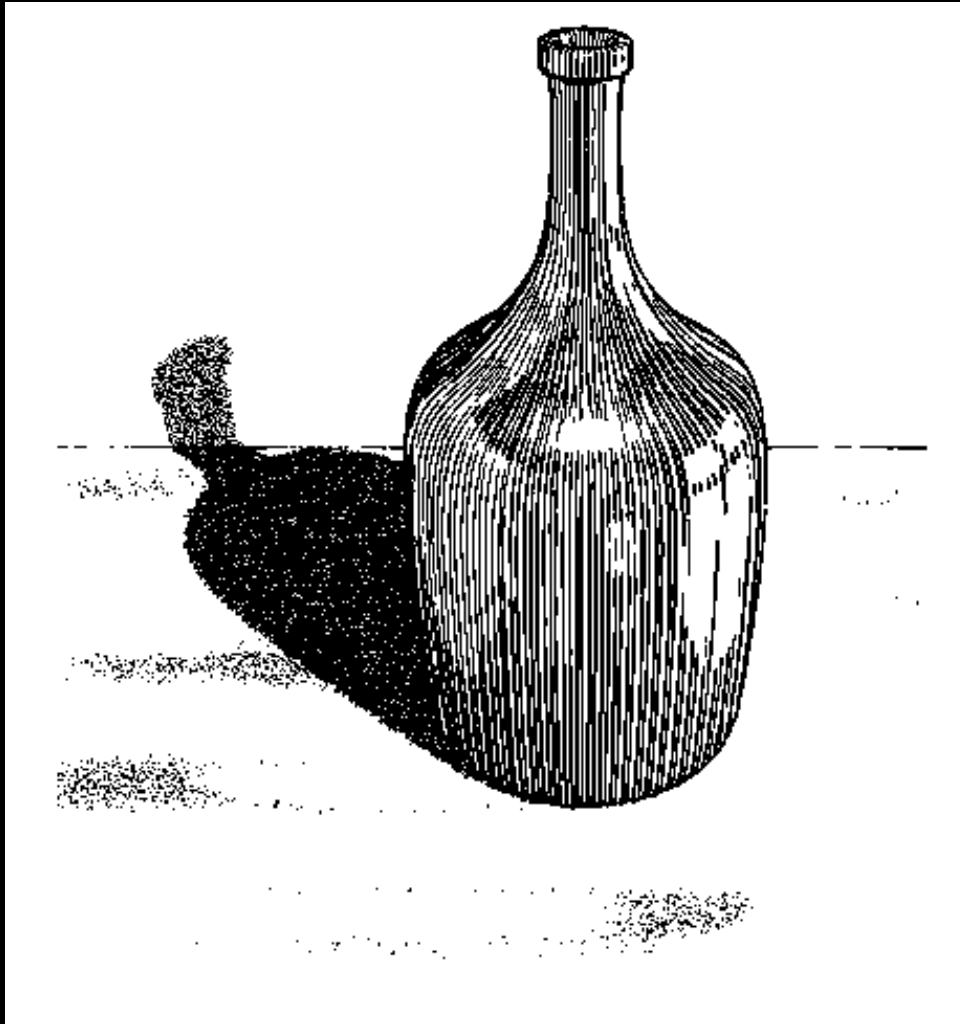# Outlines

- 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
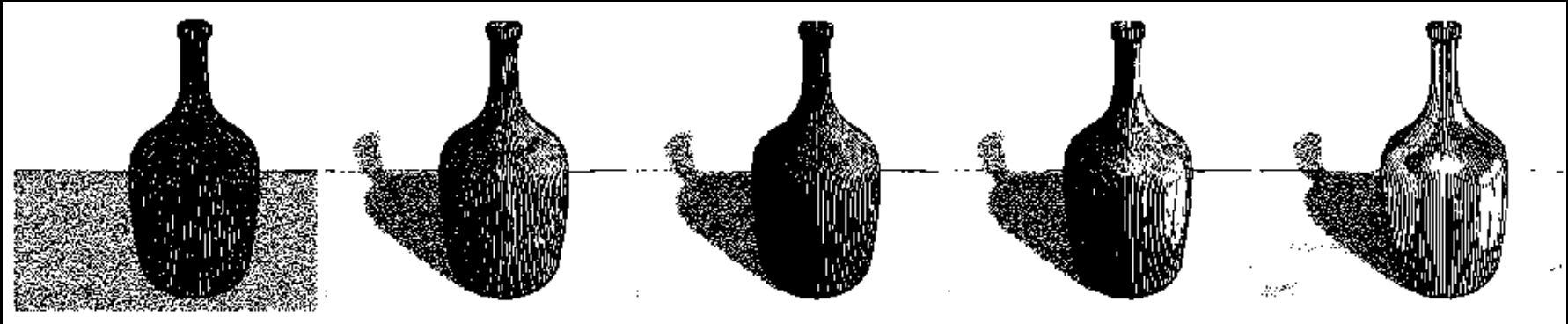 - Choose density for desired tone
  - tone = spacing / width

Parametric Surface Example

Winkenbach and
Salesin 1996

Hatching + standard rendering

Constant-density hatching

Smooth shading with single light

Longer smoother strokes for glass
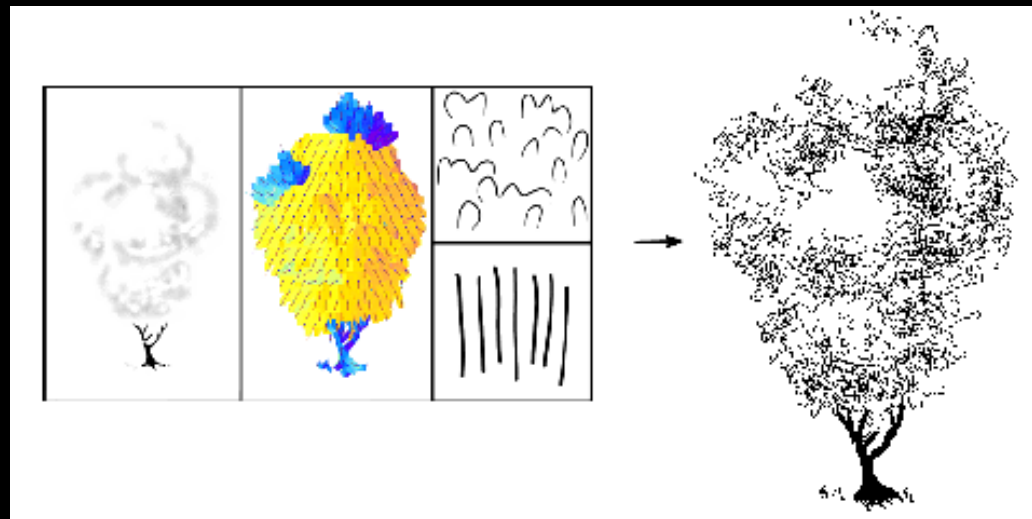
Environment mapping

Varying reflection coefficient

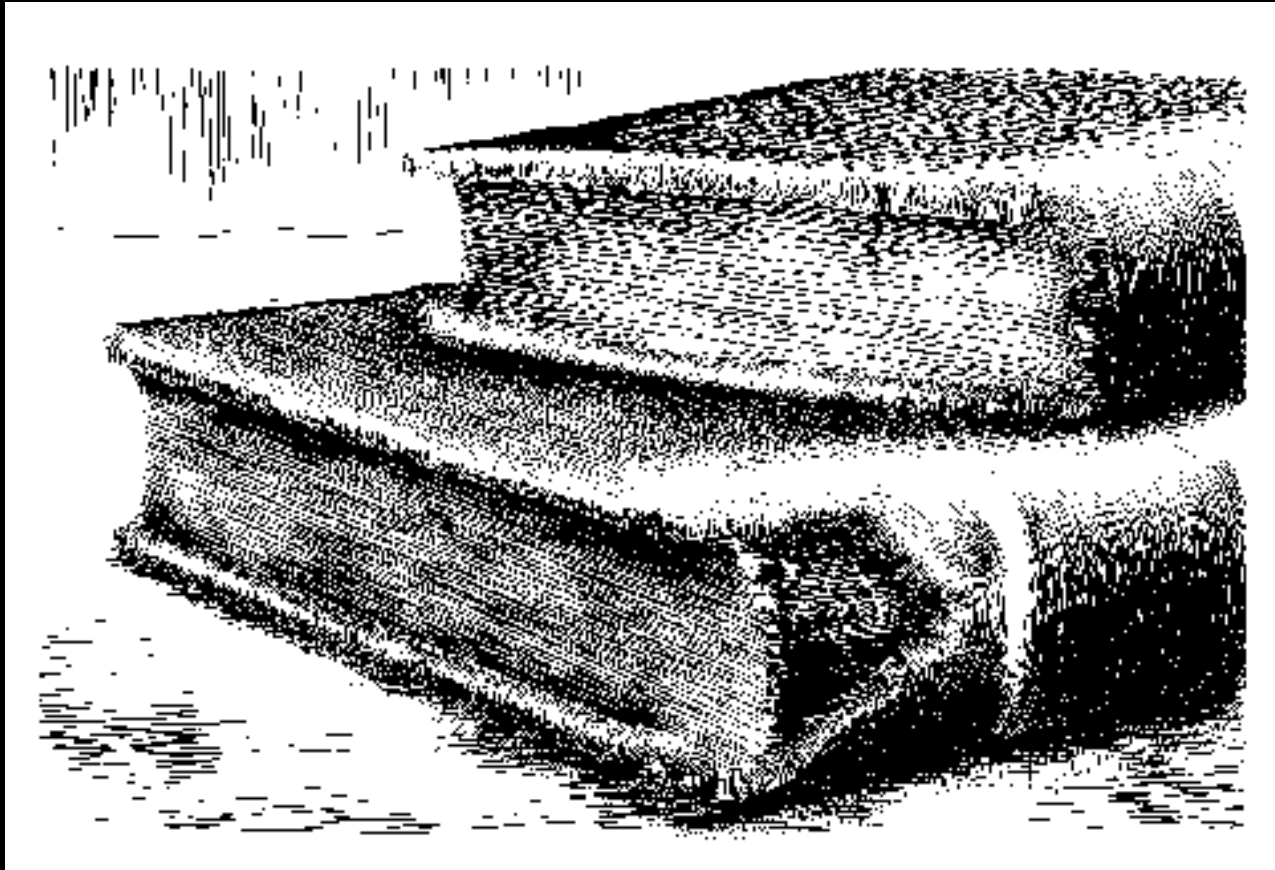Standard rendering techniques are still important!

Orientable Textures

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

Salisbury et al. 1997

- Output
  - Stroke shaded image

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
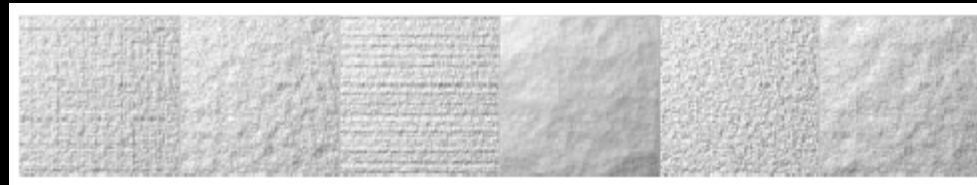 - Computer generates all strokes

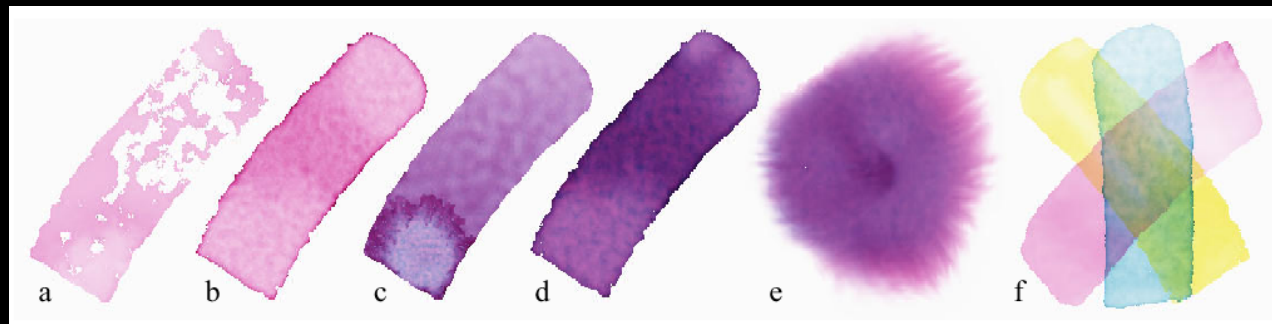# Physical Simulation Example

Curtis et al. 1997, *Computer Generated Watercolor*

Computer-Generated Watercolor

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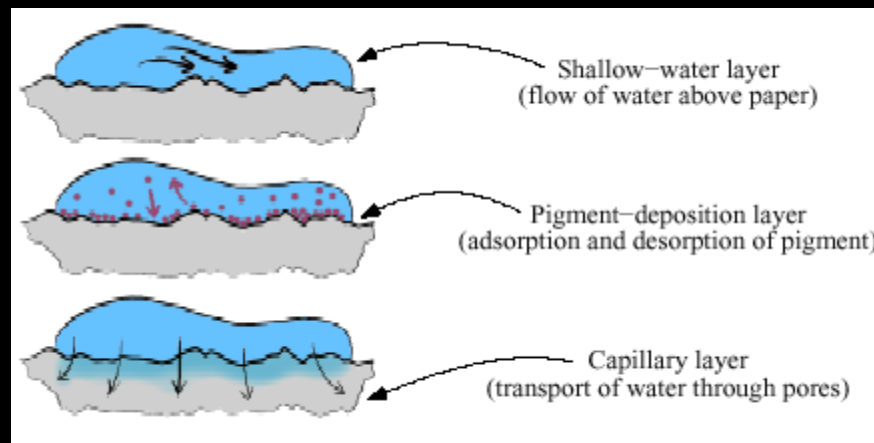- Paper generation as random height field
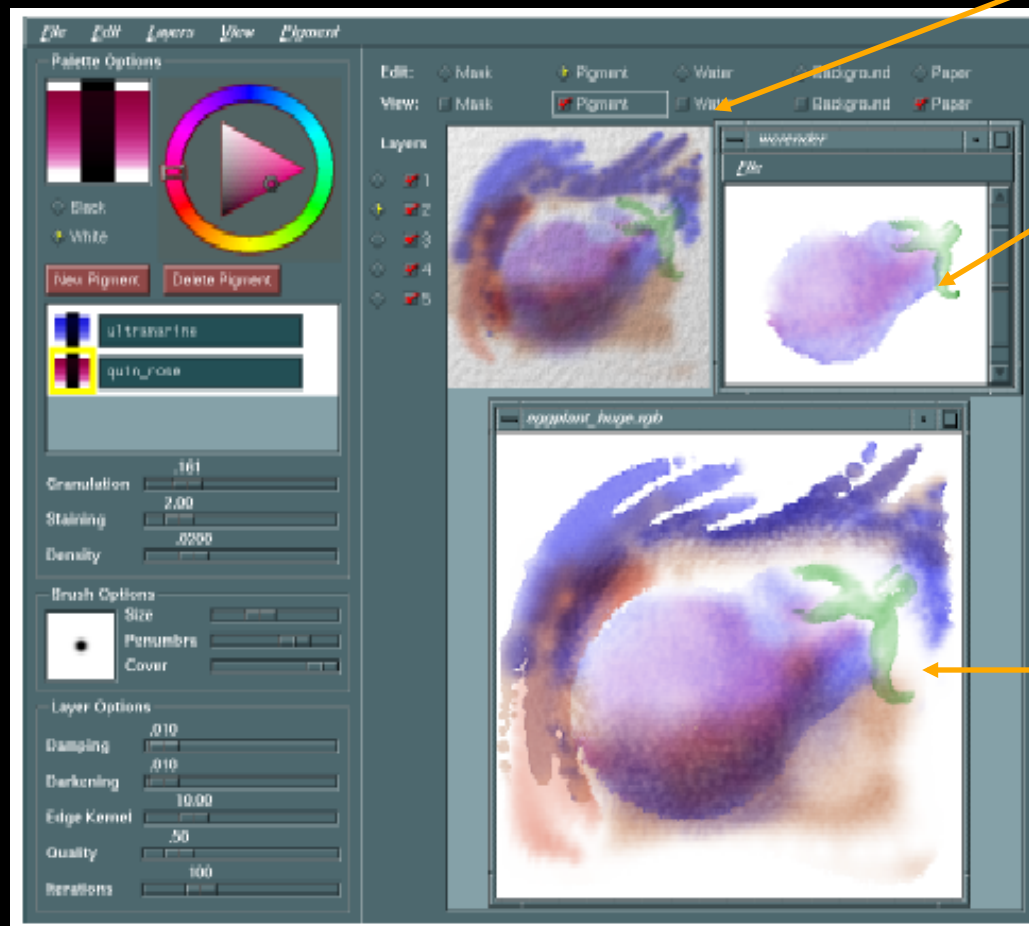

- Simulated effects

Fluid Dynamic Simulation

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

Shallow−water layer
(flow of water above paper)

Pigment−deposition layer
(adsorption and desorption of pigment)

Capillary layer
(transport of water through pores)

- Discretize and use cellular automata

Interactive Painting

User input

Simulation in progress

Finished painting

28

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 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
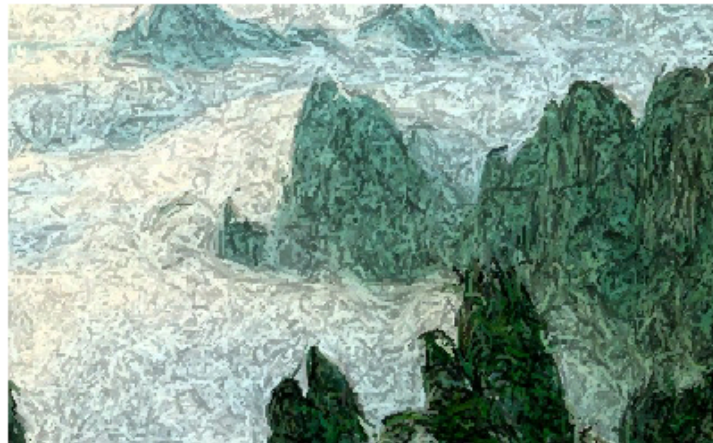- Encapsulate parameter settings as style

Style Examples

Source image

"Impressionist"
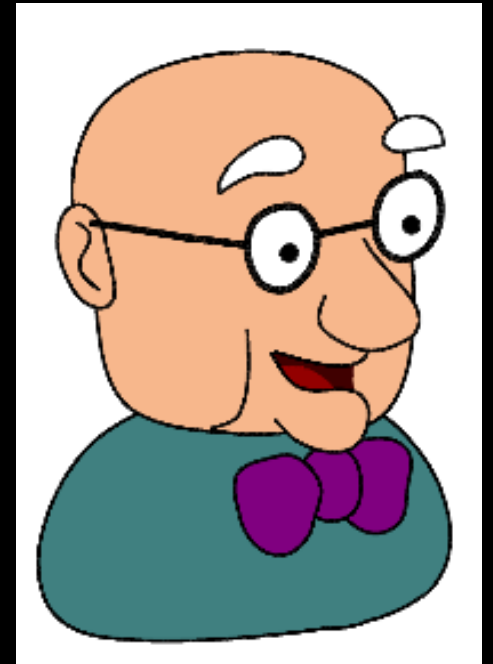
"Expressionist"

"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?)

Outline

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- Cartoon Shading
- Technical Illustrations
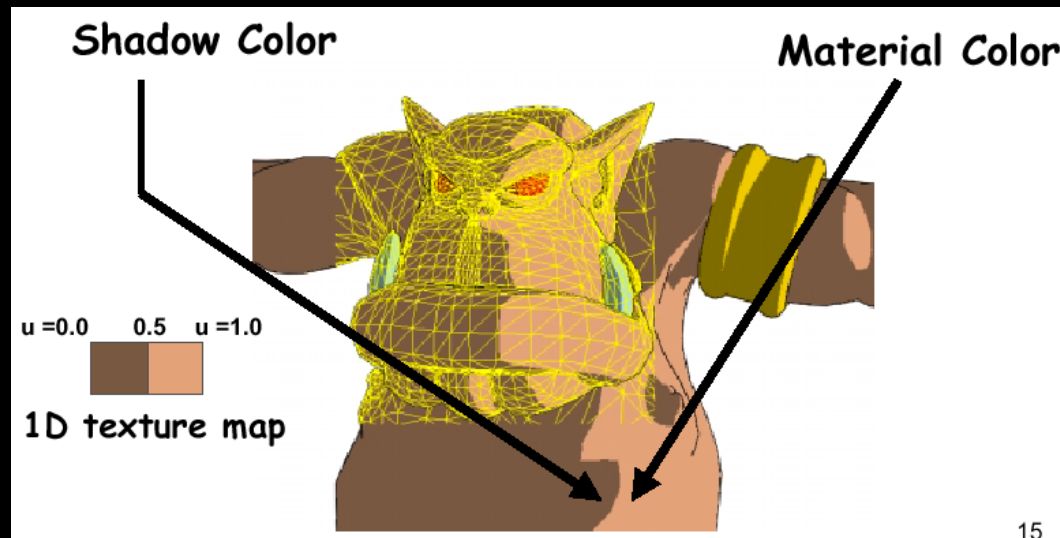
Cartoon Shading

- 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
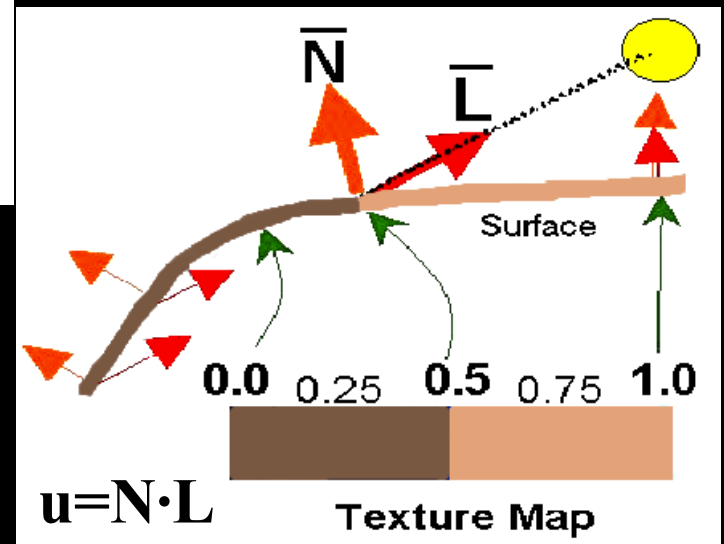

Source:
Alec Rivers

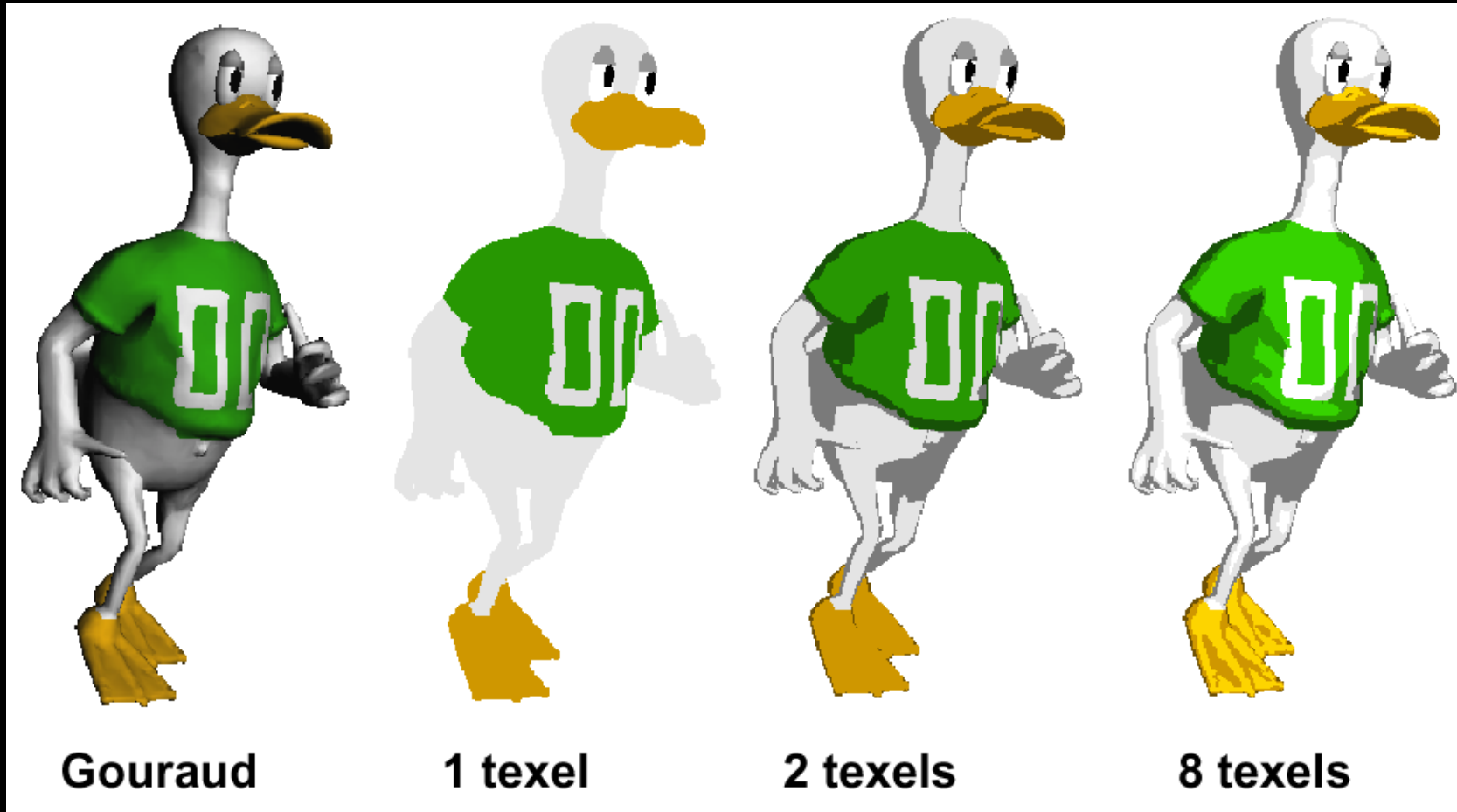# Cartoon Shading as Texture Map

- 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

Gouraud   1 texel   2 texels   8 texels

Flat shading   Shadow   Shadow + highlight

Outline

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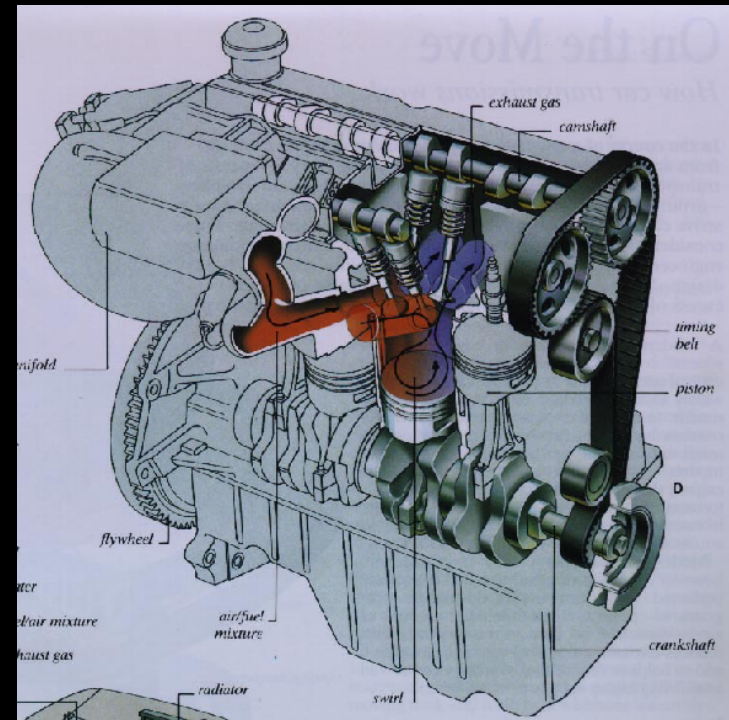- Painterly Rendering
- Cartoon Shading
- Technical Illustrations

Technical Illustrations

- Level of abstraction
  - Accent important 3D properties
  - Dimish or eliminate extraneous details   Ruppel 1995
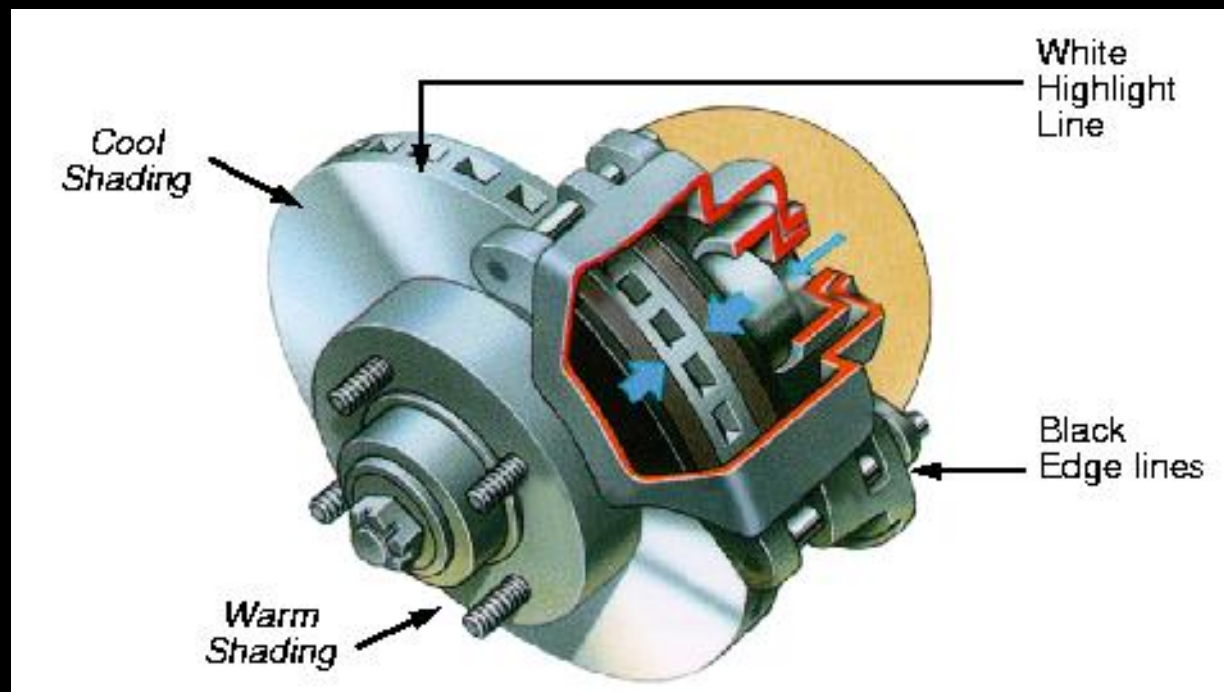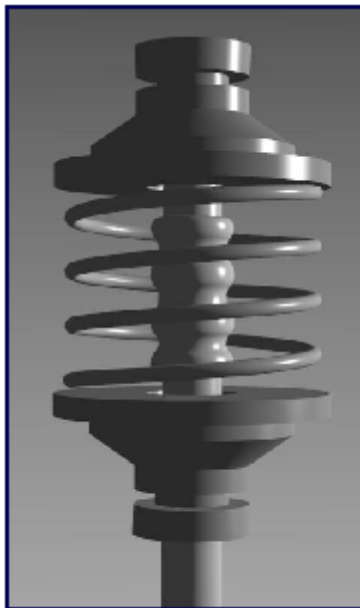
- Do not represent reality

Photo

Conventions in Technical Illustrations

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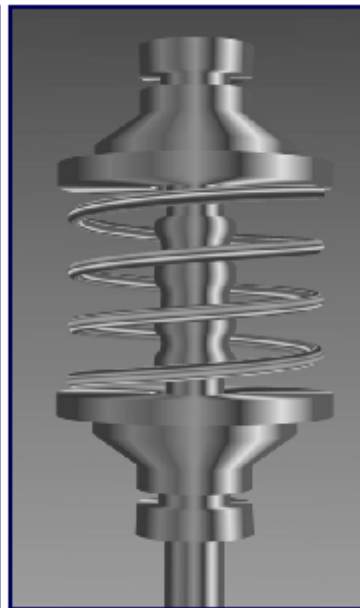- Single light source; shadows rarely used

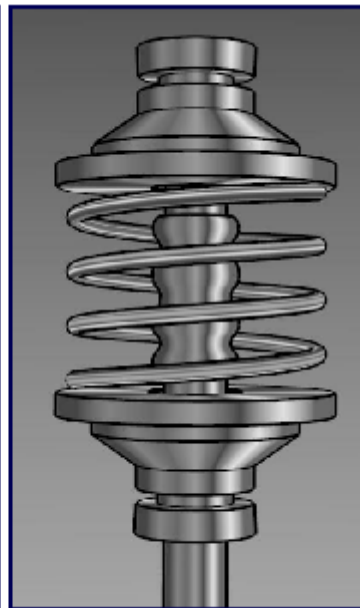# Technical Illustration Example
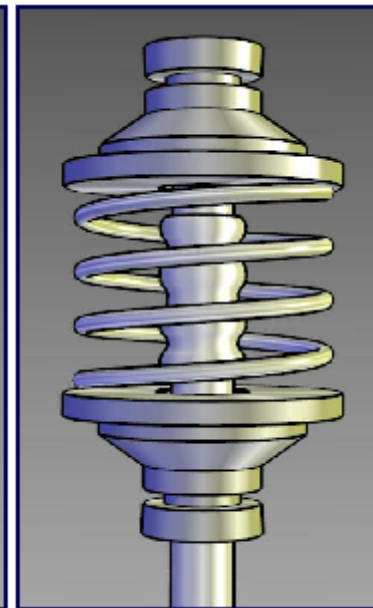

Phong shading

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!