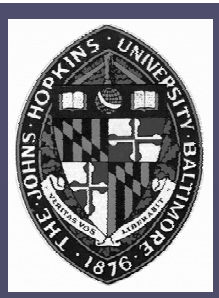
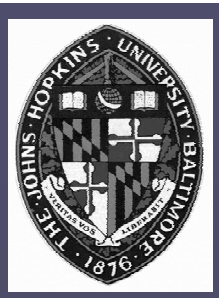


Non-Photorealistic Rendering

Pen-and-Ink Illustration



Stylized Illustrations

As compared to photorealistic images, sometimes:

- **Convey more information**
- **Allow more compact storage**
- **More easily reproduced**
- **More attractive**

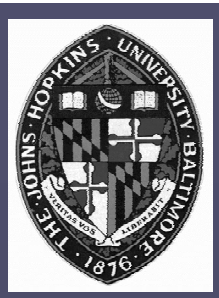
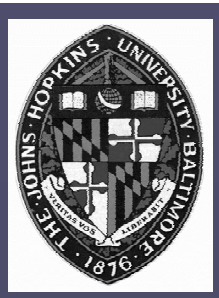


Illustration Applications

Architectural design

Medical texts

Industrial repair manuals



Types of Non-Photorealistic Rendering

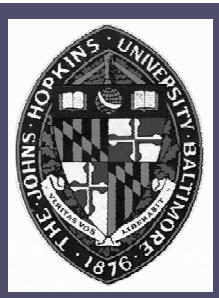
Pen-and-ink Drawings

Paintings

Rendering enhancements

Other artistic modalities

- **e.g. screening, floral ornamentation, cartoons, etc.**



Pen and Ink Concepts

Strokes

- Curved lines of varying thickness and density of placement

Texture

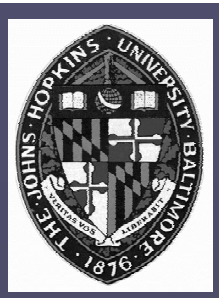
- Character conveyed by collection of strokes, e.g. crisp and clean vs. rough and sketchy

Tone

- Perceived gray level across the image

Outline

- Boundary lines which disambiguate structure information



Algorithm Goal

Place strokes on surfaces to achieve particular tone functions

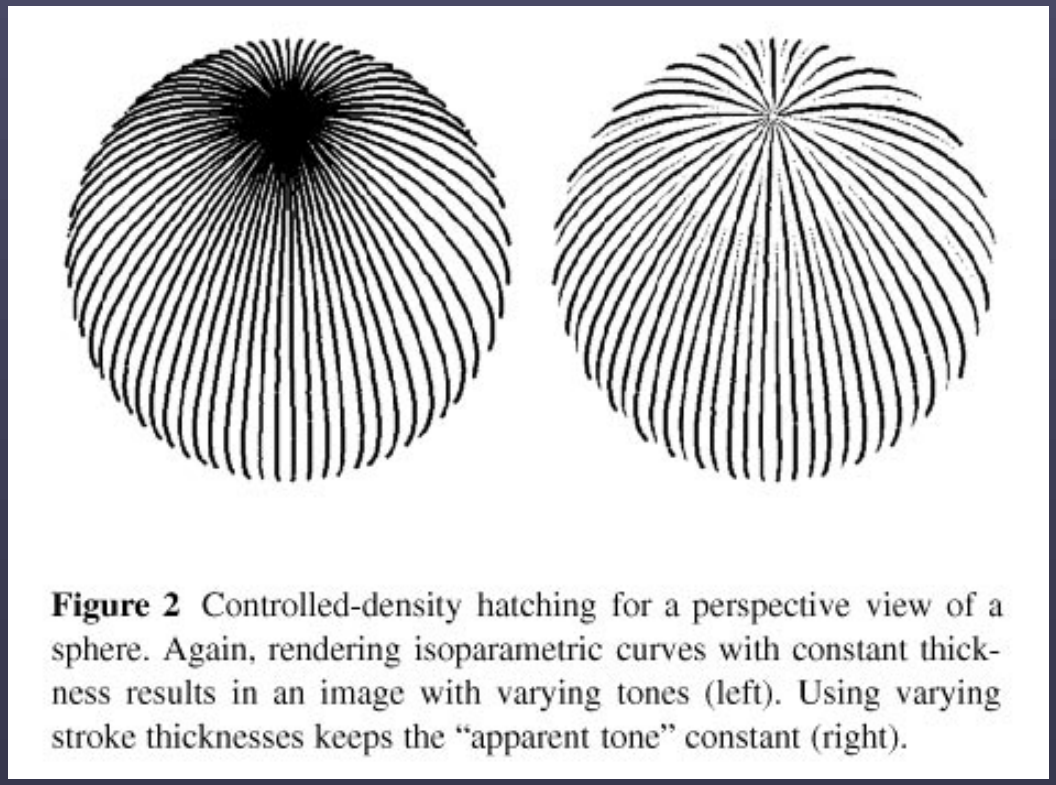
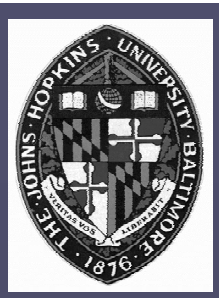


Figure 2 Controlled-density hatching for a perspective view of a sphere. Again, rendering isoparametric curves with constant thickness results in an image with varying tones (left). Using varying stroke thicknesses keeps the "apparent tone" constant (right).

from Winkenbach and Salesin. "Rendering Parametric Surfaces in Pen and Ink." *Proceedings of SIGGRAPH 96*. Page 471.

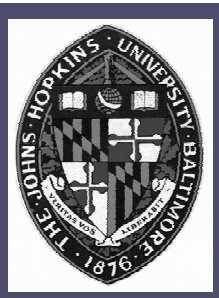


Algorithm Components

Tone specification

Stroke placement

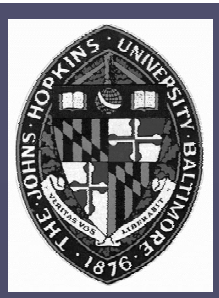
Stroke width computation



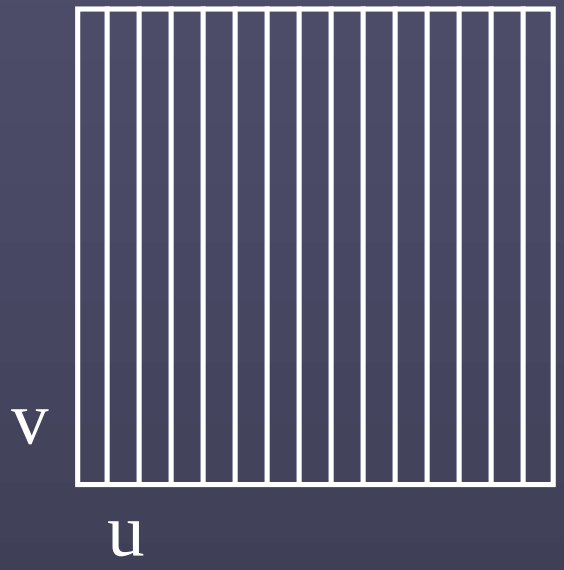
Tone Specification

Gray levels may be assigned according to conventional rendering:

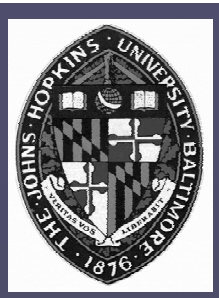
- **Local/global Illumination**
- **Material color**
- **Texture mapping**
- **Bump mapping**
- **Environment mapping**
- **Shadow mapping**



Stroke Placement



- Places strokes along isoparameter lines of parameterized surface
- Choose density according to maximum gray level and maximum allowable stroke width



Planar Maps

Compute visibility and store in planar map

- Planar map is partition of image plane
- Each partition corresponds to a visible portion of a primitive (curved surfaces are tessellated).
- Shadows may be explicitly represented as map partitions

Clip strokes according to planar map

- Reduces computation and allows rendering with hidden surfaces already removed

Create outlines from partition boundaries

Planar Map Example

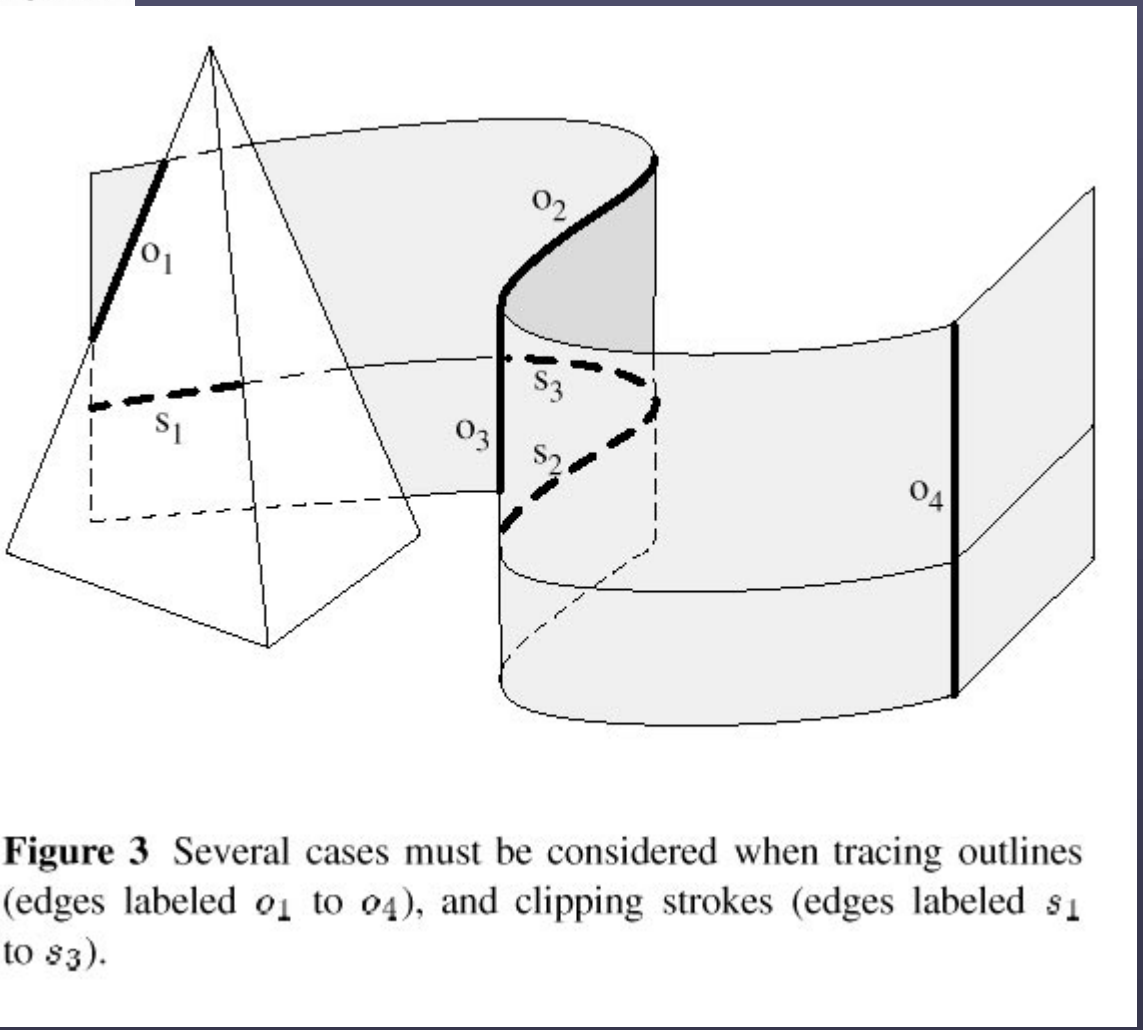
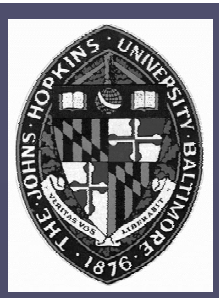


Figure 3 Several cases must be considered when tracing outlines (edges labeled o_1 to o_4), and clipping strokes (edges labeled s_1 to s_3).

from Winkenbach and Salesin. "Rendering Parametric Surfaces in Pen and Ink." *Proceedings of SIGGRAPH 96*. Page 474.



Stroke Width

Vary width across each stroke line

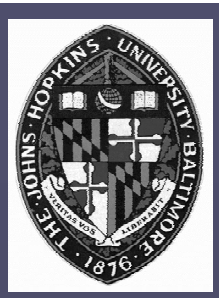
$S: (u,v) \rightarrow (x_w,y_w,z_w)$

$V: (x_w,y_w,z_w) \rightarrow (x_s,y_s)$

$M = V\ S : (u,v) \rightarrow (x_s,y_s)$

Use Jacobian of M to estimate divergence of lines in screen space

Adjust width to account for divergence and desired tone along each stroke



Advanced Techniques

Recursive filler strokes

- Allow larger gaps between strokes, then fill gaps by adding new strokes

Stippling

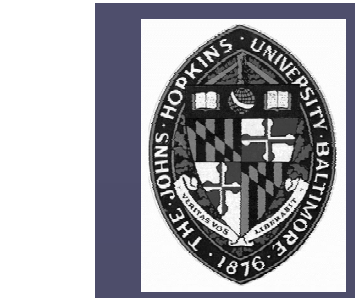
- draw stipple pattern along strokes

Cross hatching

- use more than one hatching direction

Prioritized strokes

- stroke thicknesses determined in prioritized order



Pen and Ink Example

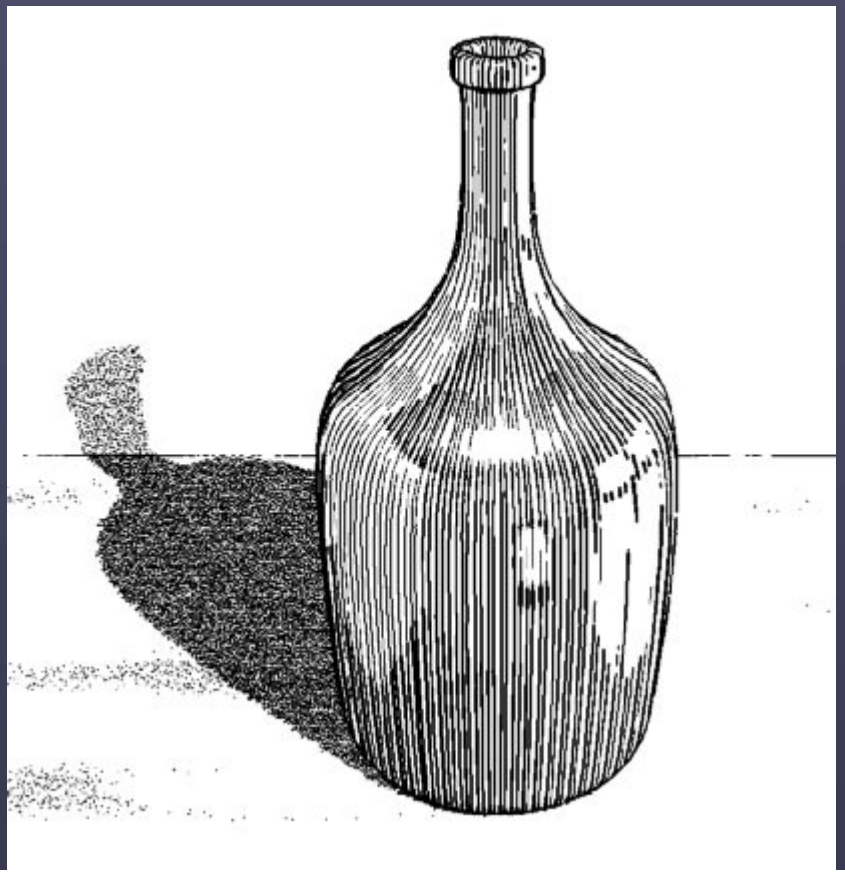
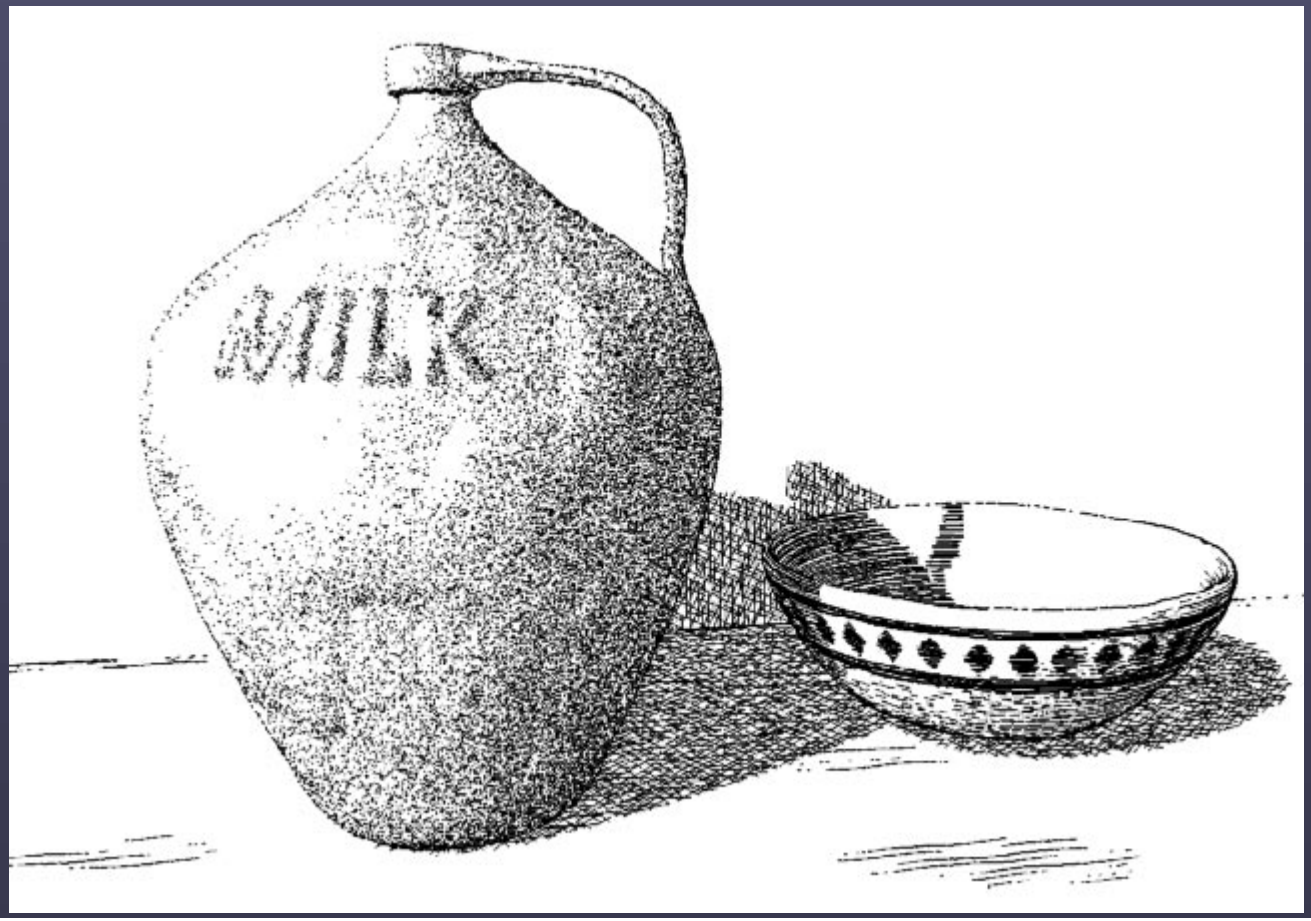


Figure 5 Glass bottle. An environment map is used to give the illusion of a reflected surrounding.

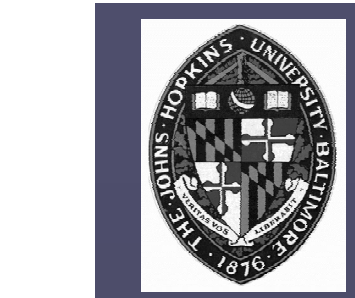
from Winkenbach and Salesin. “Rendering Parametric Surfaces in Pen and Ink.” *Proceedings of SIGGRAPH 96*. Page 474.

Pen and Ink Example



from Winkenbach and Salesin. “Rendering Parametric Surfaces in Pen and Ink.” *Proceedings of SIGGRAPH 96*. Page 475.

Figure 7 Ceramic jug and bowl. A traditional (image-based) texture map is used to model the details on the bowl as well as the stains on the table. A bump map is used to emboss the word “MILK” on the jug, and to give some irregular variation to its surface.



Pen and Ink Example

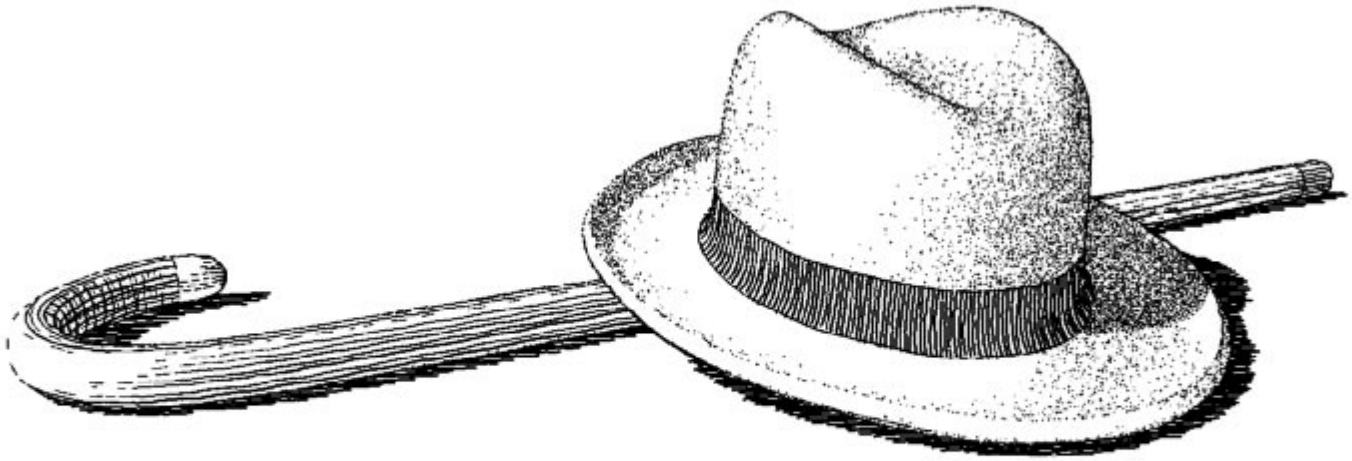
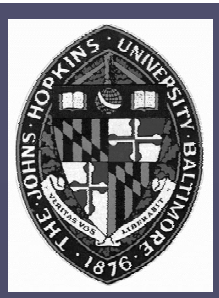


Figure 8 Hat and cane. Both the hat and the cane are modeled with B-spline surfaces. The ribbon is modeled as a separate B-spline surface. Note the curved shadow that the hat projects on its rim, and the use of crosshatching on the curved portion of the cane.

from Winkenbach and Salesin. “Rendering Parametric Surfaces in Pen and Ink.” *Proceedings of SIGGRAPH 96*. Page 476.



Other Variants of Pen and Ink

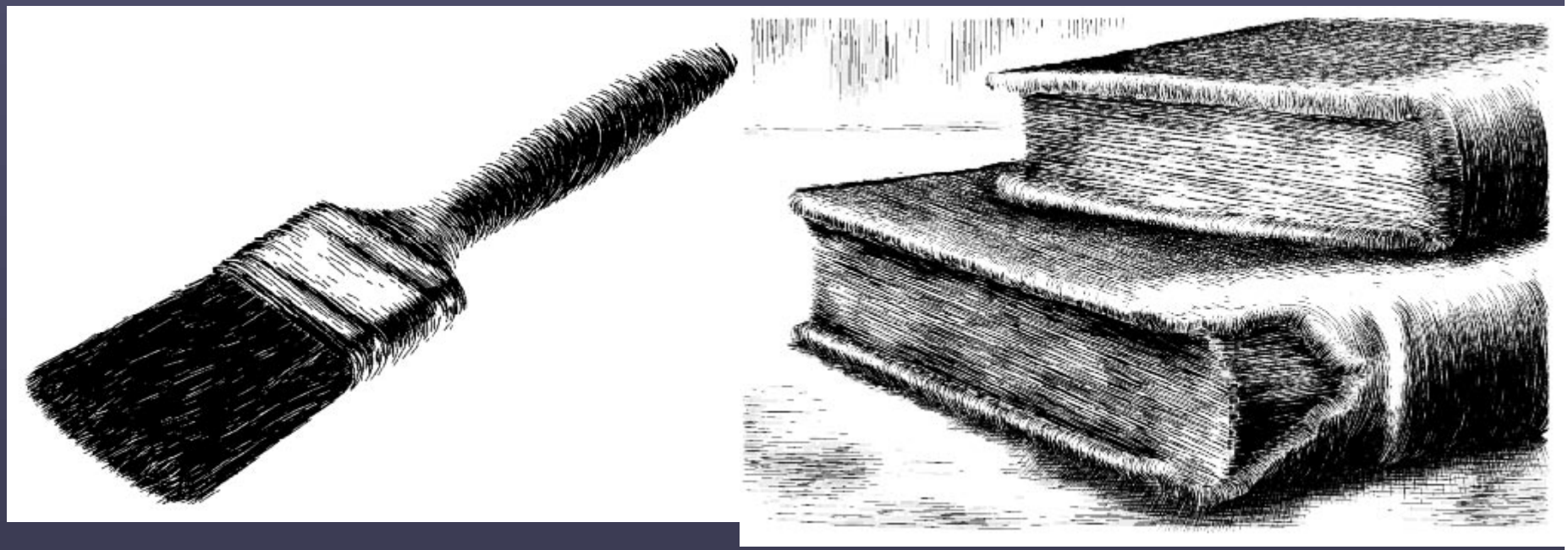
Orientable Textures

- Greyscale image as input (describes tone)
- User specifies direction field and stroke character
- Stroke shaded image output

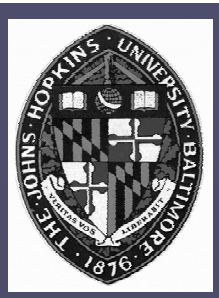
Real-time NPR

- Fast visibility computation of silhouette and other feature edges
- Render visible edges in modified styles

Orientable Textures Examples

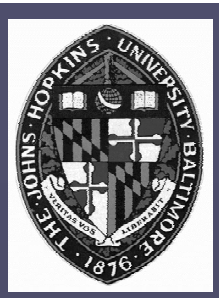


from Salissbury et al. “Orientable Textures for Imabe-Based Pen-and-Ink Illustration.” *Proceedings of SIGGRAPH 97*. Pages 402, 403.



Real-Time NPR Examples

from Markosian et al. “Real-Time Nonphotorealistic Rendering.” *Proceedings of SIGGRAPH 97*. Page 420.



Videos

- Salisbury, Wong, Hughes, and Salesin. "Orientable Texture for Image-Based Pen-and-Ink Illustration." *Proceedings of SIGGRAPH 97.*
- Markosian, Kowalski, and Hughes. "Real-Time Nonphotorealistic Rendering." *Proceedings of SIGGRAPH 97.*
- Banks and Turk. "Image-guided Streamline Placement." *Proceedings of SIGGRAPH 96.*