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

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*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). 

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 $s_2$).


Stroke Width

Vary width across each stroke line

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

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

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

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

![Pen and Ink Example](image)

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

Pen and Ink Example

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.

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

Real-Time NPR Examples


Videos

