Pen & Ink Illustration

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Reasons

- To communicate complex information more effectively through abstraction
- Convey information better by omitting extraneous detail
- Focuses attention on what is relevant
- Clarifies and simplifies shapes
- Exposes hidden parts in illustrations
- Less storage for illustrations
- More easily reproduced, transmitted, and scaled
- Can add a sense of vitality (warmer artistic look)
- Blend well with text
Reasons (Examples)

Medical texts most frequently use illustrations in place of or in conjunction with photographs.

Most assembly, maintenance, and repair manuals for hardware employ illustrations.
It is a limiting medium

- No color
- No tone
- Difficult to express texture

Tone and texture must be suggested through individual strokes

Irregularities in path and pressure of the stroke to make it more expressive

Economy of expression since a few small strokes can convey tone and texture
Principles of Pen & Ink
- Strokes -

Stroke is produced by placing the nib of a pen and tracing a path. Varying pressure on the nib changes the thickness of the stroke.

- Even-weight lines seem lifeless. Vary the thickness of the stroke.
- Vary the pen position as nib makes a turn along the stroke
- Wavy lines to indicate a drawing is schematic
- Thin strokes give a washed out appearance
- Coarse strokes detract from delicate details
Principles of Pen & Ink
- Tones and Texture -

Combinations of strokes used to create an overall impression of the desired tone.

Tone can be achieved by a function of the ratio of black ink to white paper over a given region in the illustration.

Texture can be achieved by varying the character of the same stroke used for tone.
Principles of Pen & Ink
- Outlines -

- Can vary thickness and character to add expressiveness.
- Delineate the essentials of the interior.
- Classic principles:
  - Quality to convey texture (e.g. crisp straight lines for hard objects like glass).
  - Thick outlines to suggest shadows or bring objects forward to in the scene.
  - Outlines haloed where object passes behind another object.
  - Use “indication” for drawing outlines.
Computer generated pen-and-ink illustrations
- How -

Traditional “graphics rendering pipeline” vs. pen-and-ink rendering

- In traditional, rendering and strokes are independent but in the pen-and-ink rendering tone is produced through the same strokes for texture.

- In traditional the rendering information is completely 3D and conversion to 2D is just sampling the rendered shades, but in the pen-and-ink rendering, 3D information is needed for the 2D rendering process as well (e.g. lines passing behind the other).
Computer generated pen-and-ink illustrations
- The pipeline -

Traditional way with added changes:

- The model (any polygonal 3D model)
- Assignment of textures (described by stroke textures)
- Lighting Model (used Phong model)
- Visible surface algorithm (BSP trees)
- Shadow algorithm (Chin and Feiner’s BSP tree shadow volumes)
Computer generated pen-and-ink illustrations
- The pipeline -

Major differences from the traditional way:

- Maintaining a 2D spatial subdivision (need to consider 2D adjacency – use half-edge data structure to maintain the planar map)
- Polygons are not scan-converted. Texture and tone is conveyed with some form of hatching
- Clipping strokes to the regions they are texturing (sometimes allow stroke to wave outside clipping area)
- Outlining: Boundary outlines drawn in a way that takes into account the texture of surrounding regions as well as adjacency information from the planar map. Interior outlines to suggest shadow directions
The general procedure

1. Compute visible surfaces and shadow polygons
2. Use those polygons projected to Normalized Device Coordinate to build 2D BSP tree and planar map
3. Render each visible surface
4. Procedural texture is of each surface is invoked to generate all strokes to convey tone and texture
5. Strokes clipped using set operations on the 2D BSP tree
6. Outline strokes drawn by extracting from planar map the outline edges necessary for the illustration
Computer generated pen-and-ink illustrations
- The process -

- M: the model (collection of polygons)
- BspTree: 2D BSP tree representation of the visible polygons projected to Normalized Device Coordinates (NDC)
- PlanarMap: partition of the NDC into vertices, edges, and faces

procedure RenderScene(M):
      (BspTree, PlanarMap) ← VisibleSurfaces(M)
      for each visible surface S ∈ M do
         Strokes ← Texture(S, Tone(S))
         for each stroke s ∈ Strokes do
            Render( ClippedStroke (s, BspTree) )
         end
      end
 Render( ConstructMinimalOutline( S, PlanarMap ) )
end procedure
Strokes and Textures

Strokes generated by placing a nib along the path. Perturbing the path with a waviness function and the nib with a pressure function

\[ S = (P(u) + Cw(u)) \times N(Cp(u)) \]

Stroke textures

A stroke texture is a collection of strokes to indicate texture and tone.

Use a prioritized stroke texture to render highest priority strokes first and if the rendered stroke is still too light, render next priority texture and so on. (e.g. in cross-hatching textures vertical strokes have higher priority than horizontal ones)
Resolution dependencies

Most drawing programs suffer from scaling problems. Same strokes at higher resolution produce thinner lines. Similarly at lower resolution produces black mass of overlapping strokes.

The prioritized strokes however do not suffer from these problems since strokes are applied only when necessary.
Strokes and Textures

Indication
Suggest texture without drawing every stroke

Fully automated process not practical. Implement a semiautomatic method where user specifies where detail (through “detail segments”) is to be added and indication is used everywhere else.

\[ w(x, y) = (a + b \times \text{distance}(x, y, l)) - c \]
Outline

- Texture with outline: Each stroke $T$ has a boundary outline texture associated with it.
- Minimizing outline: The shared edge between two faces is drawn if the tones of the two faces are not sufficiently different. When it is drawn however, use the outline texture for the face closest to the viewer.
- Accented outlines for shadowing and relief: If line casts a shadow then draw it thicker.
- Dependence of viewing direction: depending on direction of viewing, outline drawing needs to be changed.
Results

System developed on a Macintosh Quadra 700 using ThinkC

Only input was the geometry, texture assignments for each surface, and some field lines specifying “indication”

Frank Lloyd Wright’s “Robie House” was rendered.

- Consisted of 1043 polygons.
- 30 minutes to compute and print
  - 22 minutes for computing the planar map
  - 8 minutes for rendering at 600 dots per inch