Conveying Shape

Pat Hanrahan

Conveying Shape

Shading
Lines

From Gooch\textsuperscript{2}
Perception
Artistic Enhancement in Scientific Visualization

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Visualizing Anatomy
A photographic depiction captures the exact appearance of the object as we actually see it. Subtle, complex details of coloration and texture are fully represented, with great accuracy.

A drawing offers the possibility to clarify structural or conceptual information that may be difficult to perceive in even a very good photo.

Color drawing of the same subject.


Photo vs. Drawing in Archaeology

Photo vs. Drawing in Archaeology


Photo vs. Drawing

Hand-drawn illustrations are routinely used to emphasize important features that are difficult to capture in a photograph, while minimizing secondary detail.

Drawings are also useful to portray information that cannot be captured or represented photographically, such as hidden surfaces.
**Perception of the 3D configuration of familiar objects**

Speed of imitation of position, in seconds (mean):
- 0.039 photo
- 0.044 shaded drawing
- 0.070 line drawing
- 0.046 cartoon


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**Perception of the 3D configuration of familiar objects**

Speed of naming open switch, in seconds (mean)
- 0.690 photo
- 0.719 shaded drawing
- 1.169 line drawing
- 0.288 cartoon


Speed of stating stage of cycle, in seconds (mean):
- 0.235 photo
- 0.316 shaded drawing
- 0.375 line drawing
- 0.262 cartoon

Their Conclusion:

Superiority of performance (photograph vs. drawing) varies with the application

Response times were consistently longest for the basic line drawing images

Study of Picture Preferences

Realistic

Patent Ductus Arteriosus
Wedge Resection
Esophageal Fundoplication

Study of Picture Preferences

Semi-Schematic

Patent Ductus Arteriosus
Wedge Resection
Esophageal Fundoplication

Study of Picture Preferences


Results

Surgeons rated the ‘schematic’ representation least preferable; the ‘semi-schematic’ and ‘realistic’ representations were preferred in equivalent numbers.
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Lines
Classic Line Types

- Isoparametric lines
- Discontinuities: creases and self-intersections
- External and internal boundaries
- Silhouettes and contours and cusps
Extended Line Types

- Principal directions and lines of curvature
- Parabolic lines

- Attached and unattached shadows
- Isoluminance and luminance extrema
- Highlights

Space Curve
Normal Curvature

Principal Curvatures

Hilbert and Cohn-Vossen (1952)
Geometry and the Imagination
Gaussian Curvature

$K_1 = \text{curvature in first principal direction}$

$K_2 = \text{curvature in second principal direction}$

Gaussian curvature: $K = K_1 \cdot K_2$

Mean curvature: $H = (K_1 + K_2) / 2$

$K > 0 : \text{elliptic, convex or concave}$

$K < 0 : \text{hyperbolic, saddle-shaped}$

$K = 0 : \text{parabolic, cylindrical or planar}$
Artistic Inspiration

Russell Drake’s “single line system of shading”

- the flow of the shape is conveyed through the directions of the carefully drawn strokes
- multiple overlapping surfaces are displayed with clarity

Russell Drake, medical illustrator, Mayo Foundation, 1932.

Surface grid texture (aligned with the principal directions)

Solid grid texture (aligned with the coordinate axes)
Principal Directions

Klein bottle
From Hertzmann and Zorin

Occluding Contour

From Koenderink, Solid Shape
Definitions [Koenderink]

Rim – the closed space curve on the shape that makes up the silhouette; the space curve is smooth and has no discontinuities except when the surface is discontinuous; the rim is not a plane curve!

Contour – the projection of the rim; the projection may have singularities

Silhouette – the visible part of the contour

Generic Position

1. Perturbed ray meets in two points
2. Enter, leave, enter: cusp or contour ends
3. Self-intersection

Good views are in generic position
Koenderink

\[ \text{Kt} = \text{tangential curvature} \]
\[ \text{Kr} = \text{radial curvature (along the line of sight)} \]
\[ \text{Kr Kt} = K \text{ (the Gaussian Curvature)} \]

- Cannot see concave regions of the surface
- Convex Kt > 0, convex region of the surface
- Concave Kt < 0, hyperbolic region of the surface
- Inflection points along parabolic lines

Cusp

![Diagram of Cusp](image)
Koenderink

The visible end of a contour must lie on a hyperbolic surface
At the end point, the direction of view is along the asymptote (0 curvature)
At the end point, the contour is concave
DeCarlo, Finkelstein, Rusinkiewicz, Santella, Suggestive contours for conveying shape, SIGGRAPH 2003
Parabolic Lines

Felix Klein Apollo
Parabolic Lines

1. Segmentation of the object into convex, concave and saddle-shaped regions
2. Inflection points of the visual contour
3. Changes of topology of the contour with viewpoint changes
4. Qualitative structure of the illuminance distribution
5. Loci that create and annihilate highlights

Graphical Conventions
Types of Lines

Haloed lines
Taper near t-junction (See Dooley and Cohen)
Eye-lashing (Guild)
Sketchiness (Strothotte)
Conventions in engineering drawing

Martin, Technical Illustration
Dooley and Cohen
Fig. 12-1  Line contrast shading.

**Line Drawing Conventions**

- Single weight
- Two weights
- Distance weighting

From Martin (reproduced in Gooch and Gooch)
Summary

Illustrations often better than photographs
  - Enhance important features
  - Deemphasize unimportant detail

Grand challenge
  - Produce a good line drawing
  - What lines, not just how to draw lines
Edge Detectors

Photoshop “Find Edges ...”

Feature Detectors!

Graphite and charcoal, Musée Picasso, Paris, France
Texture and Tone

Texture and Tone


Page 30
Stroke Collections

Prioritized Stroke Textures
[Salisbury et al. ‘94]
[Winkenbach et al. ‘94]

Art Maps
[Klein et al. 2000]

Tonal Art Maps

Collection of stroke images
Will blend → design with high coherence
Stroke nesting property