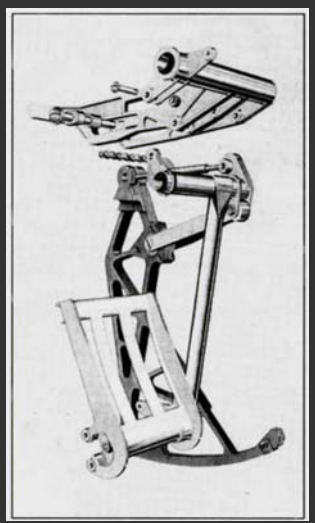
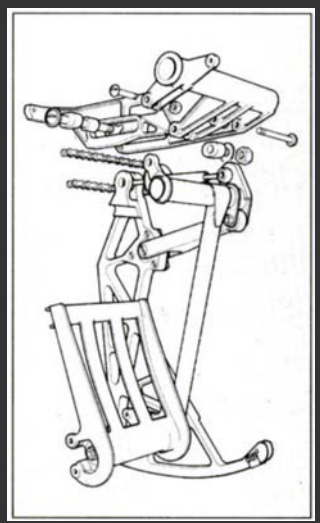
Conveying Shape

Pat Hanrahan

Conveying Shape

Shading
Lines





From Gooch[2]

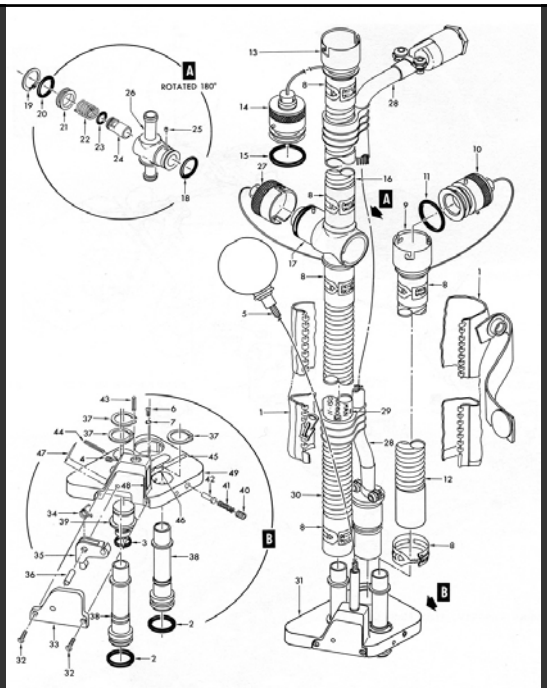


Fig. 1-25 Group-assembly illustration. (Lockheed Aircraft Corp.)

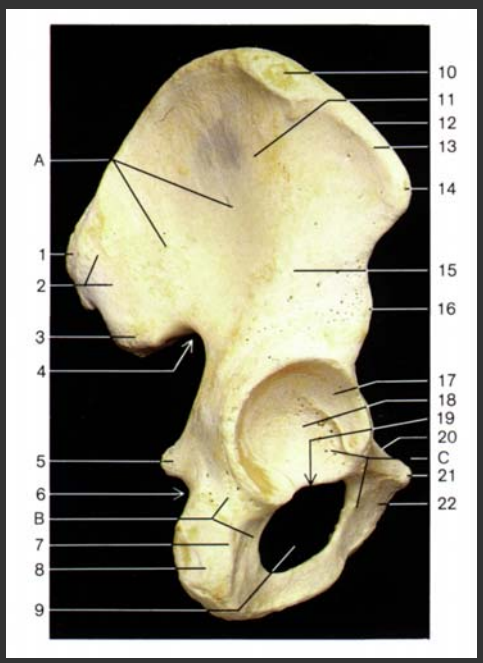
Perception

Artistic Enhancement in Scientific Visualization

Victoria Interrante

Computer Science and Engineering

University of Minnesota-Twin Cities



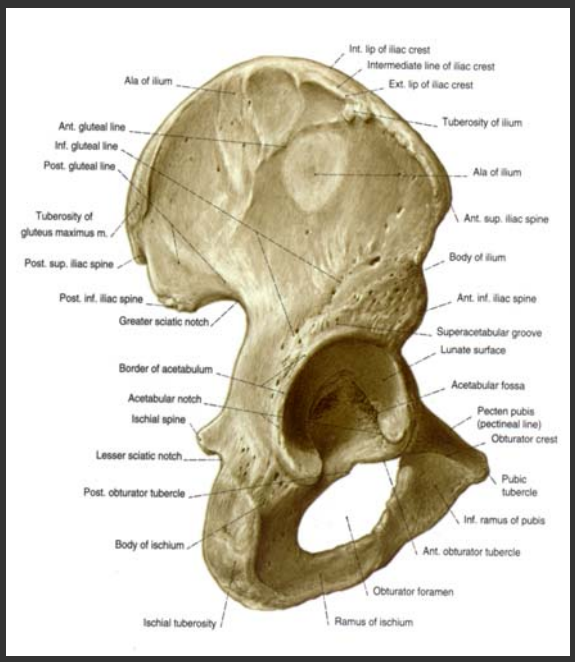
Visualizing Anatomy

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

Photograph of the right hip bone (lateral aspe

Johannes W. Rohen and Chihiro Yokochi.
Color Atlas of Anatomy:
A Photographic Study of the Human Body,
Igaku-Shoin, 1993.



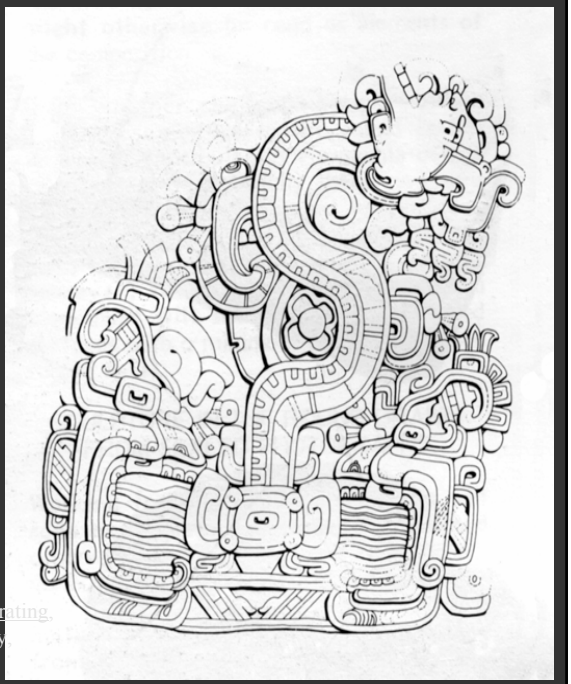
A drawing offers the possibility to clarify structural or conceptual information that may be difficult to perceive in even a very good photo.

Color drawing of the same subject.
Sobotta Atlas of Human Anatomy, 11th English edition, vol. 2, edited by Jochen Staubesand, translated and edited by Anna N. Taylor, Urban & Schwarzenberg, 1990.

Photo vs. Drawing in Archaeology

James B. Porter. "Relief Monuments", in
The Student's Guide to Archaeological Illustr
Brian D. Dillon, ed., Institute of Archaeology
University of California, Los Angeles, 1981

Photo vs. Drawing in Archaeology



James B. Porter. "Relief Monuments", in
The Student's Guide to Archaeological Illustrating,
Brian D. Dillon, ed., Institute of Archaeology
University of California, Los Angeles, 1981

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

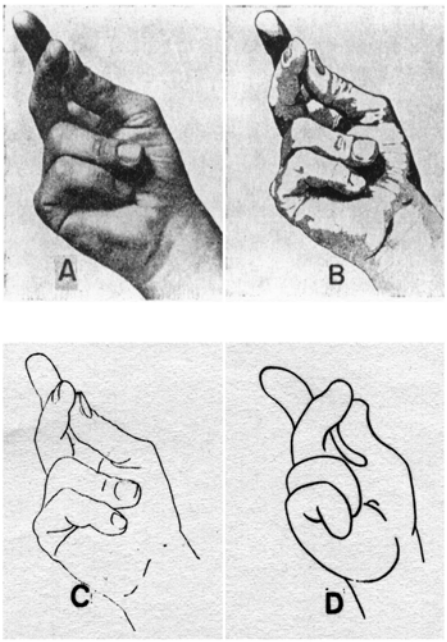


FIG. 1. FOUR REPRESENTATIONS OF THE HANDS IN POSITION 1
(A) Photograph; (B) Shaded Drawing; (C) Line Drawing; (D) Cartoon

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

T. A. Ryan and Carol B. Schwartz, "Speed of Perception as a Function of Mode of Representation", American Journal of Psychology, 69, pp. 60-69, 1956.

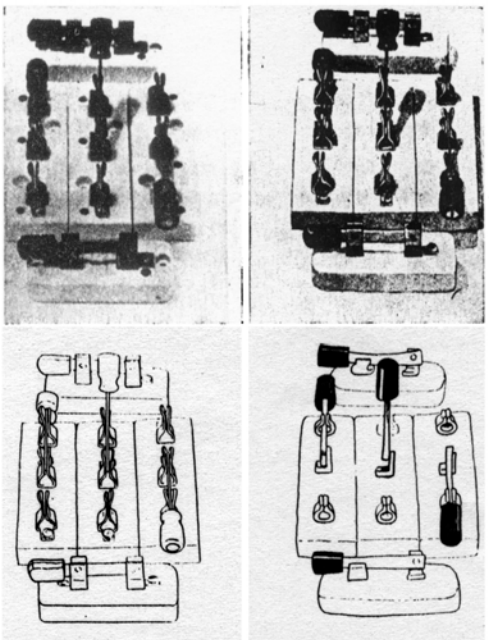


FIG. 2. FOUR REPRESENTATIONS OF THE SWITCHES IN POSITION 1

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

T. A. Ryan and Carol B. Schwartz, "Speed of Perception as a Function Mode of Representation", American Journal of Psychology, 69, pp. 60-69, 1956.

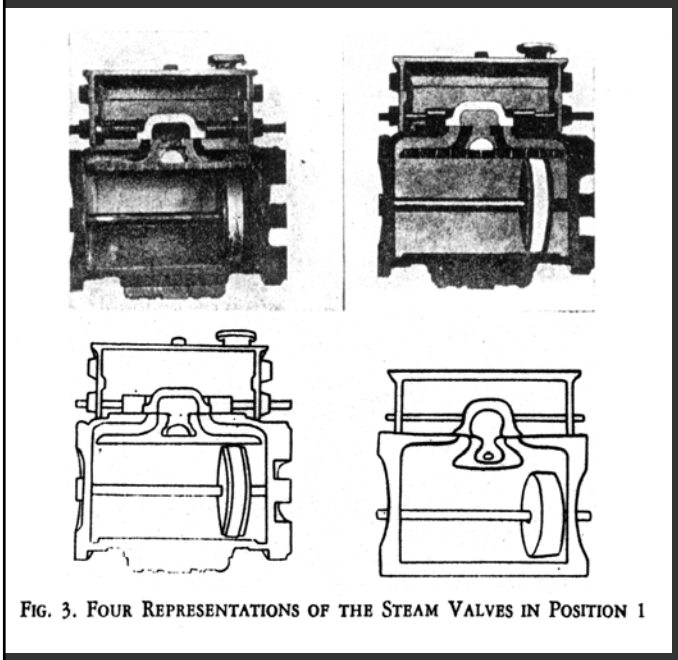


FIG. 3. FOUR REPRESENTATIONS OF THE STEAM VALVES IN POSITION 1

Speed of stating stage of cycle, in seconds (mean):

- 0.235 photo
- 0.316 shaded drawi
- 0.375 line drawing
- 0.262 cartoon

T. A. Ryan and Carol B. Schwartz, "Speed of Perception as a Function of Mode of Representation", American Journal of Psychology, 69, pp. 60-69, 1956.

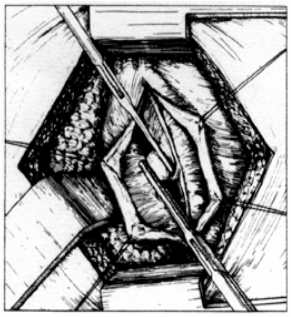
Their Conclusion:

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

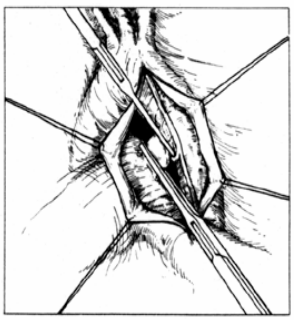
Wedge Resection

Esophageal Fundoplication

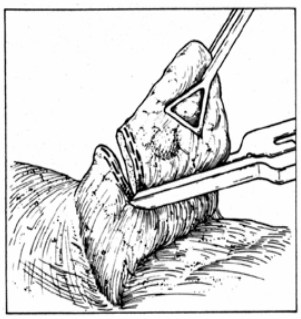
K. Hirsch and D. A. McConathy, "Picture Preferences of Thoracic Surgeons", Journal of BioCommunications, Winter 1986, pp. 26-30.

Study of Picture Preferences

Semi-Schematic



Patent Ductus Arteriosus



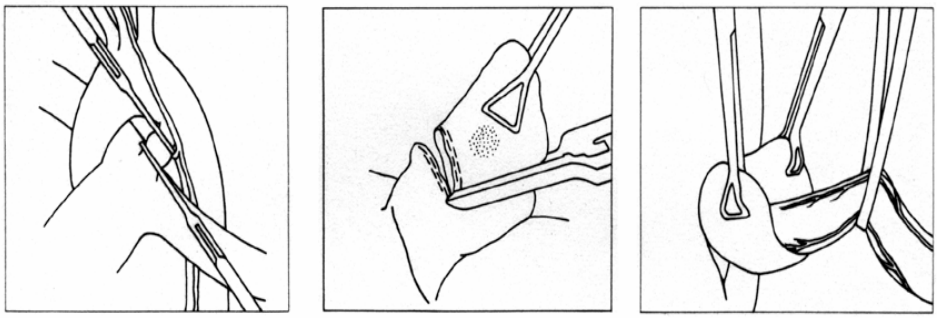
Wedge Resection

Esophageal Fundoplication

K. Hirsch and D. A. McConathy, "Picture Preferences of Thoracic Surgeons", Journal of BioCommunications, Winter 1986, pp. 26-30.

Study of Picture Preferences

Schematic



Patent Ductus Arteriosus | Wedge Resection | Esophageal Fundoplication

K. Hirsch and D. A. McConathy, "Picture Preferences of Thoracic Surgeons", Journal of BioCommunications, Winter 1986, pp. 26-30.

Results

Surgeons rated the 'schematic' representation least preferable; the 'semi-schematic' and 'realistic' representations were preferred in equivalent numbers.

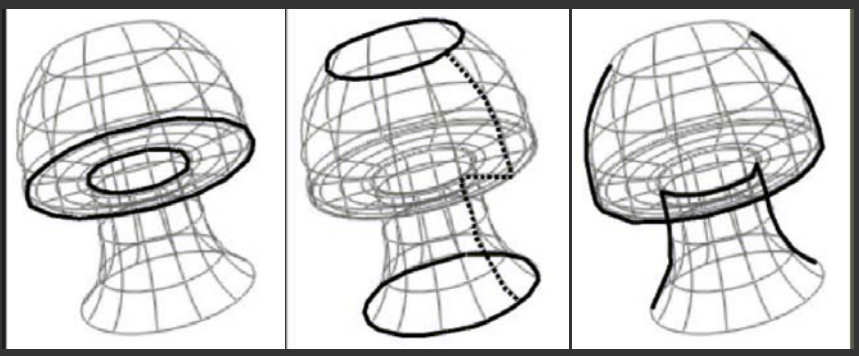
Artistic Enhancement in Scientific Visualization

Victoria Interrante
Computer Science and Engineering
University of Minnesota-Twin Cities

Lines

Classic Line Types

Isoparametric



Discontinuities Boundaries Silhouettes

Classic Line Types

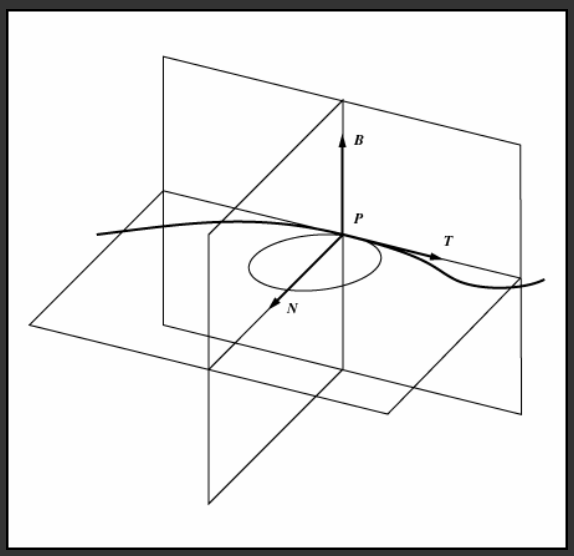
- Isoparametric lines
- Discontinuities: creases and self-intersections
- External and internal boundaries
- Silhouettes and contours and cusps

Extended Line Types

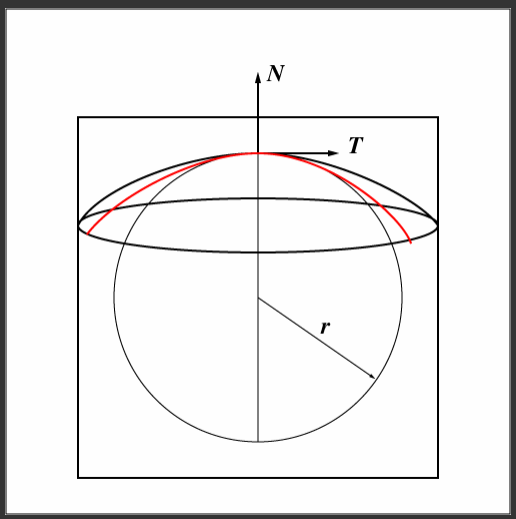
- Principal directions and lines of curvature
- Parabolic lines

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

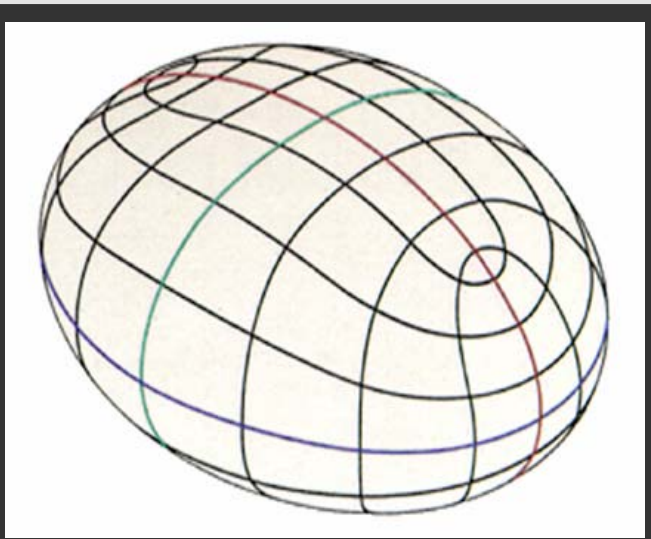
Space Curve



Normal Curvature

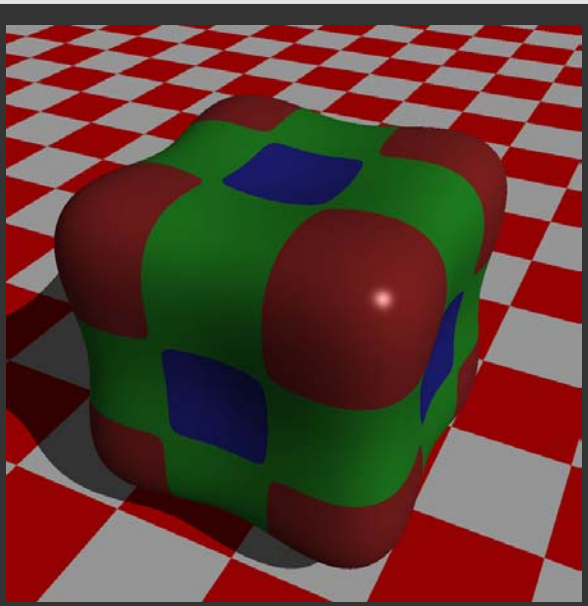


Principal Curvatures



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

Gaussian Curvature



Gaussian Curvature

K_1 = curvature in first principal direction

K_2 = curvature in second principal direction

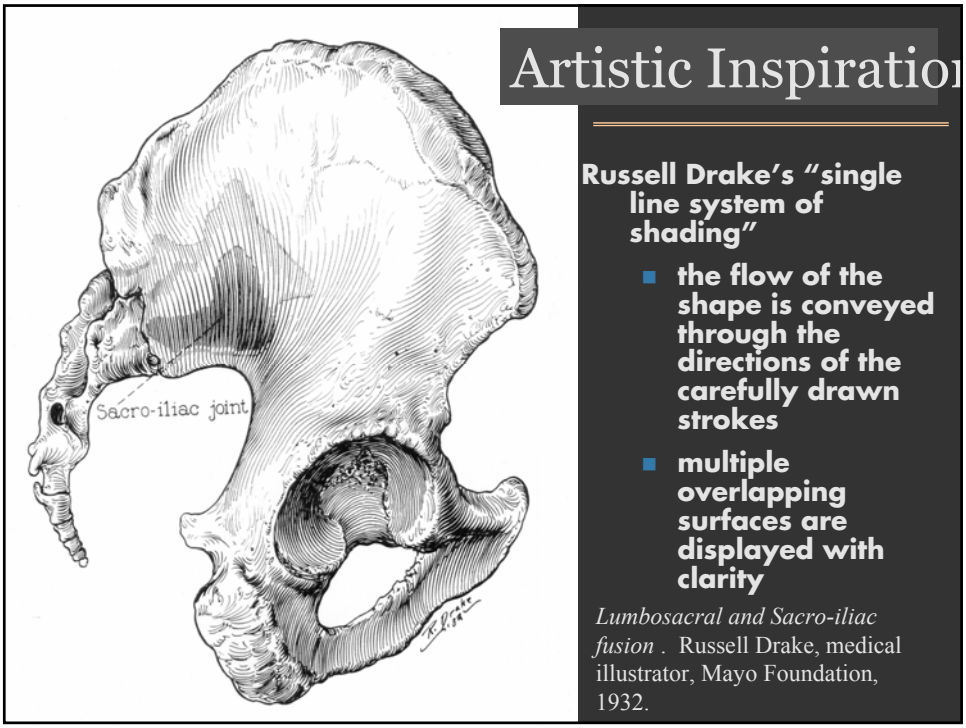
Gaussian curvature: $K = K_1 K_2$

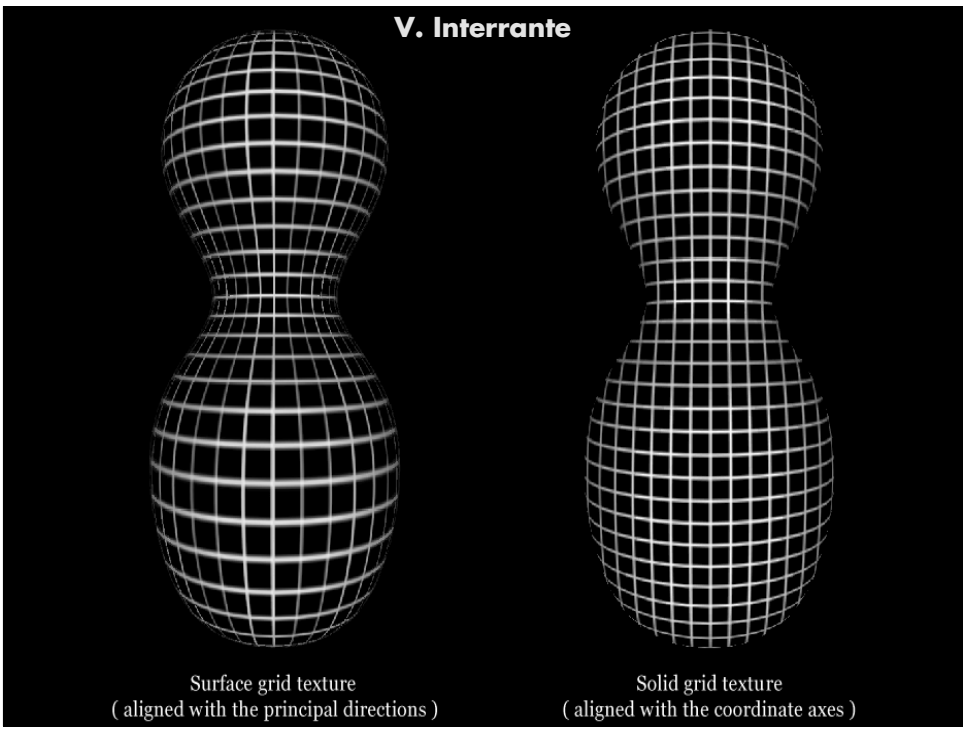
Mean curvature: $H = (K_1 + K_2) / 2$

$K > 0$: elliptic, convex or concave

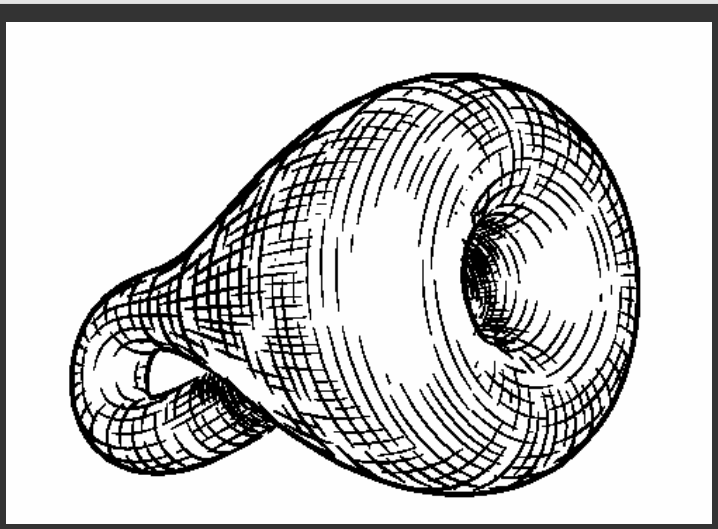
$K < 0$: hyperbolic, saddle-shaped

$K = 0$: parabolic, cylindrical or planar


Artistic Inspiratio
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
Sacro-iliac joint
Lumbosacral and Sacro-iliac fusion . Russell Drake, medical illustrator, Mayo Foundation, 1932.


V. Interrante
Surface grid texture
(aligned with the principal directions)
Solid grid texture
(aligned with the coordinate axes)

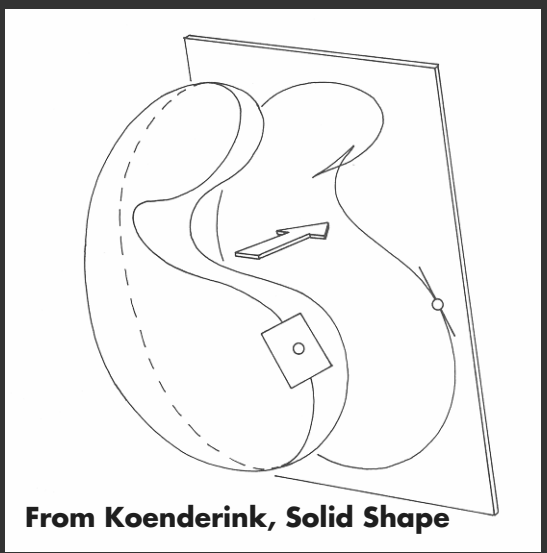
Principal Directions



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

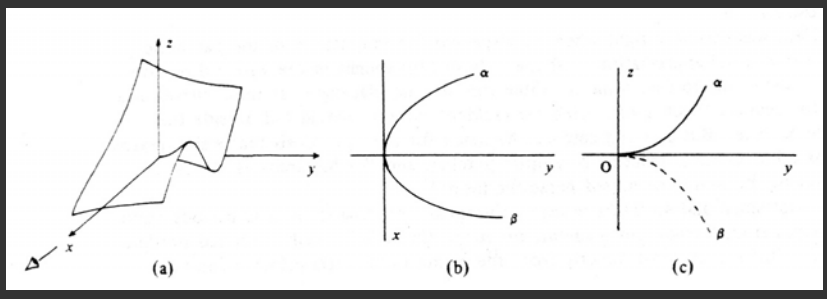
Kt = tangential curvature

Kr = radial curvature (along the line of sight)

Kr Kt = K (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

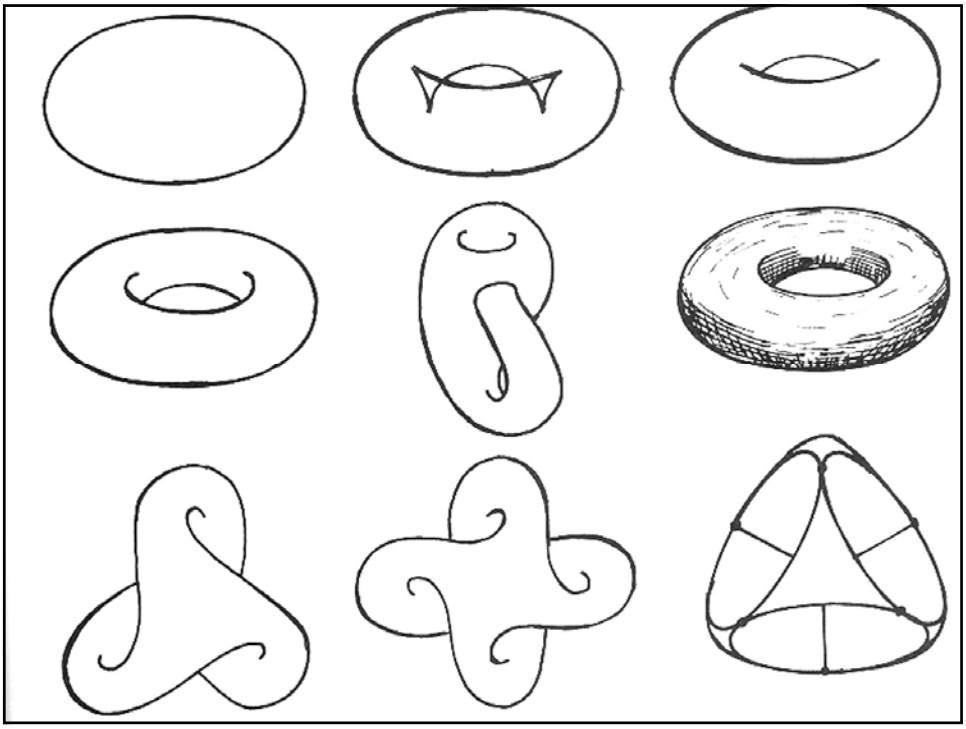
Cusp

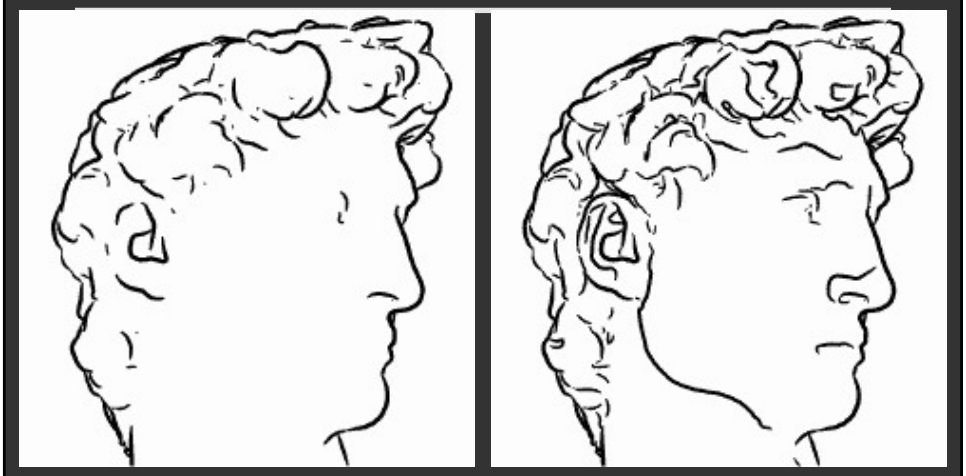


Koenderink

- The visible end of a contour must lie on a hyperbolic surface
- At the end point, the direction of view is along the aymptote (0 curvature)
- At the end point, the contour is concave

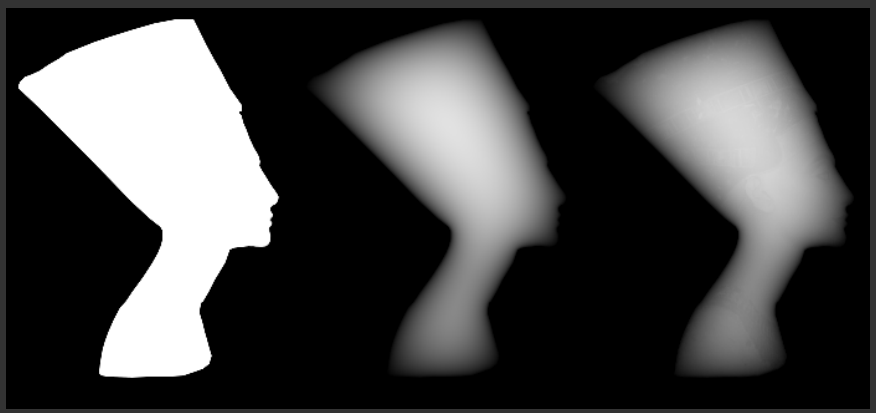
Figure 6. Picasso: *Nu couché* 1920.



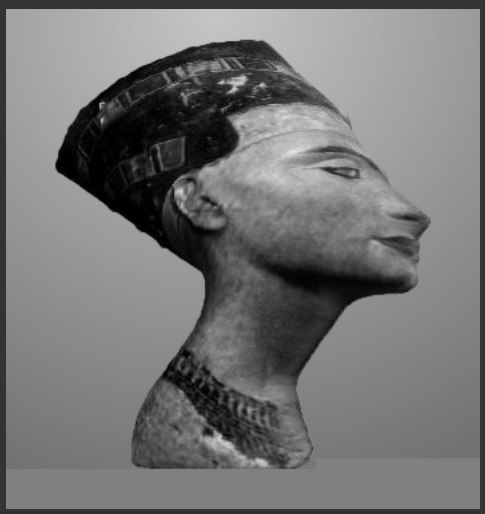


DeCarlo, Finkelstein, Rusinkiewicz, Santella, Suggestive contours for conveying shape, SIGGRAPH 2003

http://www-graphics.stanford.edu/workshops/ibr98/Talks/Lance/silhouettes.html

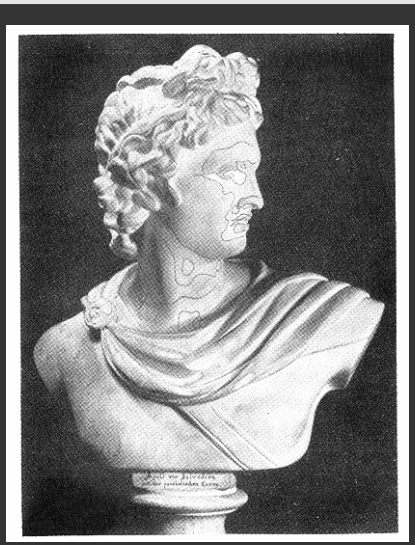


http://www-graphics.stanford.edu/workshops/ibr98/Talks/Lance/silhouettes.html



http://www-graphics.stanford.edu/workshops/ibr98/Talks/Lance/silhouettes.html

Parabolic Lines



Felix Klein Apollo

Parabolic Lines

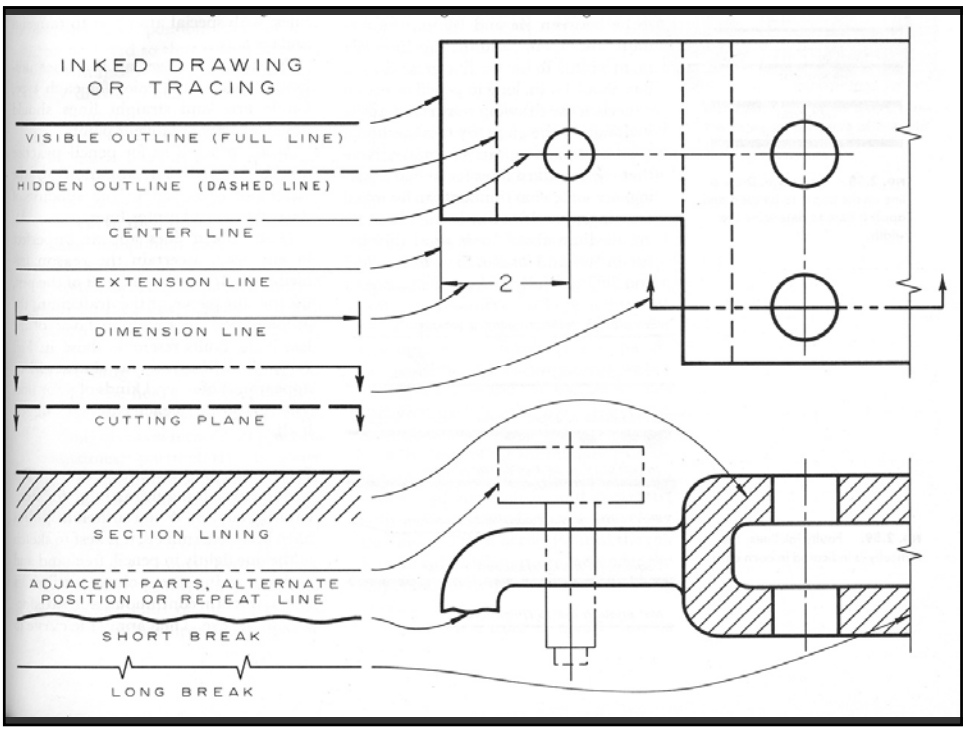
1. Segmentation of the object into convex, concave and saddle-shaped regions
2. Inflection points of the visual contour
3. Changes of topology of the contour with viewpoint changes
4. Qualitative structure of the illuminance distribution
5. Loci that create and annihilate highlights

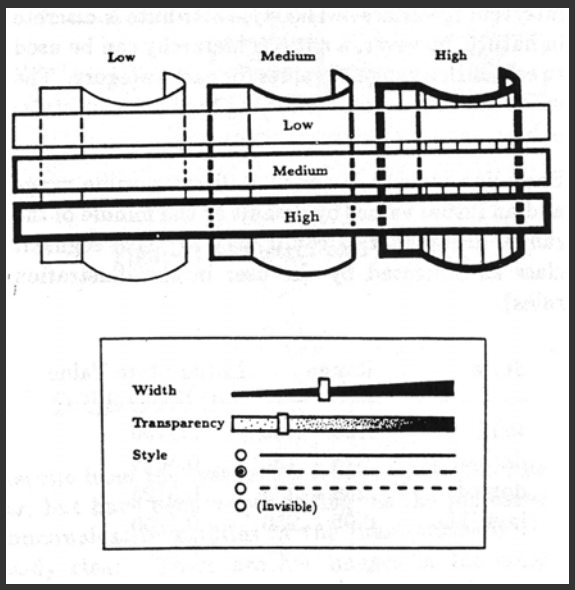
Graphical Conventions

Types of Lines

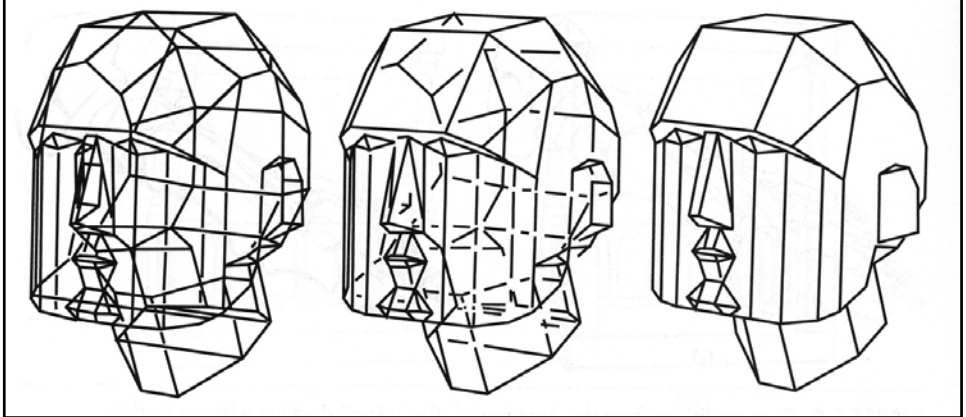
Haloed lines
Taper near t-junction (See Dooley and Cohen)
Eye-lashing (Guild)
Sketchiness (Strothotte)
Conventions in engineering drawing

Martin, Technical Illustration





Dooley and Cohen



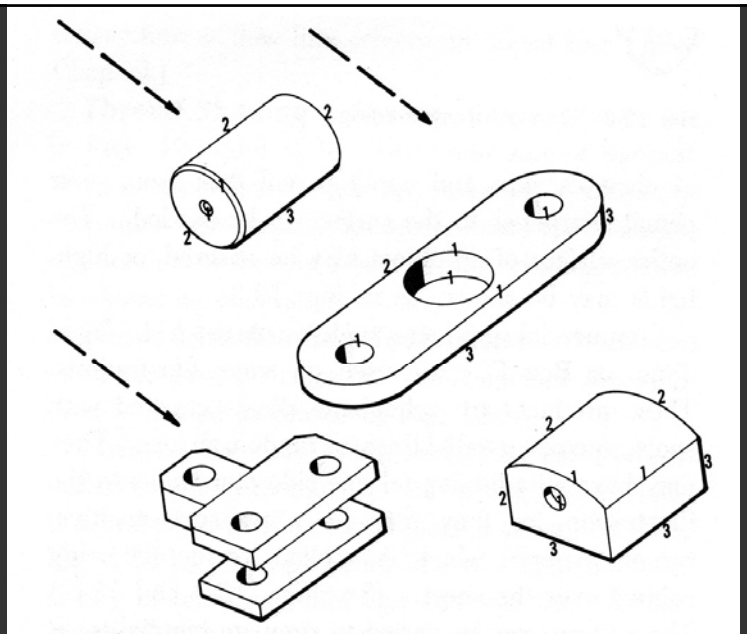
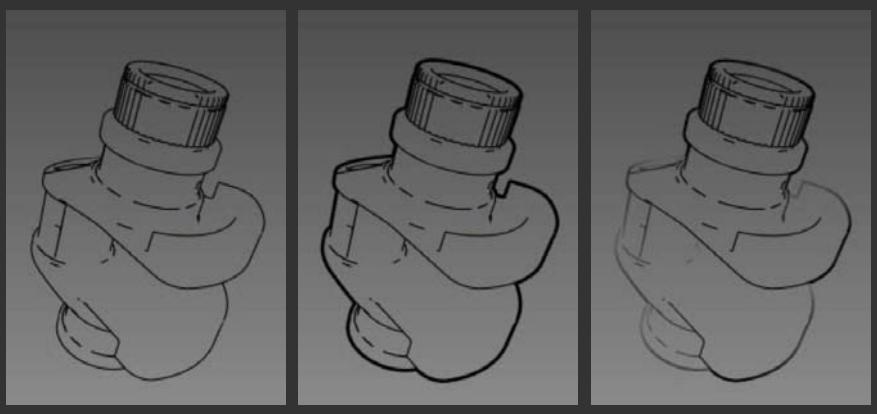


Fig. 12-1 Line contrast shading.

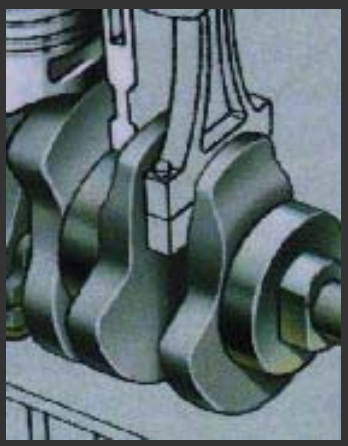
Line Drawing Conventions

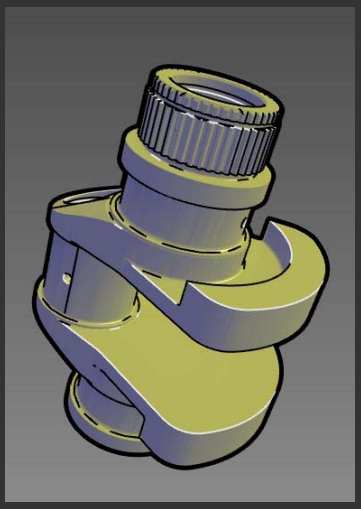


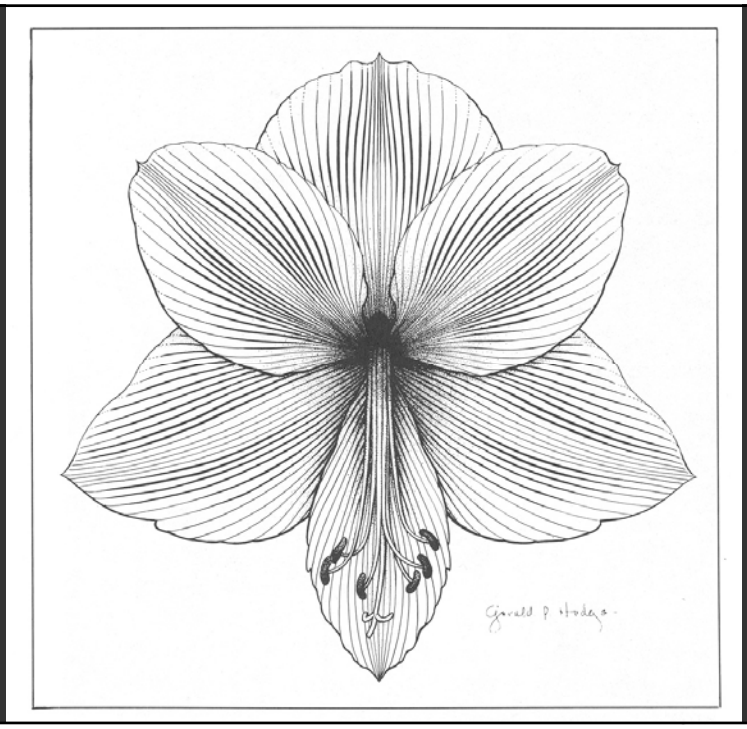
Single weight **Two weights** **Distance weighting**

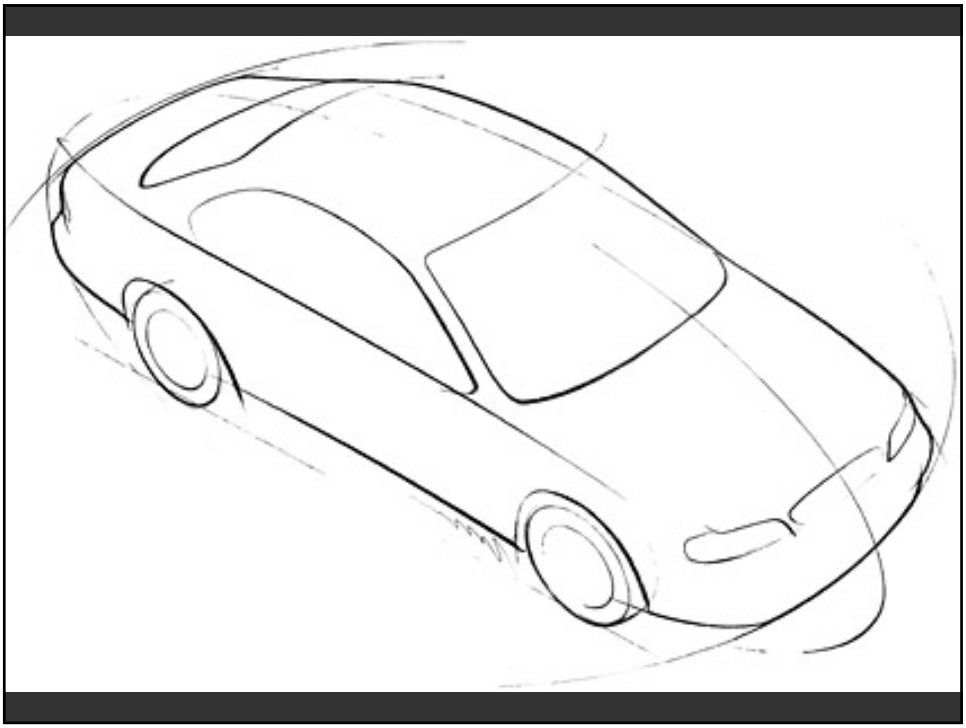
From Martin (reproduced in Gooch and Gooch)

Highlighting









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

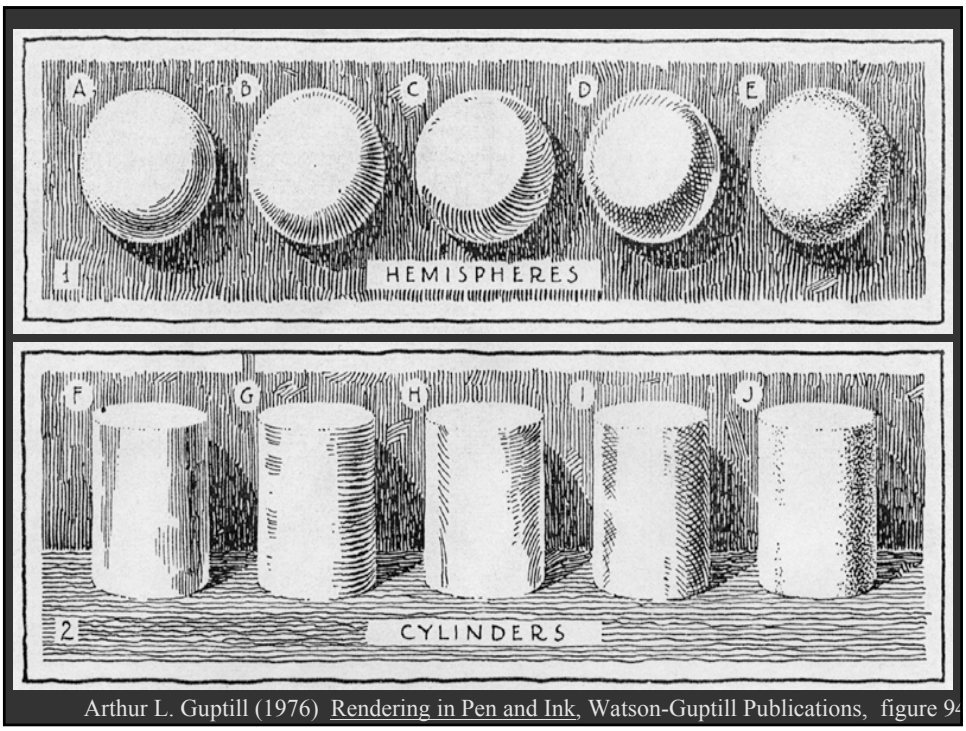
Edge Detectors

Photoshop "Find Edges ..."

Feature Detectors!

Picasso, Portrait of Igor Stravinsky, 1920.
Graphite and charcoal, Musée Picasso, Paris, France

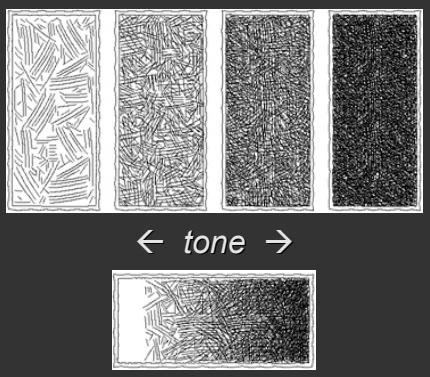
Texture and Tone



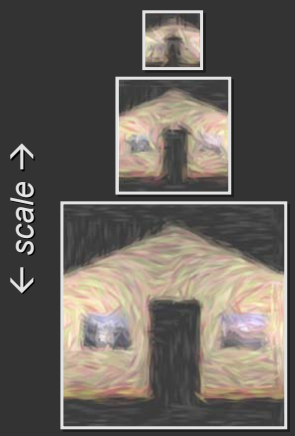
Arthur L. Guptill (1976) Rendering in Pen and Ink, Watson-Guptill Publications, figure 94

Stroke Collections

Prioritized Stroke Textures
[Salisbury *et al.* '94]
[Winkenbach *et al.* '94]

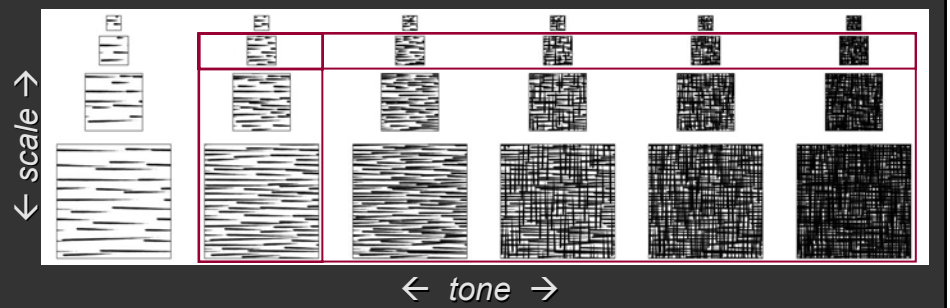


Art Maps
[Klein *et al.* 2000]



Tonal Art Maps

Collection of stroke images

Will blend → design with high coherence

Stroke nesting property