Illustrative rendering is also often called non-photorealistic rendering (NPR)

- we shall use these terms here interchangeably

NPR offers many opportunities for visualization that conventional photo-realistic rendering does not offer

- for this course, we may call our present lighting models (ambient, diffuse, specular) photo-realistic models

Computer Mouse

- photo-realistic, transparent
- photo-realistic, opaque
- technical drawing
- illustrative, transparent
Illustration in Medical Textbooks…

Frank Netter (1906 – 1991)
- often referred to as “Medicine’s Michelangelo”
- illustrative rendering was key to understanding
A photorealistic depiction captures the exact appearance of the object as we actually see it

- this can be a limiting paradigm when seeking to convey and communicate information via visuals

A non-photorealistic depiction allows more freedom in this respect:

- allows a greater differentiation in the salience (immediate importance) of the visual representation
- can emphasize critical features
- can minimize the visual salience of secondary details
- allows to hierarchically guide the attentive focus

NPR techniques also:

- allow the expression of multiple style, potentially increasing the ‘dynamic range’ of information that can be communicated
- can establish a ‘mood’ that can influence the subjective context within which the information is perceived and interpreted
“Make all visual distinctions as subtle as possible, but still clear and effective.”

“Maximize data-ink; Minimize non-data ink”

“Hide that data which does not make a difference in what you are trying to depict”

“Minimize clutter”

“Separate figure and background”
Basic Techniques: Contours and Outlines

depth-map (edges are due to $C_0$ discontinuities)

normal-map (edges are due to $C_1$ discontinuities)

combined

Gooch and Gooch, 2001
Basic Techniques: Contours and Outlines

depth-map

normal-map

combined
Basic Techniques: Contours and Outlines

mixing outlines with volume rendering

uses depth-peeling to render layers one by one

rendering interior structures as contours

Fischer et al., 2005
Basic Techniques: Silhouettes

Not an image-space method
- uses dot product $V \cdot N = 0$ criterion
  - $V$: view vector
  - $N$: surface normal

Finds curves and creases at higher quality
Allows further processing of these (for example hatching)
Must disambiguate occlusions
Suggestive Contours

Curves where the surface bends away from the viewer (as opposed bending towards them)

DeCarlo et al., 2003
Suggestive Contours

Those locations at which the surface is *almost* in contour, from the original viewpoint

- where $V \cdot N$ is a positive local minimum rather than zero.
- points of inflection along the curve
- curve switches from convex (like mountain) to concave (like valley)
Suggestive Contours

contours

suggestive contours
(image space vs. object space method)
Suggestive Contours

Require the computation of the second derivative at high accuracy

- use high-quality 2\textsuperscript{nd} derivative (curvature-estimation) filters for volume datasets

Kindlmann et al., 2003
Semitransparent iso-intensity surface for radiation treatment planning and a tumor inside.

Right: Strokes along the principal curvature are added to convey shape.

Interrante et al., 1996
Hatching

Applies this illustration style as a function of illumination and others

\[
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portion of the tonal art map

Salisbury et al., 1997
Stippling is yet another illustration technique

- vary the density of points with illumination and/or other attribute

Preim and Bartz, 2007
Highlighted Edges

Color interior edges white

- simulates anisotropic reflections at edges
Tone Shading

Typical photo-realistic image: diffuse shading removes detail in dark and white areas

Now with highlights and edges, but without diffuse shading: shape information is lost

Gooch et al., 1998
Tone Shading

With edge lines and highlights: better, but still detail is lost in dark areas.

No luminance variations, instead use tonal shading (cool-to-warm shift), along with highlights and edges.
Tone Shading

Mix luminance shift and tonal shift with a weighted sum.
Different settings for weighted luminance/hue tone rendering.
Combines two effects with edges and highlights
Tone Shading

Specifically for volume visualization
Specifically for volume visualization
Milling creates what is known as “anisotropic reflection.”

Lines are streaked in the direction of the axis of minimum curvature, parallel to the milling axis.

To simulate a milled object, Gooch et al. map a set of 20 stripes of varying intensity (random) along the parametric axis of maximum curvature.
Metal Shading

with edge lines (left) and cool-to-warm tonal shading (right)
Metal Shading
Assign most appropriate rendering technique for different features:

- skin: silhouette rendering
- eyes: shaded direct volume rendering
- skull: X-ray
- trachea: Maximum Intensity Projection

Hadwiger et al. 2003
Mixing Rendering Styles

First, classify the scene:

- *Focus Objects (FO)*: objects in the center of interest are emphasized in a particular way
- *Near Focus Objects (NFO)*: important objects for the understanding of the functional interrelation or spatial location.
- *Context Objects (CO)*: all other objects (rendered e.g., as silhouettes)
- *Container Objects (CAO)*: one object that contains all other objects.

Render these in a certain order to ensure visual consistency

Tietjen et al., 2005
Hidden Structures

Show with different rendering style

• dotted lines, faint lines

vasculature with tumor

MRI DTI lines inside a tumor

Xin et al., 2006
Halos can enhance depth perception.

Bruckner et al., 2006
Wenger et al., 2006
Bryce Canyon in the Morning

Check out the marvelous colors and geometric detail

- why is this happening?
Illustrative Lighting Effects

Inconsistent shading to show depth:

Original normals $n_i$ at level $i$

Smoothed normals $n_{i+1}$ at level $i + 1$

Light $l_{i+1}$ projected ⊥ to $n_{i+1}$

Lighting $c_i = f(\cos \theta) = f(\hat{n}_i; \hat{l}_{i+1})$

Rusinkiewicz et al., 2006

Lee et al., 2006
Acquisition

Dome of light sources
  • turned on one at a time

Camera on top
  • taking a picture for each light source’s reflections

Combine lighting information for optimal feature enhancement
Example: 4,000-Year Old Sumarian Tablet
Two Levels Of Abstraction

Low-level abstraction:
- concerned with *how* objects are represented
- stylized depiction: silhouettes, contours, pen+ink, stippling, hatching, etc.

High-level abstraction
- deal with what should be visible and recognizable and at what level of detail
- this should be importance-driven, that is, the current visualization goal controls feature rendering style and visibility
- we will discuss these next
- smart visibility: cutaways, breakaways, ghosting, exploded views
Viola et al., 2005
Ghosting

Bruckner et al., 2006
Focus + Context

Bruckner et al., 2006
Labeling And Other Abstractions

Bruckner et al., 2005
Displacement With Context

exploded views
Bruckner et al., 2005

dynamic multi-volumes

volume splitting
Islam et al., 2004

Grimm et al., 2004
Distortion Techniques

Ray deflectors:

(a) A linear ray passing through the deflector field of gravity is pulled to the left. (b) The visual result. (c) An example of the 3D visual result after deflecting rays by a single translate deflector: Starting with a box, we add a bump. (d) Starting with an MRI head scan, we pull out the nose.

Kurzion et al., 1997

Correa et al., 2006
Explaining Differences Via Exaggerations

Emphasize differences of the specimen with the reference model by exaggerating these differences.

Rautek et al., 2006
View Composition
Rendering Mode Composition
The goal is to depict the time-varying behavior of the data in a single frame via illustrative techniques.

Joshi et al., 2005

Stompel et al. 2002
Use ideas from flash photography to illustrate motion hints:

Guan et al., 2005