

CSE 332
INTRODUCTION TO VISUALIZATION
ILLUSTRATIVE RENDERING

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Introduction

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

- we shall use these terms here interchangeably

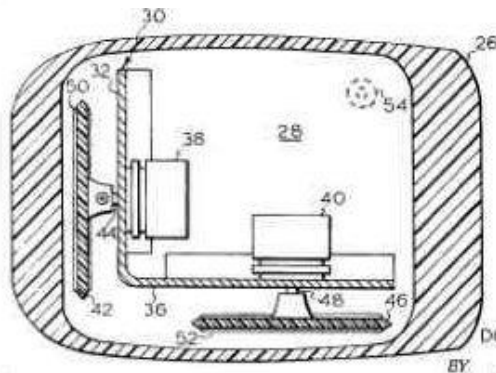
NPR offers many opportunities for visualization that conventional *photo-realistic rendering* does not offer

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



photo-realistic,
opaque

Computer Mouse

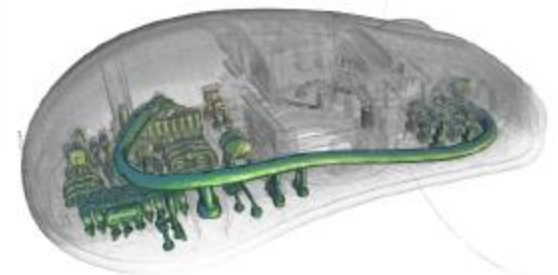


technical drawing



photo-realistic, transparent

INVENTOR:
DOUGLAS C. ENGELBART
BY: [signature]

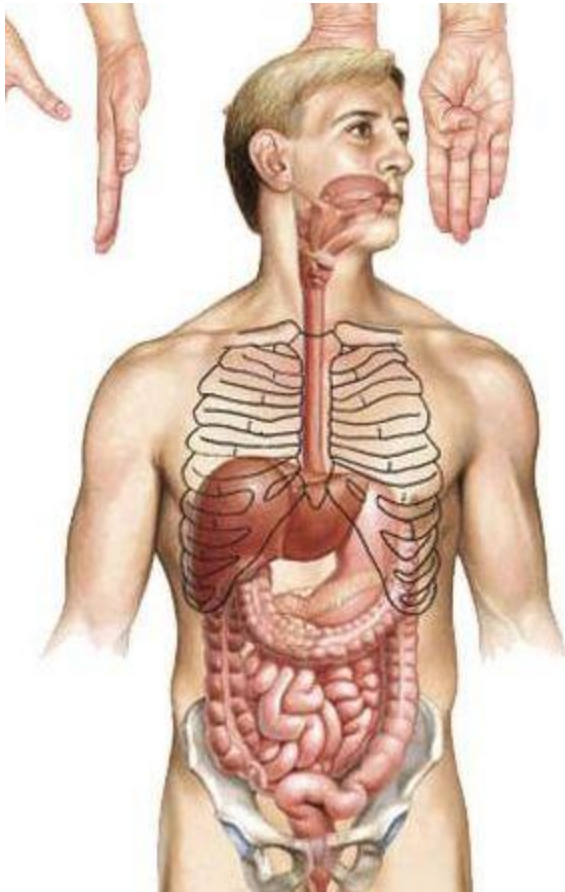


illustrative,
transparent

Illustration in Medical Textbooks...

Frank Netter (1906 – 1991)

- often referred to as “Medicine’s Michelangelo”
- illustrative rendering was key to understanding



NPR: Added Capabilities

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

A Good Argument for NPR: Tufte's Visualization Rules

“Make all visual distinctions as subtle as possible, but still clear and effective.”

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

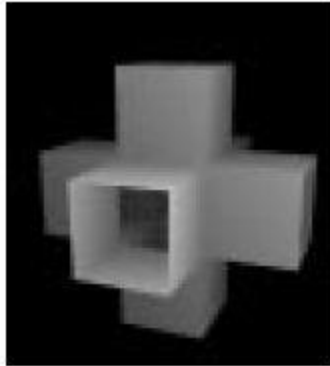
“Hide that data which does not make a difference in what you are trying to depict”

“Minimize clutter”

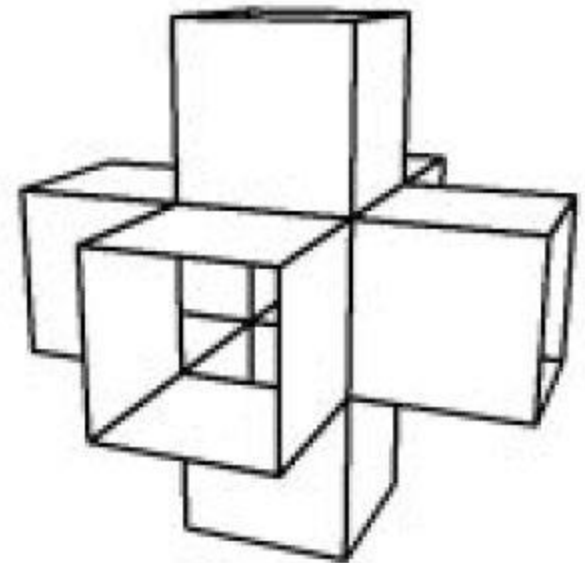
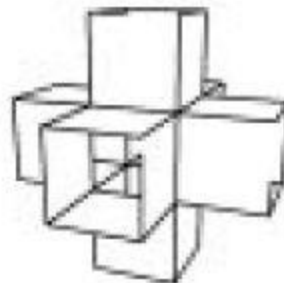
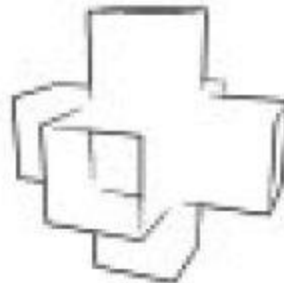
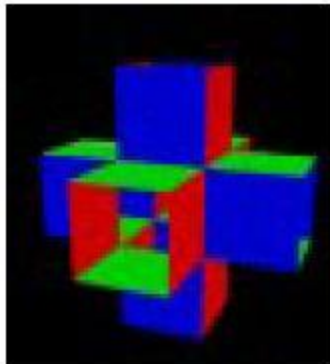
“Separate figure and background”

Basic Techniques: Contours and Outlines

depth-map
(edges are due
to C_0
discontinuities)



normal-map
(edges are due
to C_1
discontinuities)



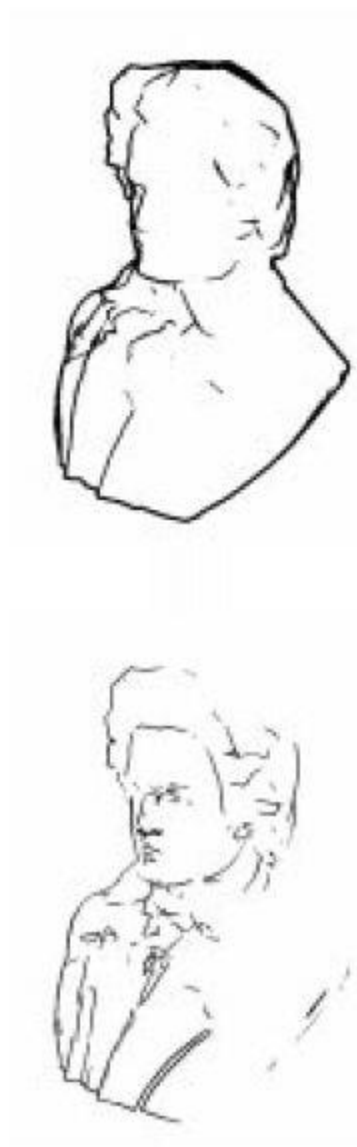
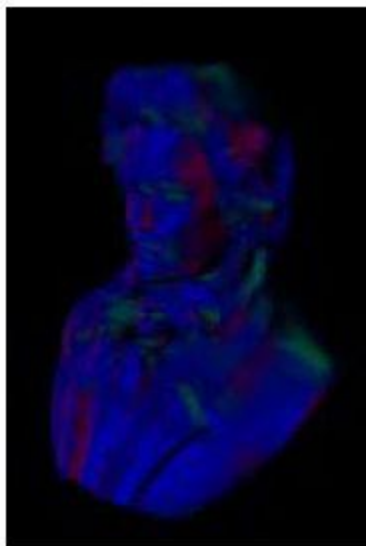
combined

Basic Techniques: Contours and Outlines

depth-map

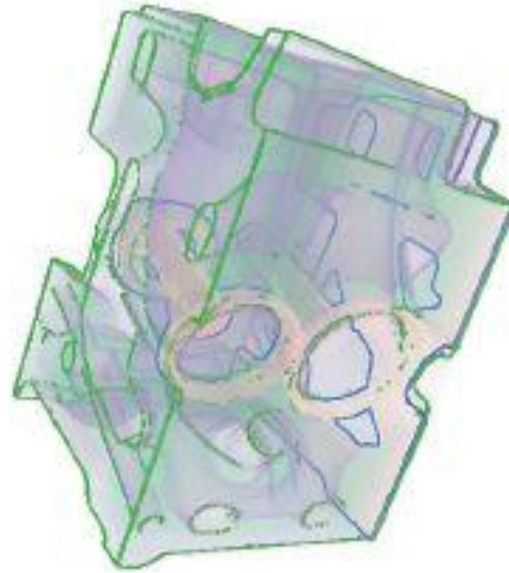
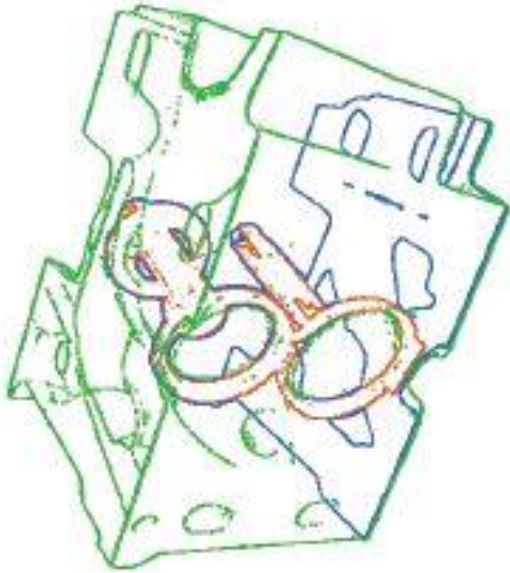


normal-map



combined

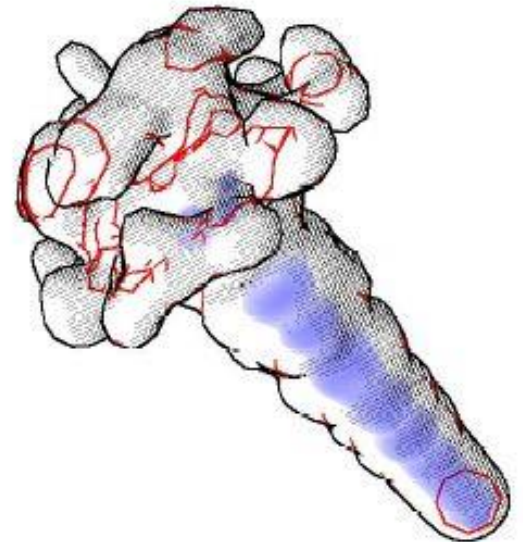
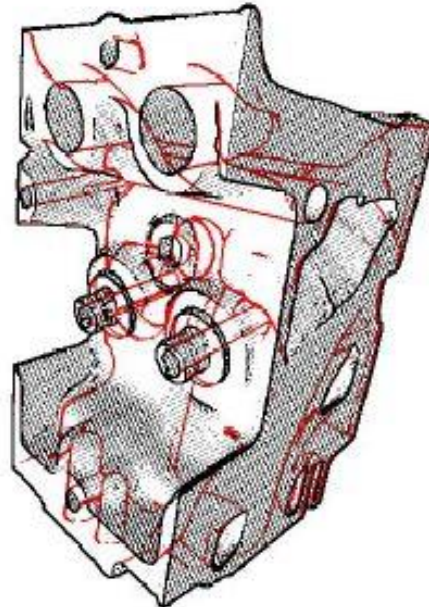
Basic Techniques: Contours and Outlines



mixing outlines with
volume rendering

uses *depth-peeling* to
render layers one
by one

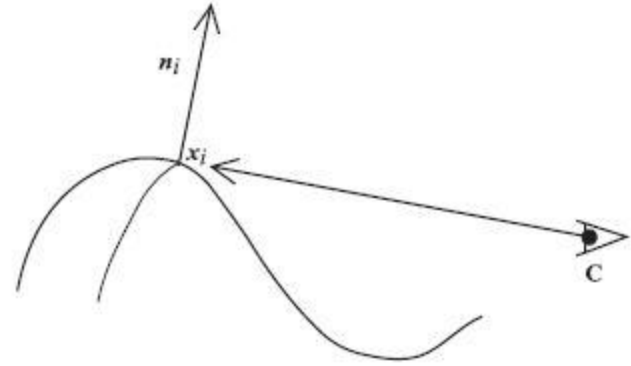
rendering interior
structures
as contours



Basic Techniques: Silhouettes

Not an image-space method

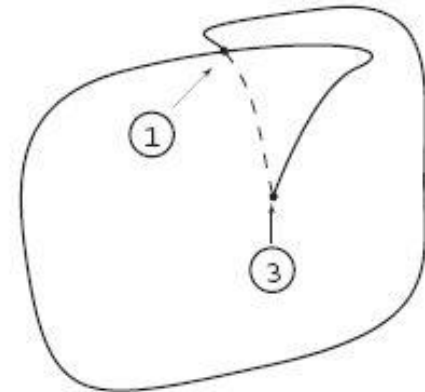
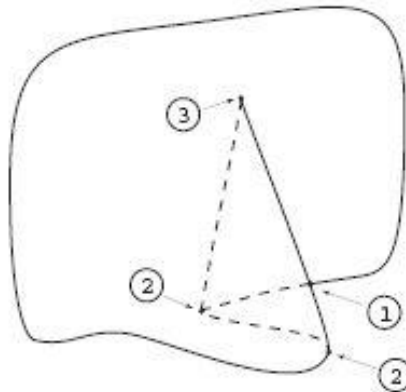
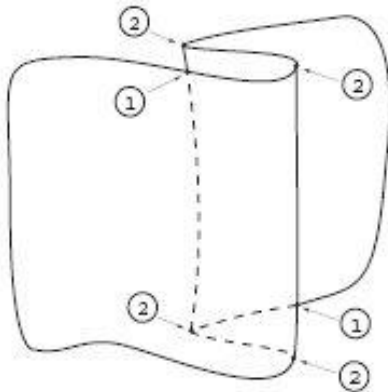
- uses dot product $V \cdot N = 0$ criterion
- V : view vector
- N : surface normal



Finds curves and creases at higher quality

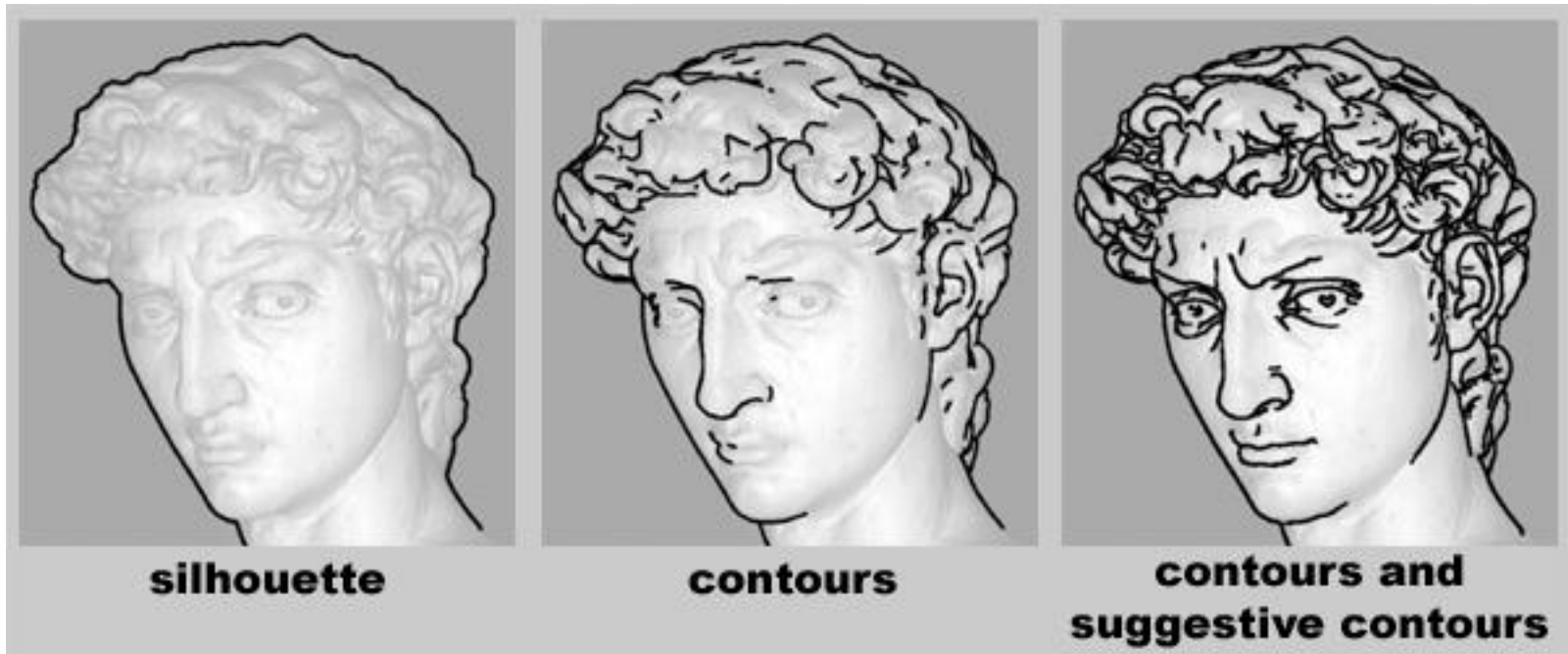
Allows further processing of these (for example hatching)

Must disambiguate occlusions



Suggestive Contours

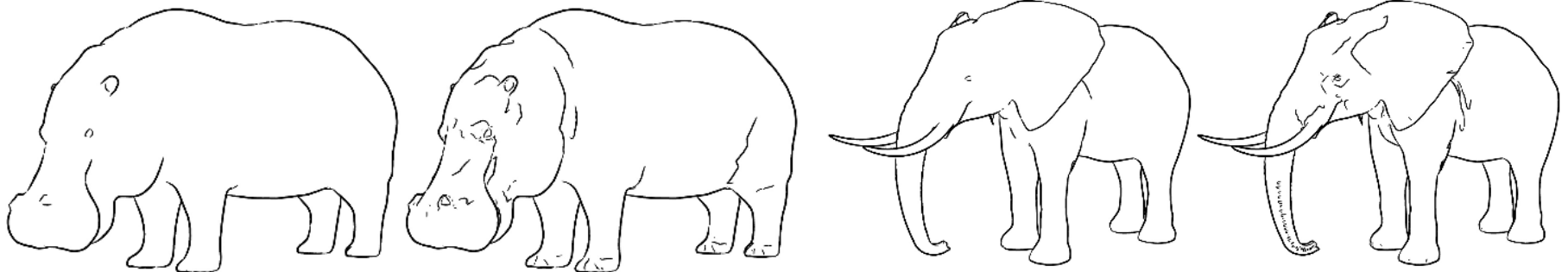
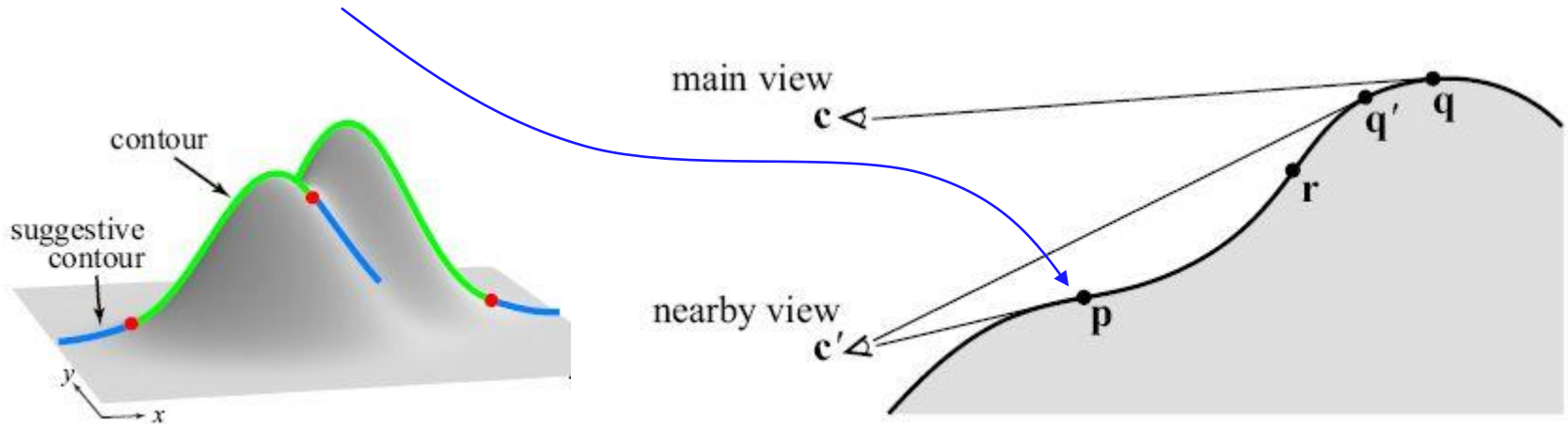
Curves where the surface bends away from the viewer (as opposed bending towards them)



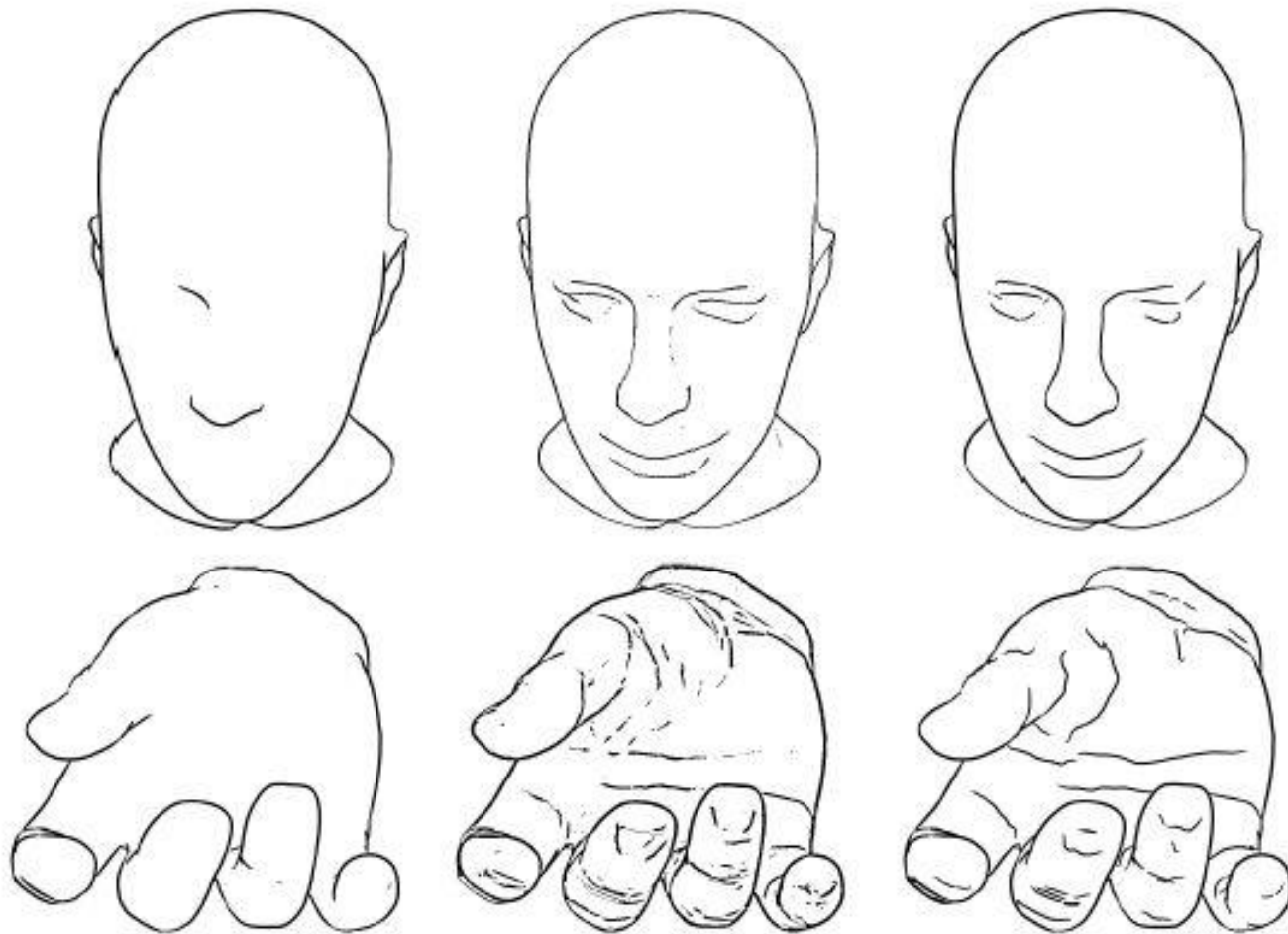
Suggestive Contours

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



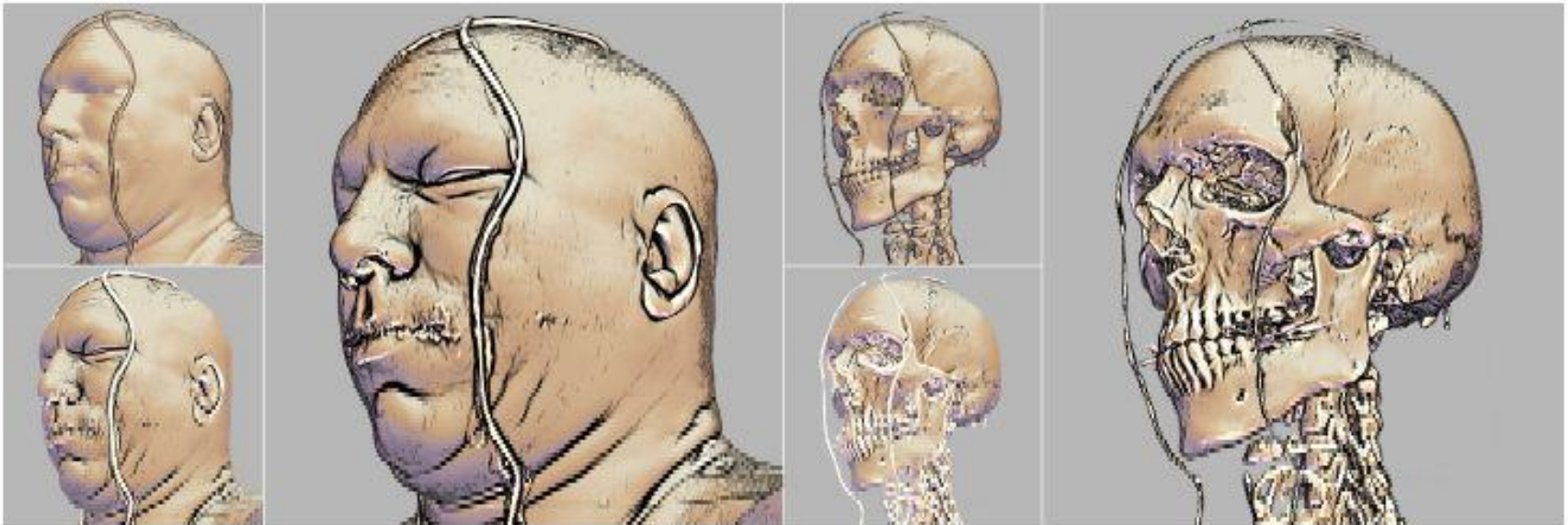
contours

suggestive contours
(image space vs. object space method)

Suggestive Contours

Require the computation of the second derivative at high accuracy

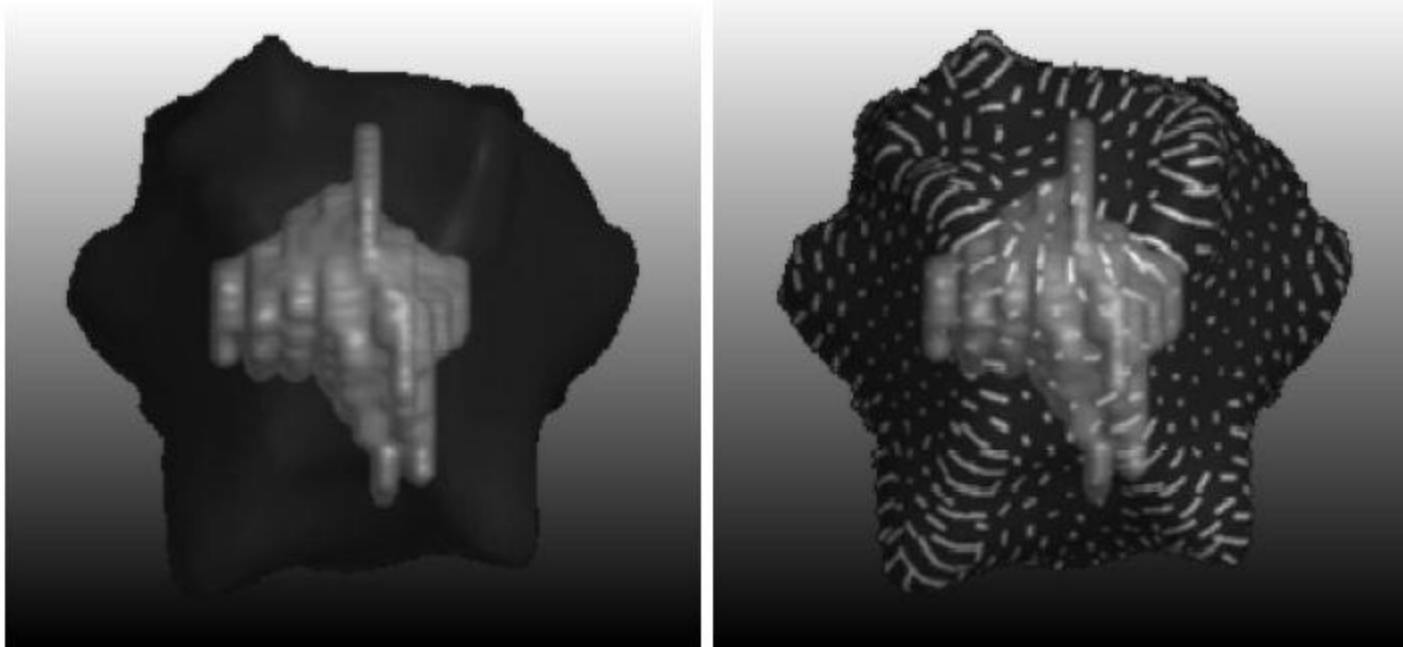
- use high-quality 2nd derivative (curvature-estimation) filters for volume datasets



Curvature Stroke Lines

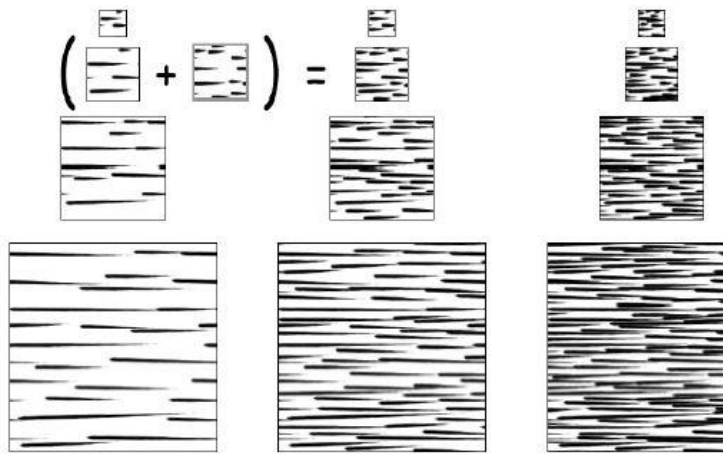
Semitransparent iso-intensity surface for radiation treatment planning and a tumor inside.

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

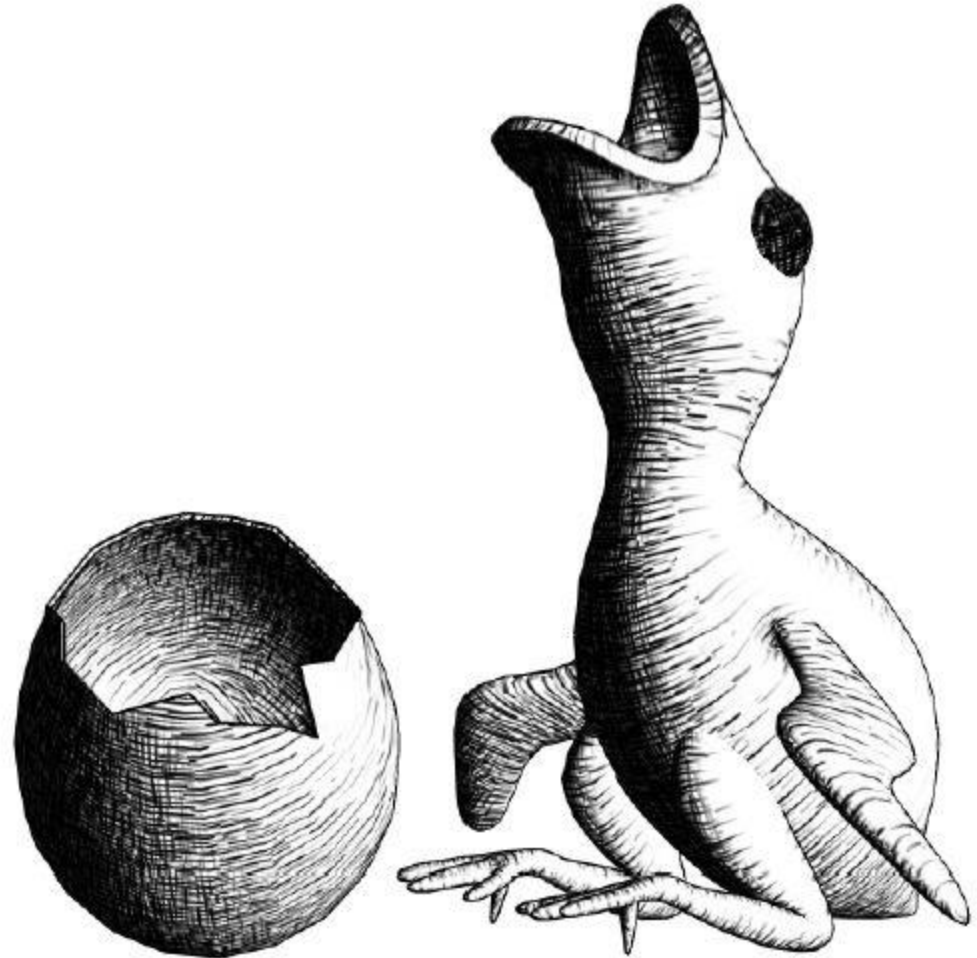


Hatching

Applies this illustration style as a function of illumination and others



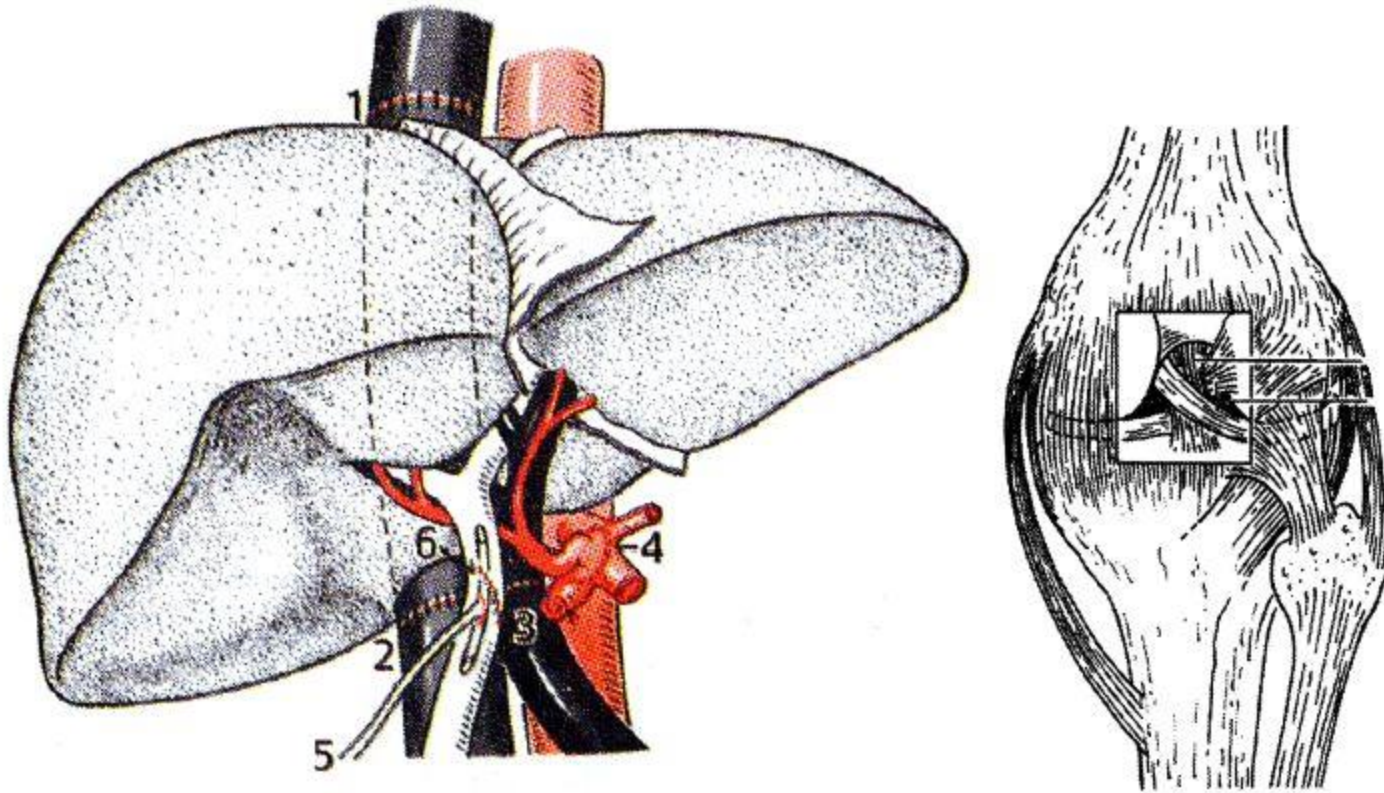
portion of the tonal art map



Stippling

Stippling is yet another illustration technique

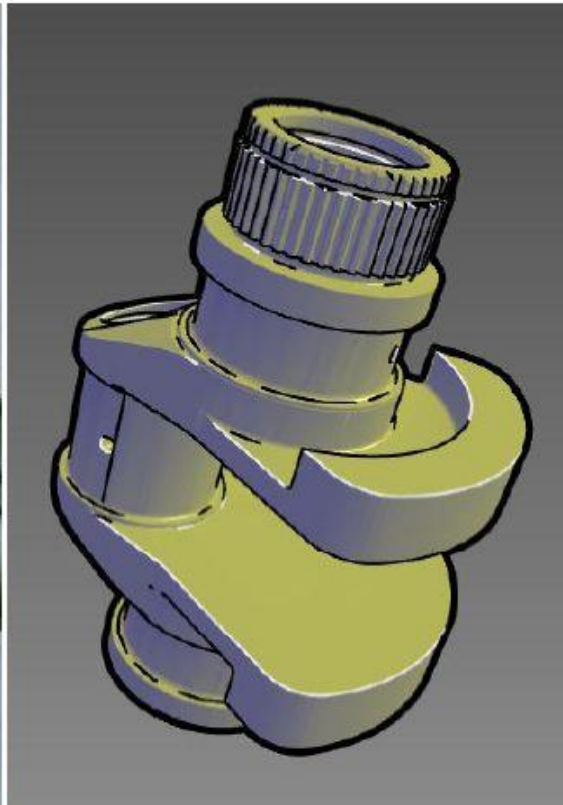
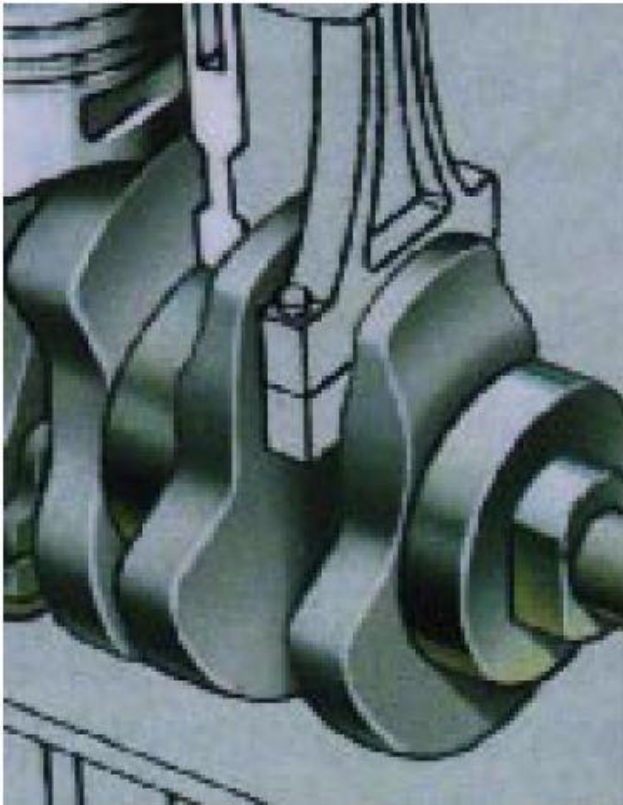
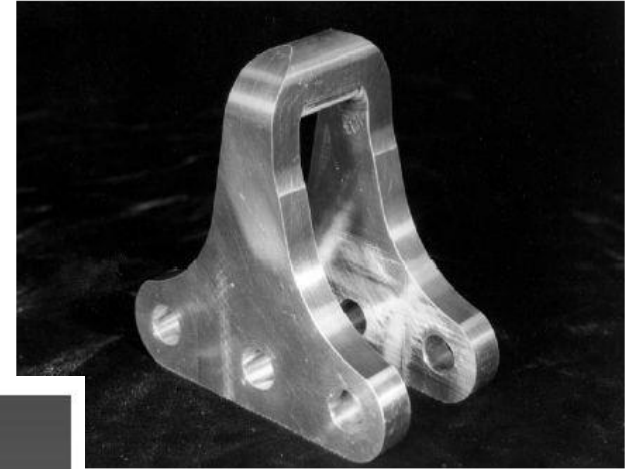
- vary the density of points with illumination and/or other attribute



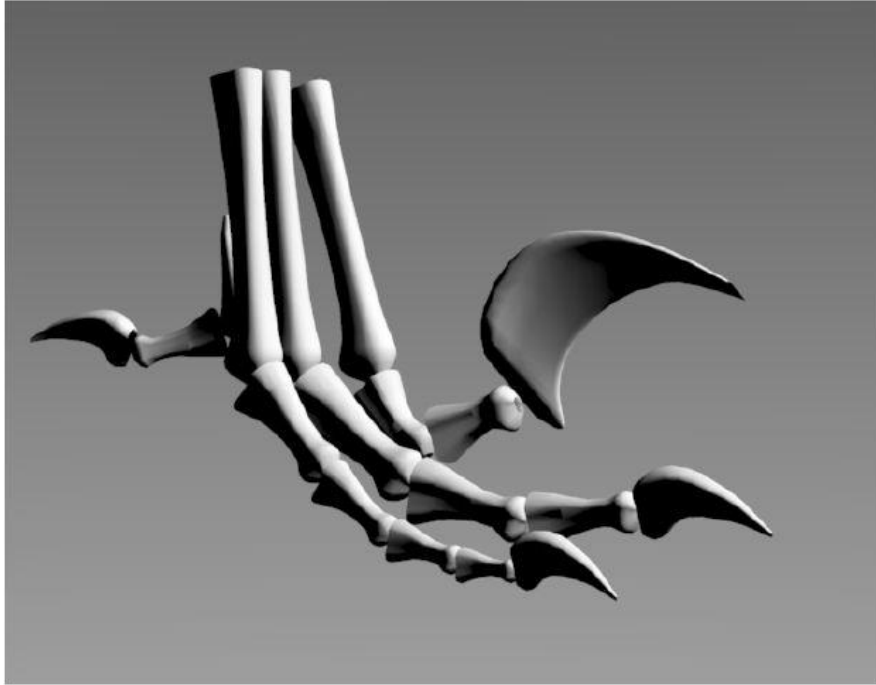
Highlighted Edges

Color interior edges white

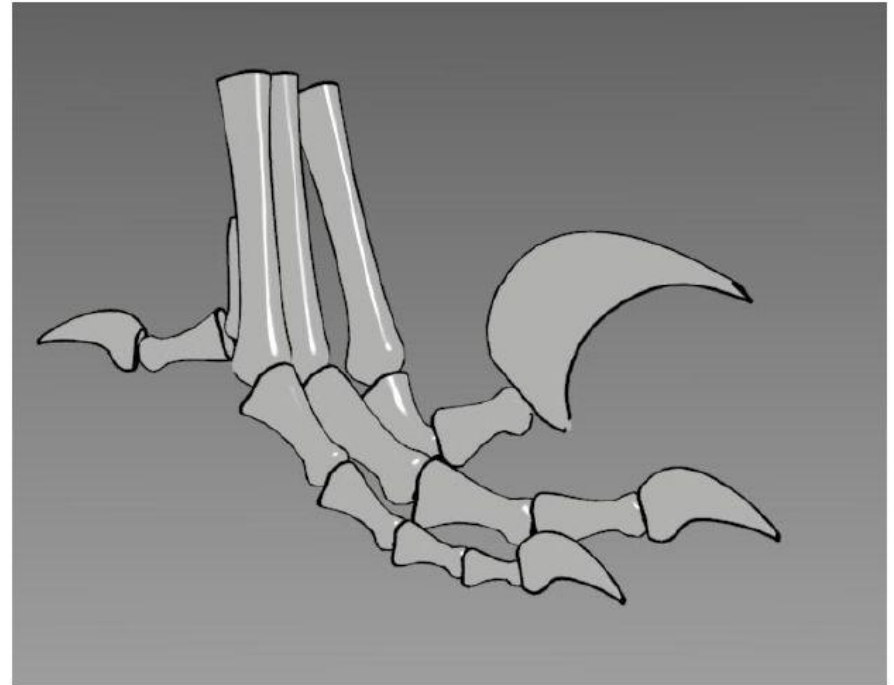
- simulates anisotropic reflections at edges



Tone Shading

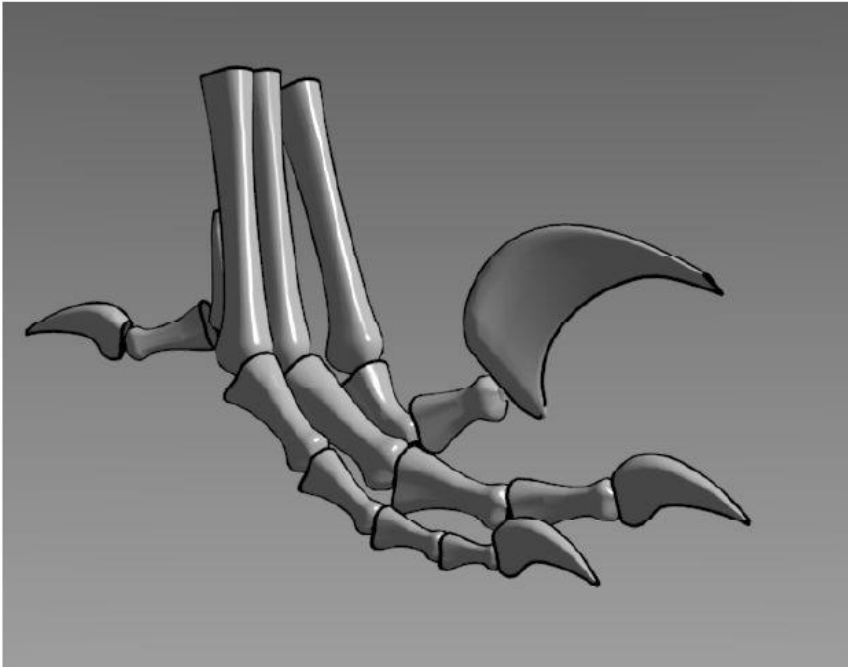


Typical photo-realistic image:
diffuse shading removes detail
in dark and white areas

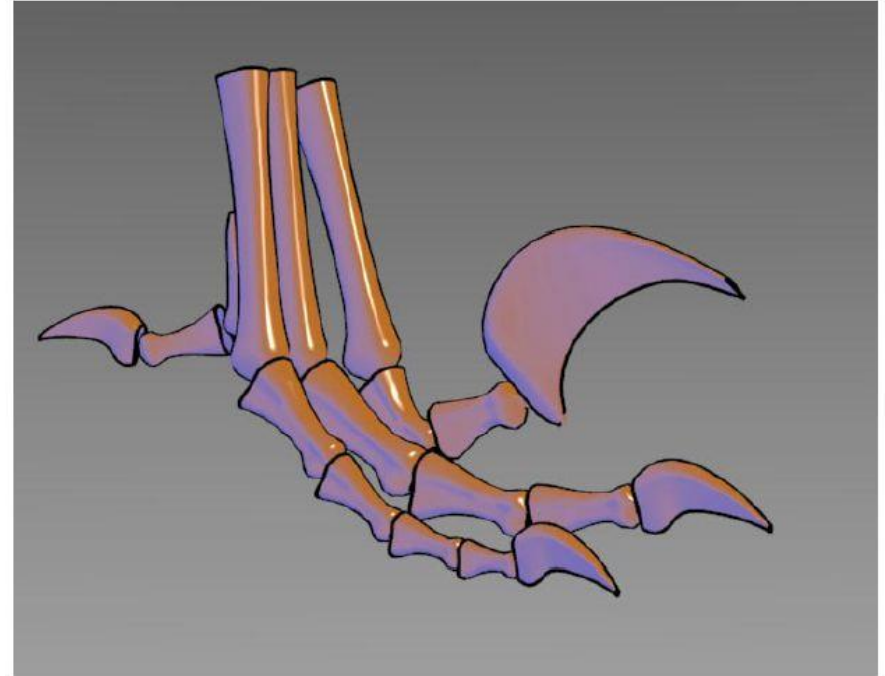


Now with highlights and
edges, but without diffuse
shading:
shape information is lost

Tone Shading



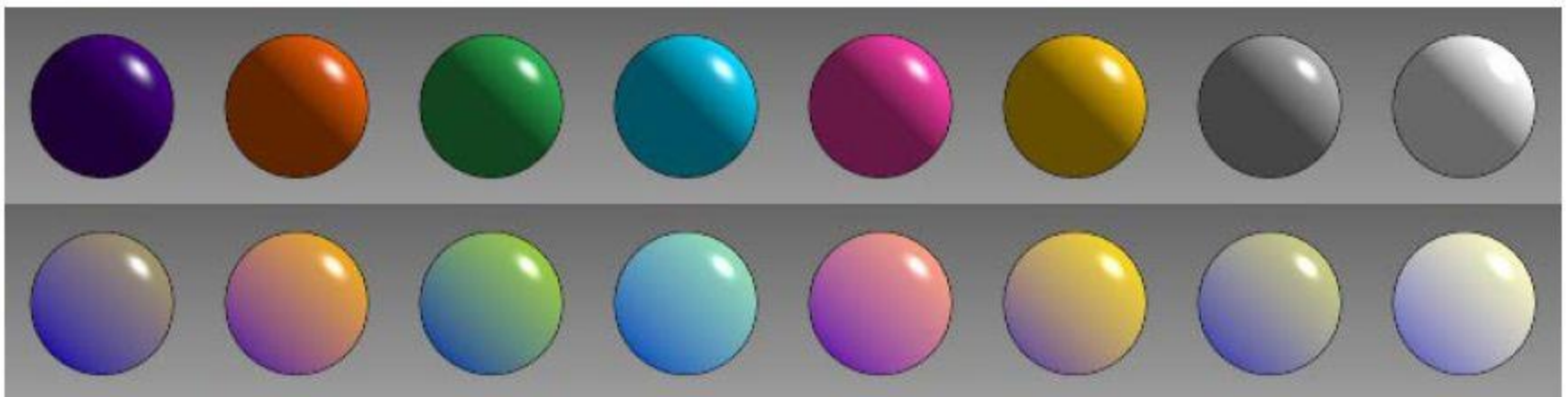
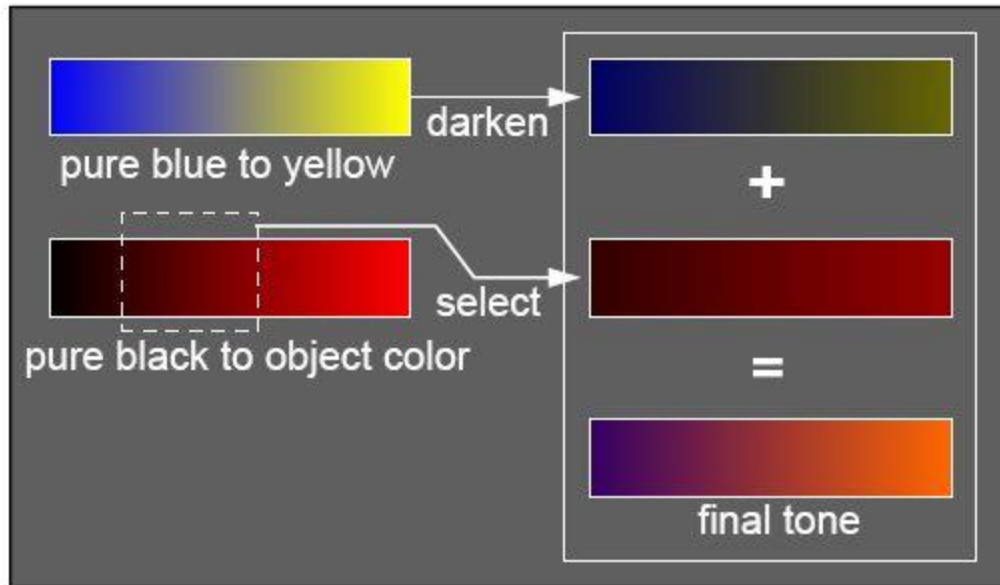
With edge lines and highlights:
better, but still detail is lost in
dark areas



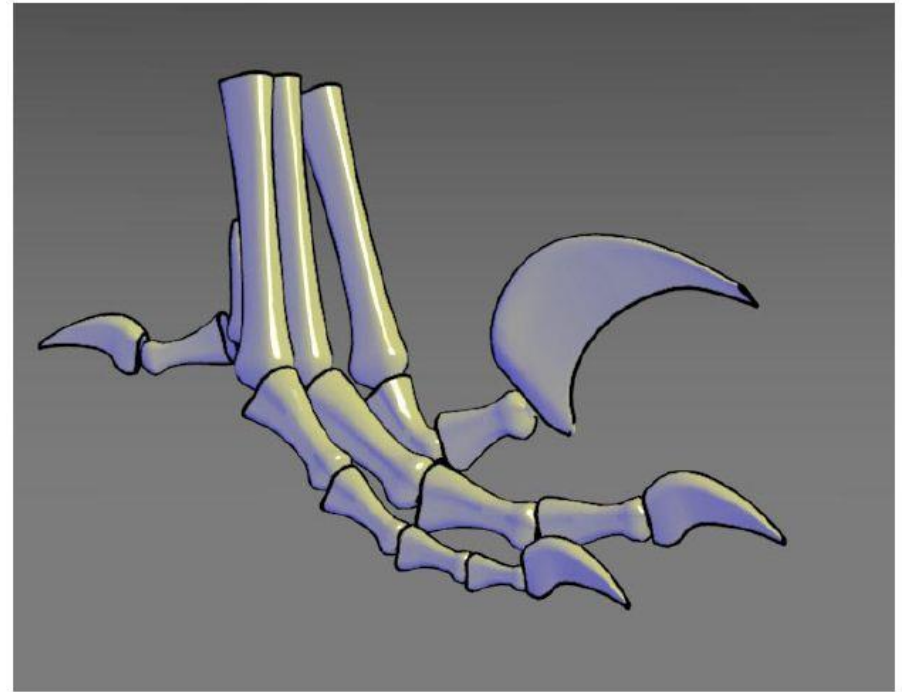
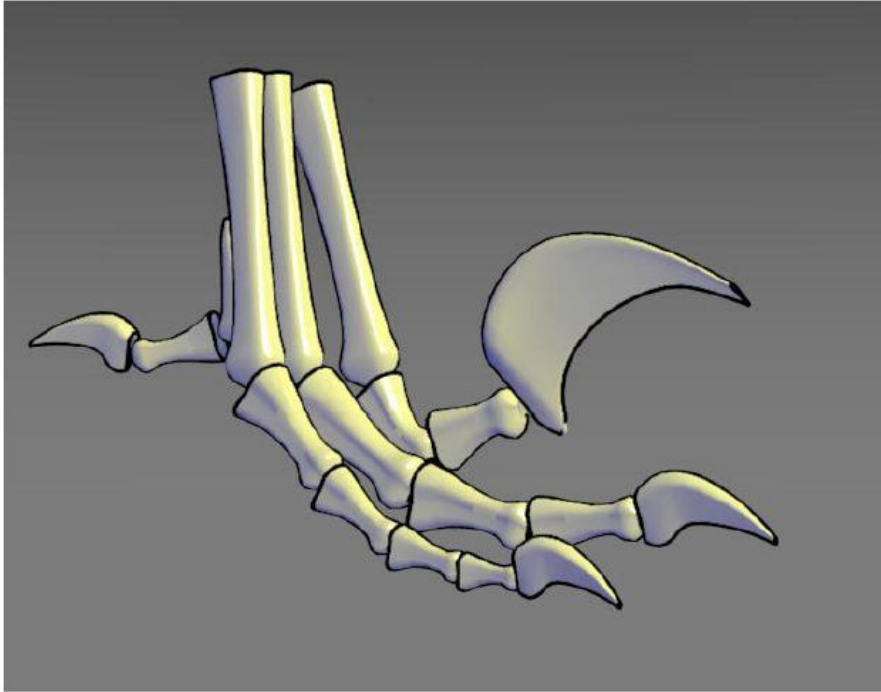
No luminance variations,
instead use tonal shading
(cool-to-warm shift), along
with highlights and edges

Tone Shading

Mix luminance shift and tonal shift with a weighted sum



Tone Shading



Different settings for weighted luminance/hue tone rendering.
Combines two effects with edges and highlights

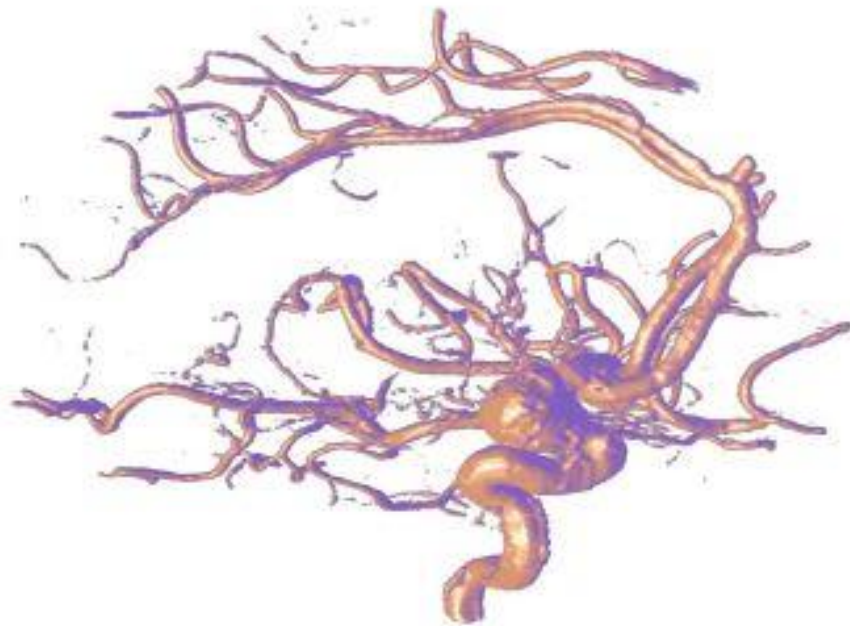
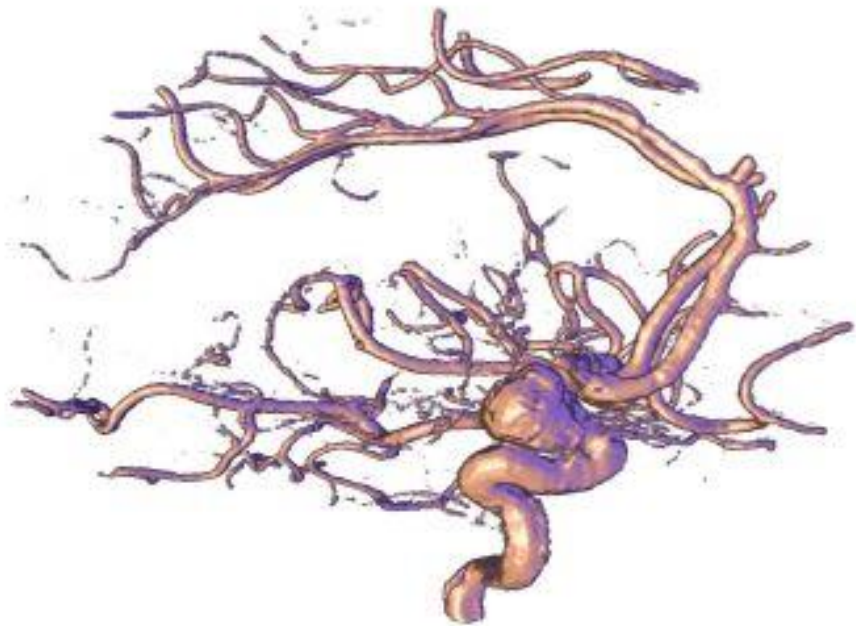
Tone Shading

Specifically for volume visualization



Tone Shading

Specifically for volume visualization



Metal Shading

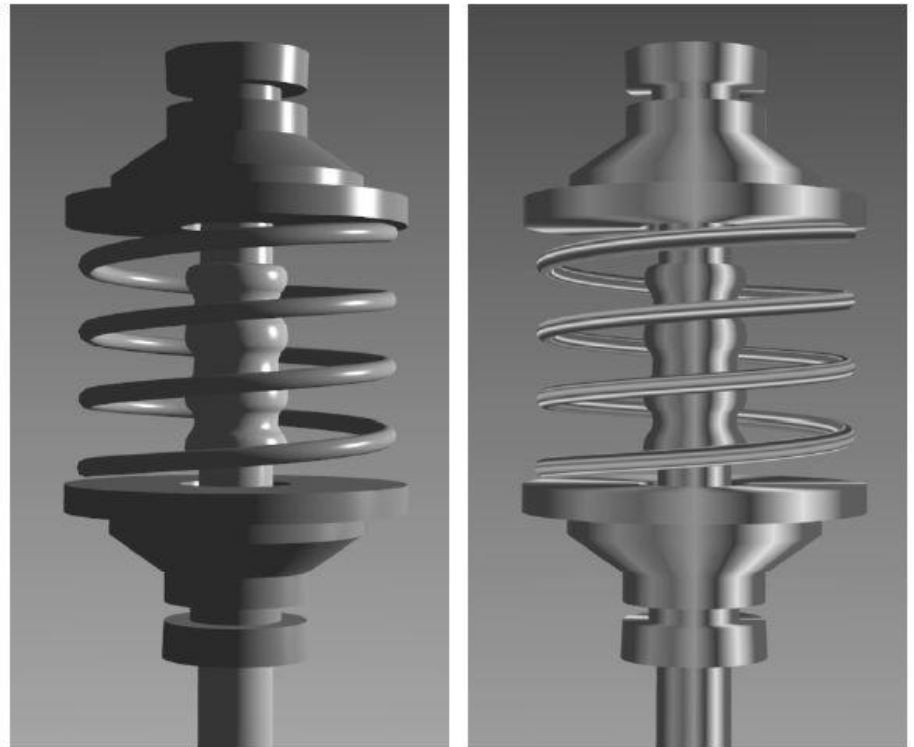
Milling creates what is known as “anisotropic reflection.”

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.

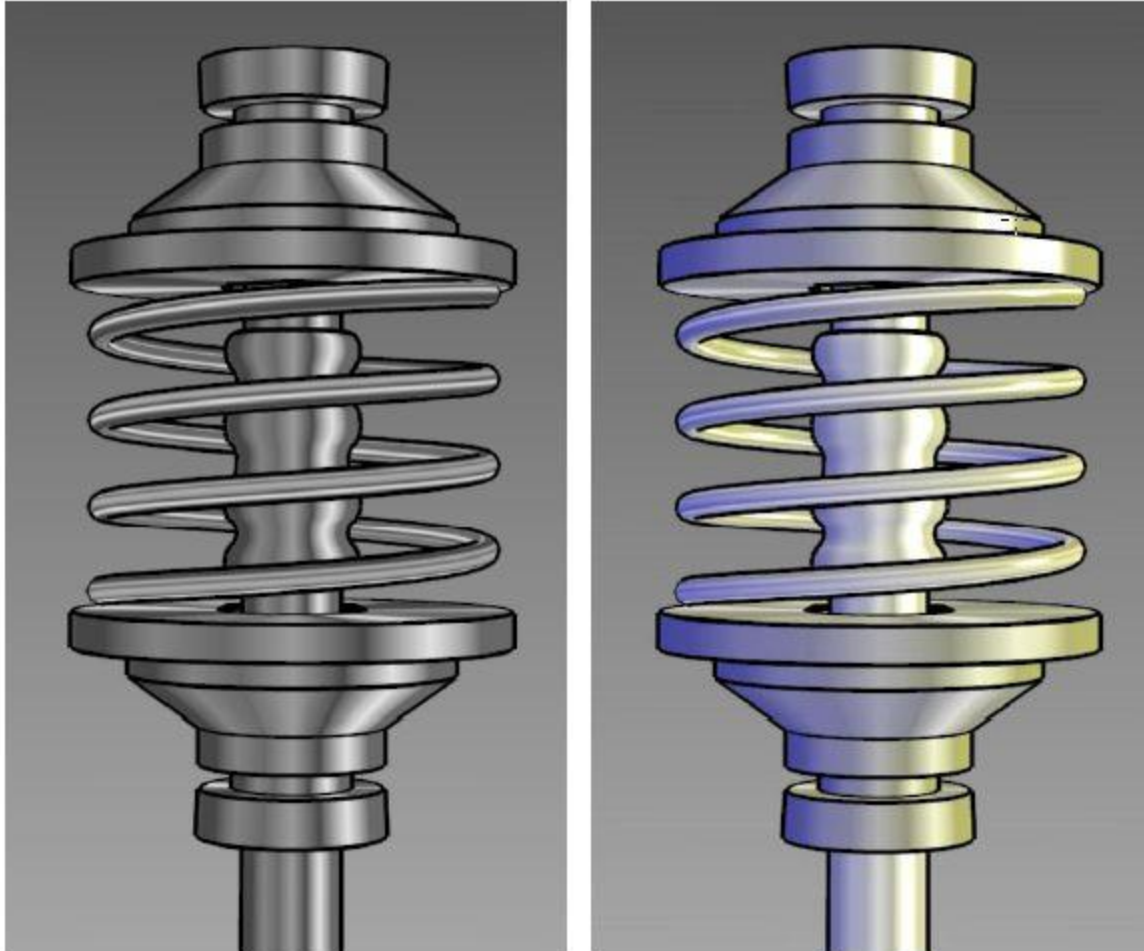


left: no metal
right: metal rendering

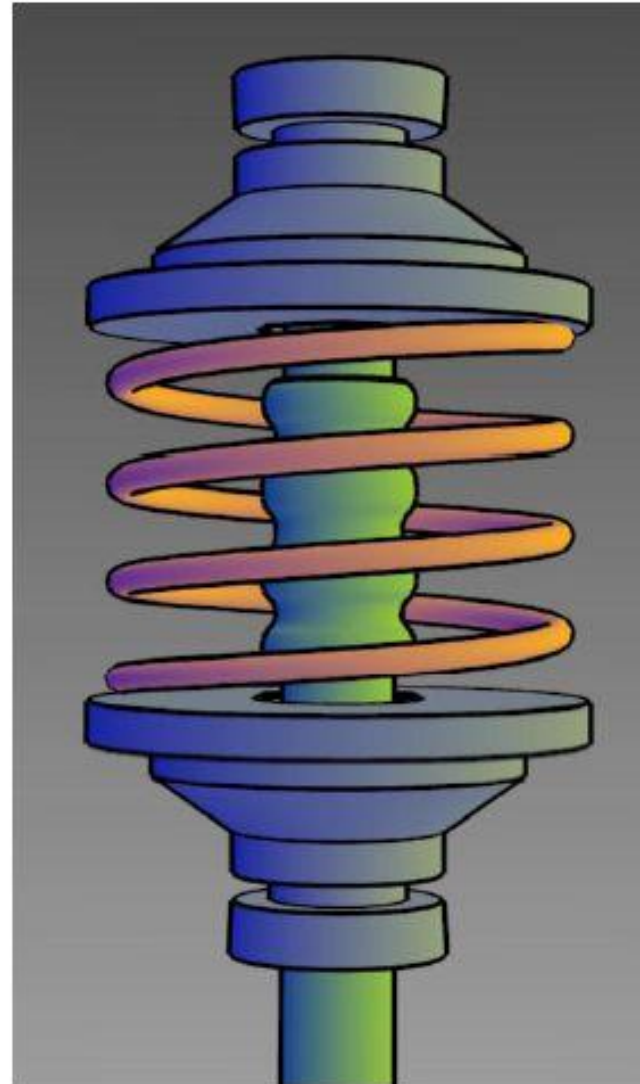
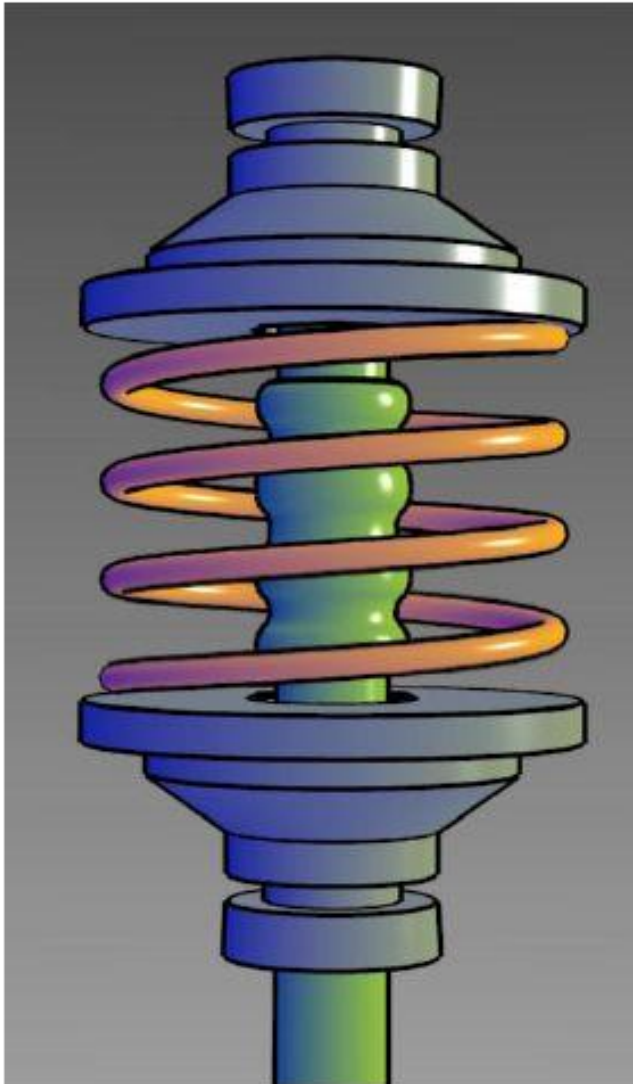


Metal Shading

with edge lines (left) and cool-to-warm tonal shading (right)



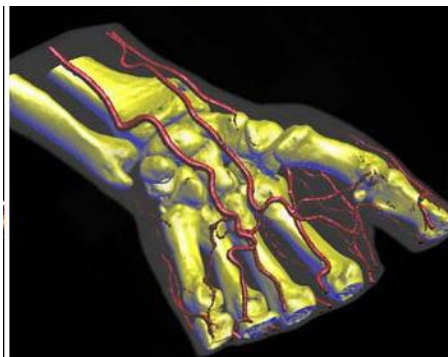
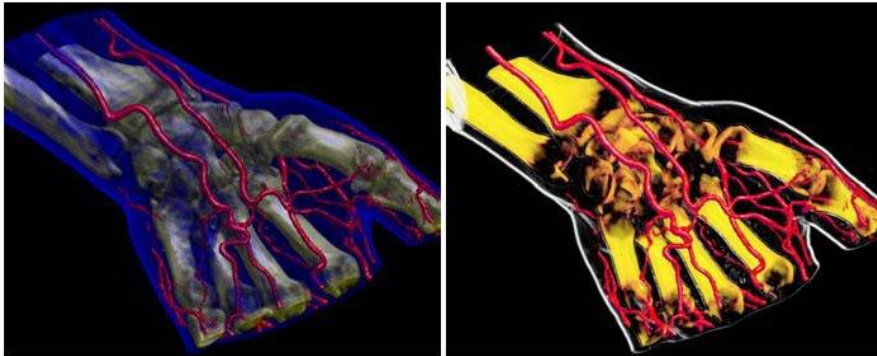
Metal Shading



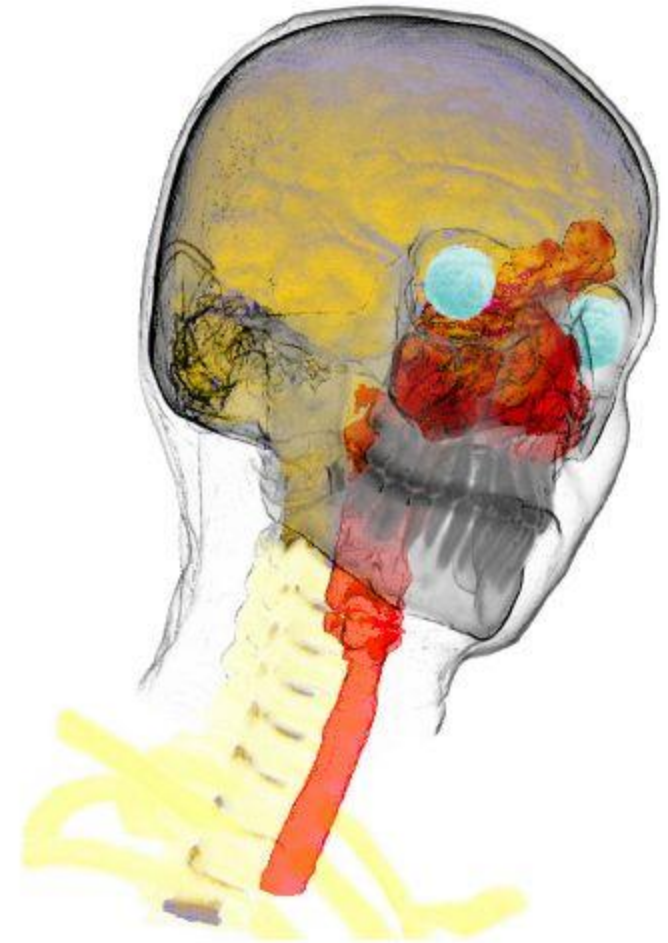
Mixing Rendering Techniques

Assign most appropriate rendering technique for different features:

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



hand dataset

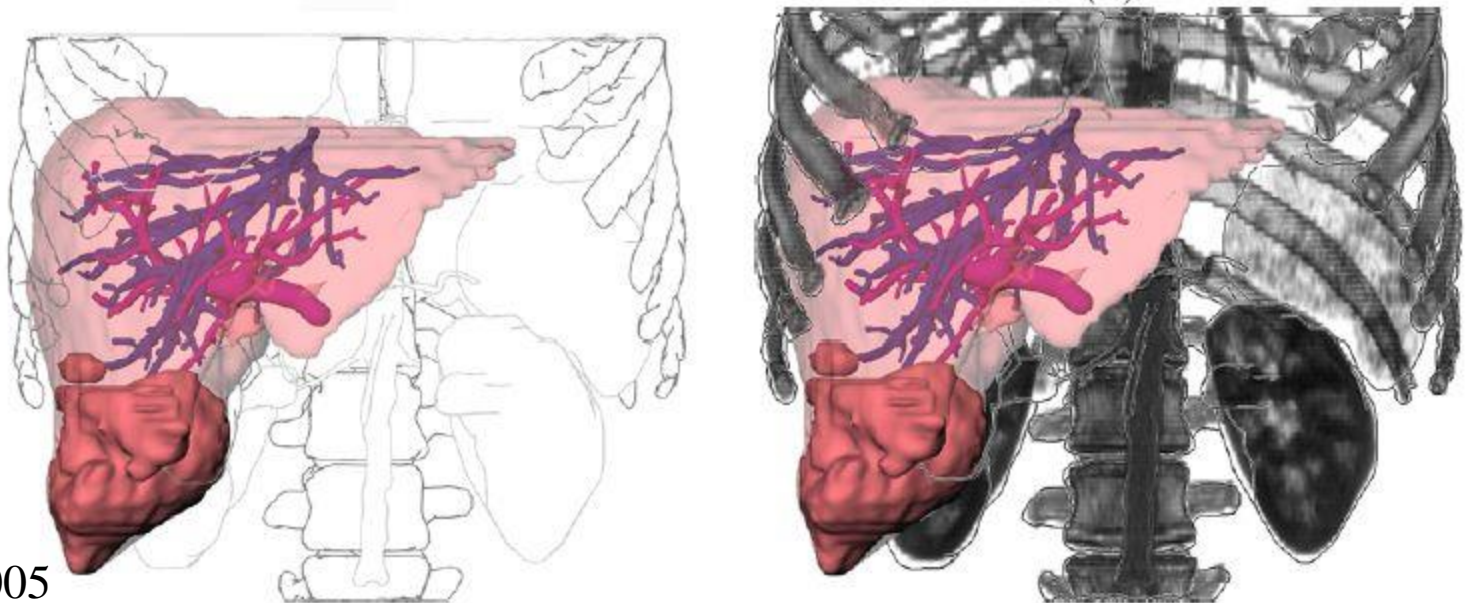


Mixing Rendering Styles

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.

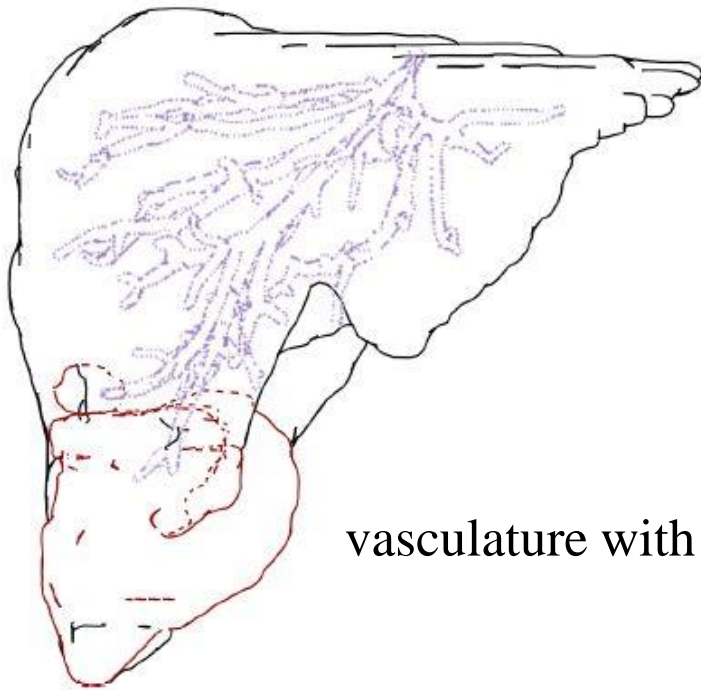
Render these in a certain order to ensure visual consistency



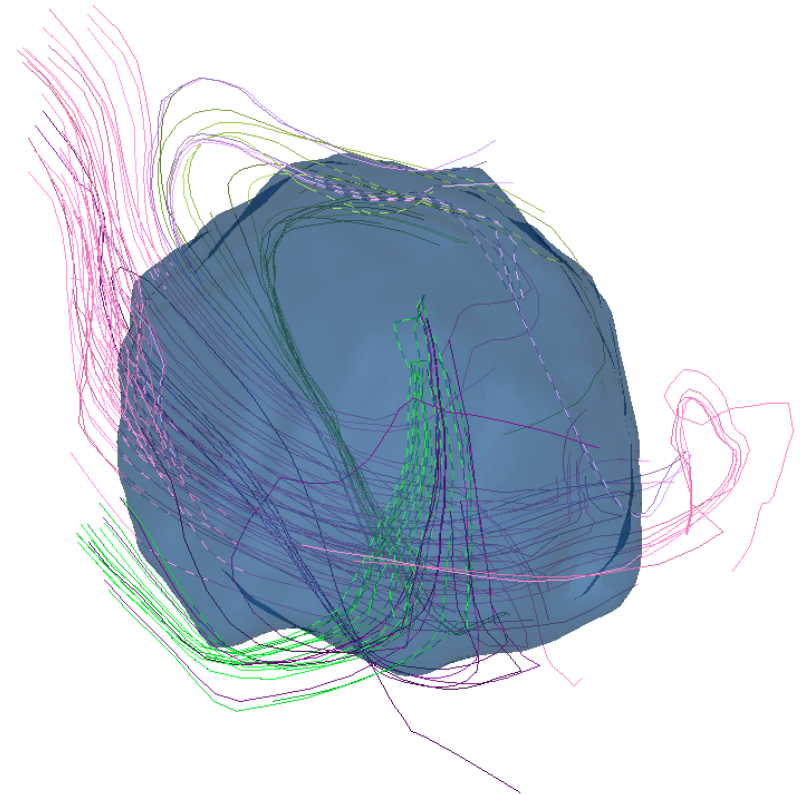
Hidden Structures

Show with different rendering style

- dotted lines, faint lines



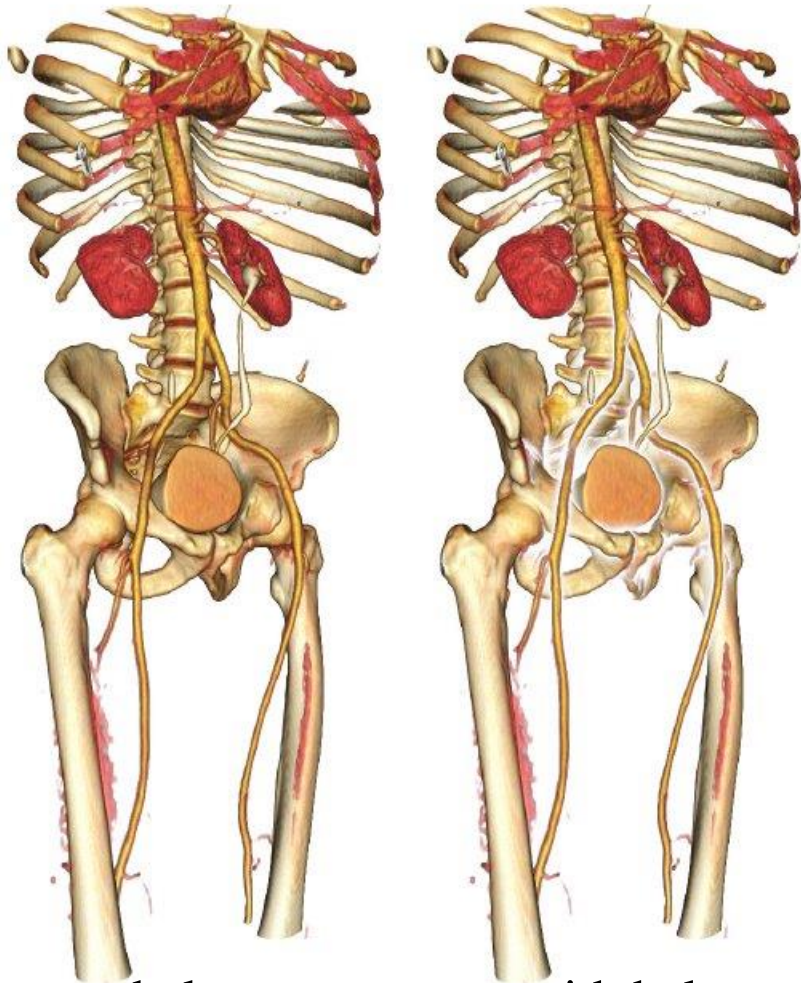
vasculature with tumor



MRI DTI lines inside a tumor

Halos

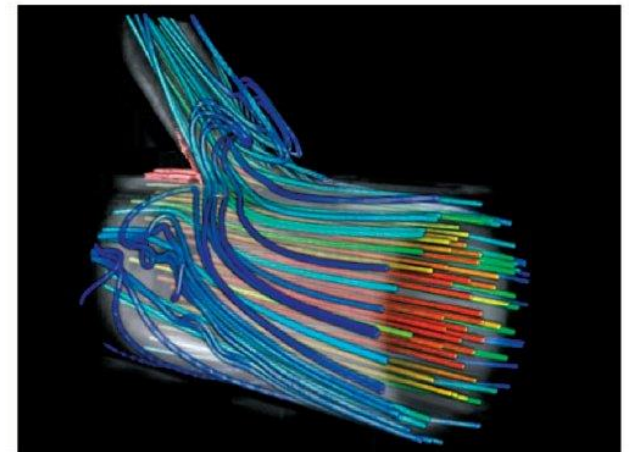
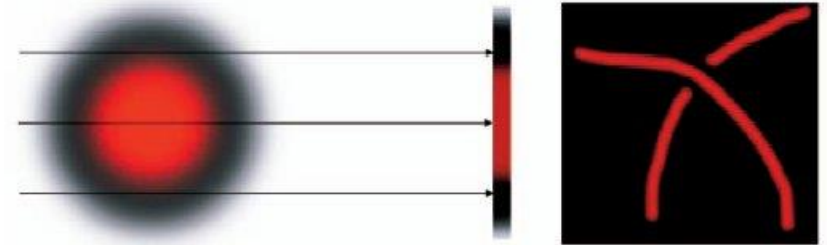
Can enhance depth perception



no halos

with halos

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

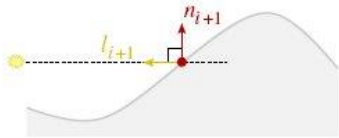
Inconsistent shading to show depth:



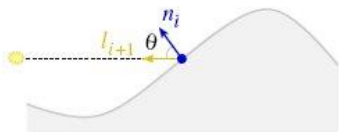
Original normals n_i at level i



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



Light l_{i+1} projected \perp to n_{i+1}



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



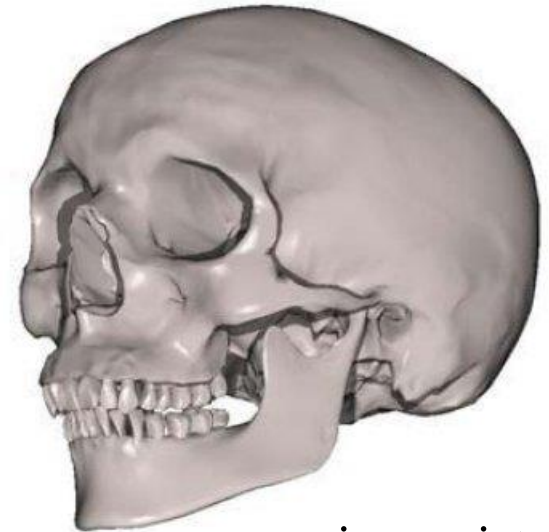
Rusinkiewicz et al., 2006



Lee et al., 2006



consistent



inconsistent

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

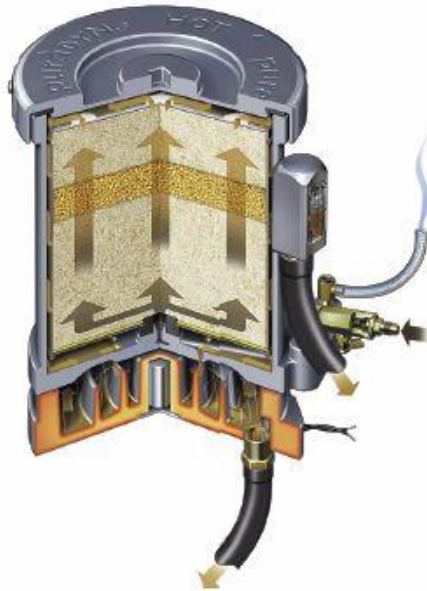
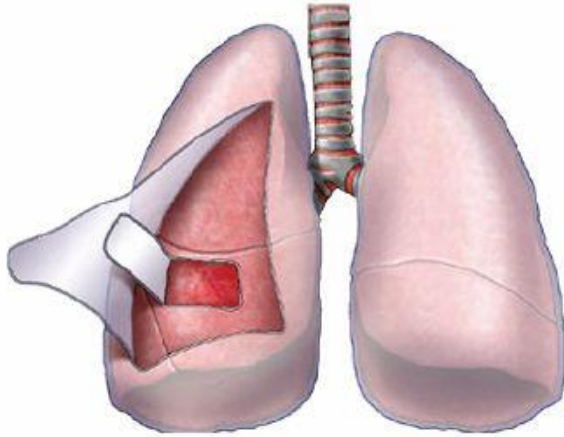
Low-level abstraction:

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

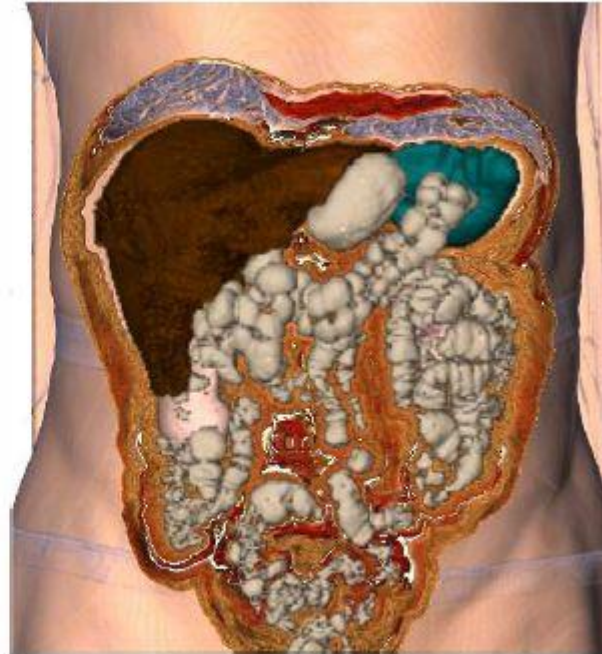
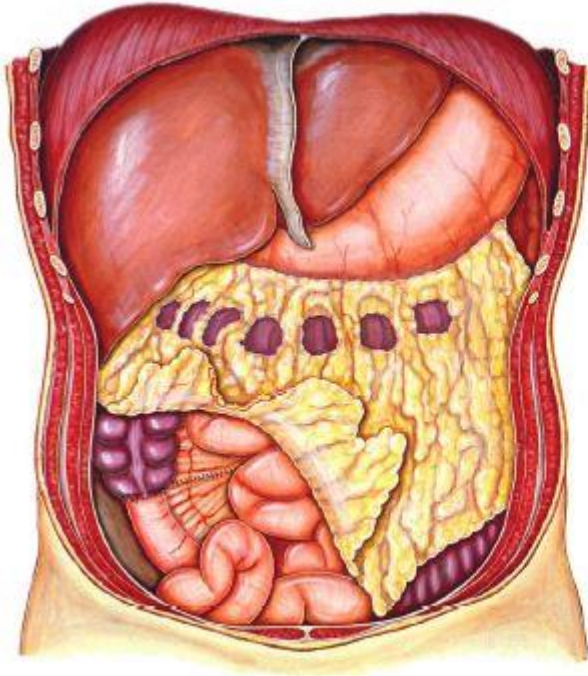
High-level abstraction

- 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

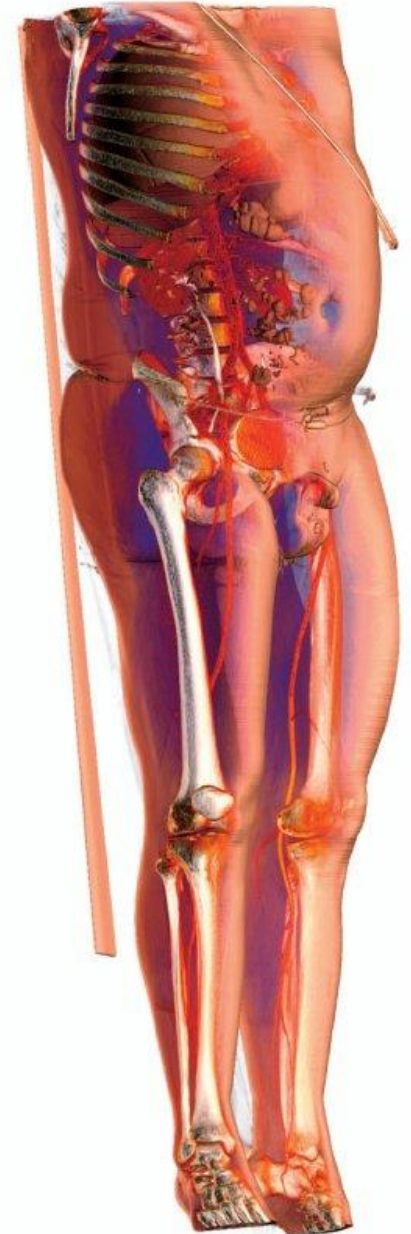
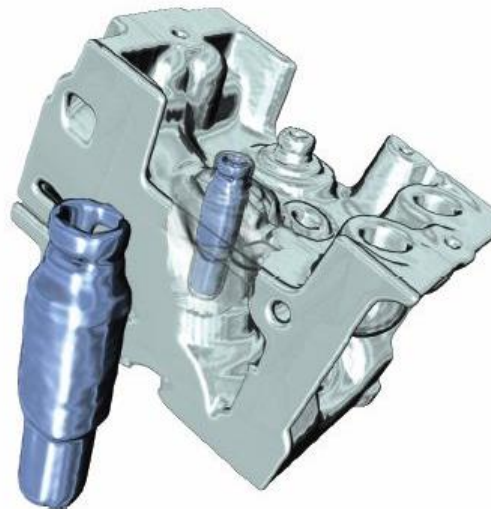
Cut-Aways



Cut-Aways

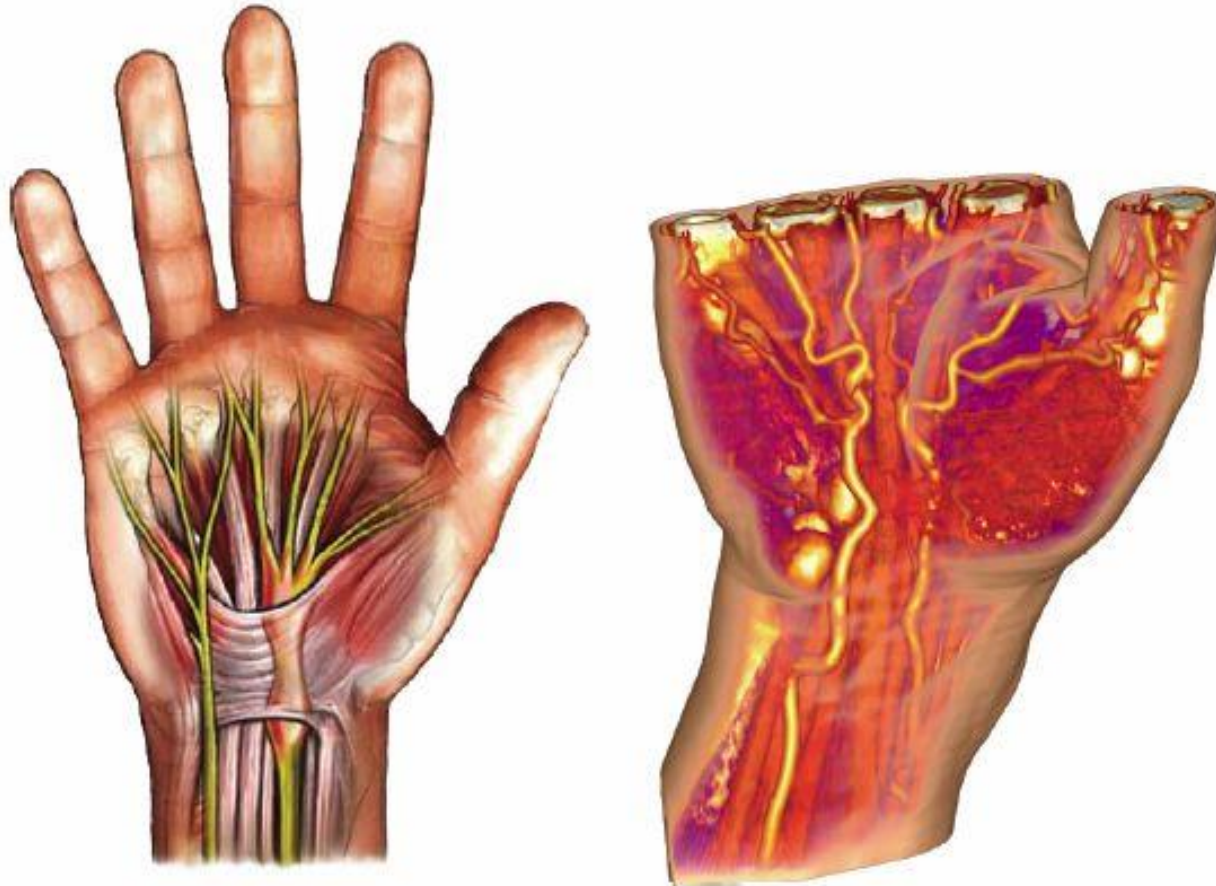


Ghosting

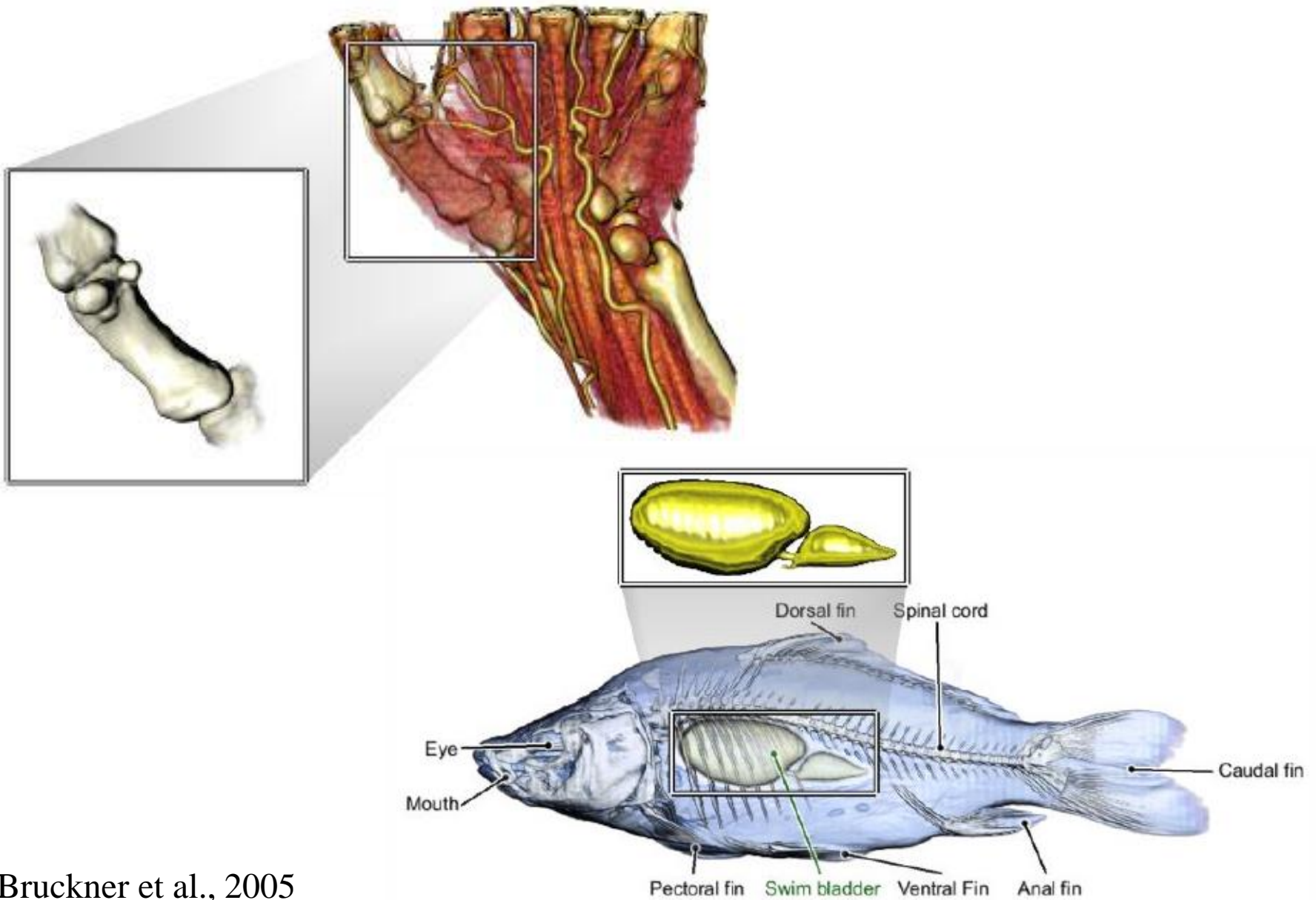


Bruckner et al., 2006

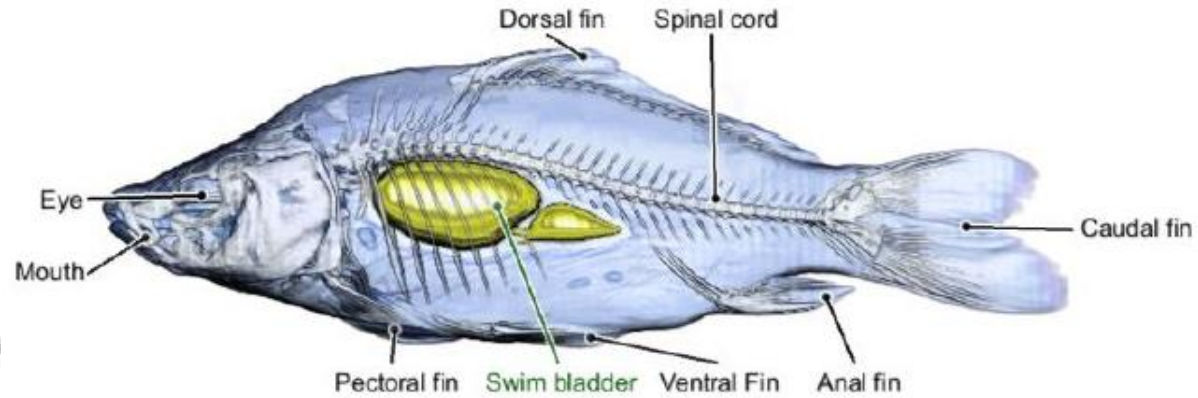
Focus + Context



Fans



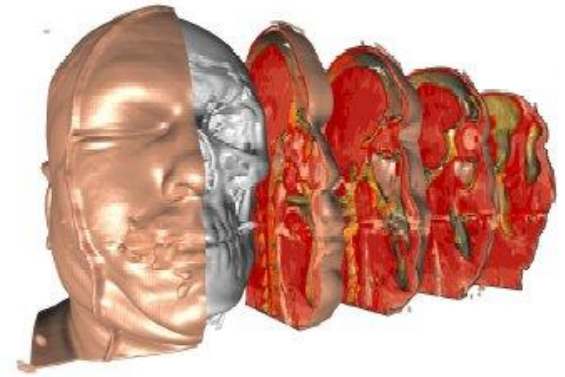
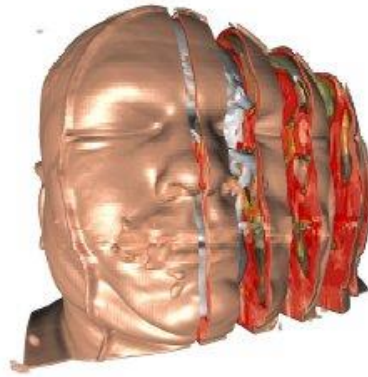
Labeling And Other Abstractions



Displacement With Context



exploded views



dynamic multi-volumes

Bruckner et al., 2005



volume splitting

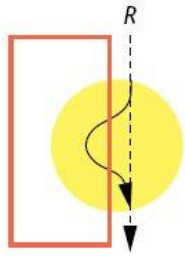
Islam et al., 2004



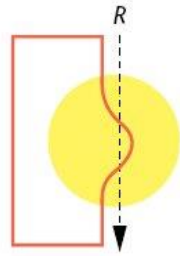
Grimm et al., 2004

Distortion Techniques

Ray deflectors:

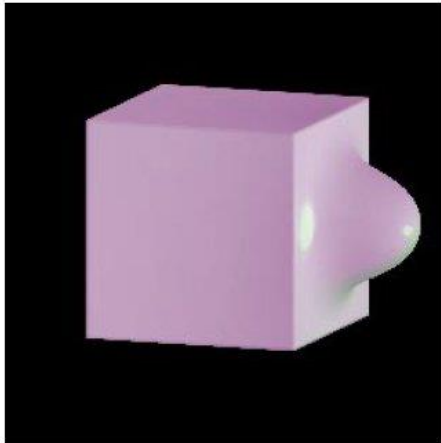


(a)



(b)

2 (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.



(c)



(d)



Explaining Differences Via Exaggerations

Caricature visualization



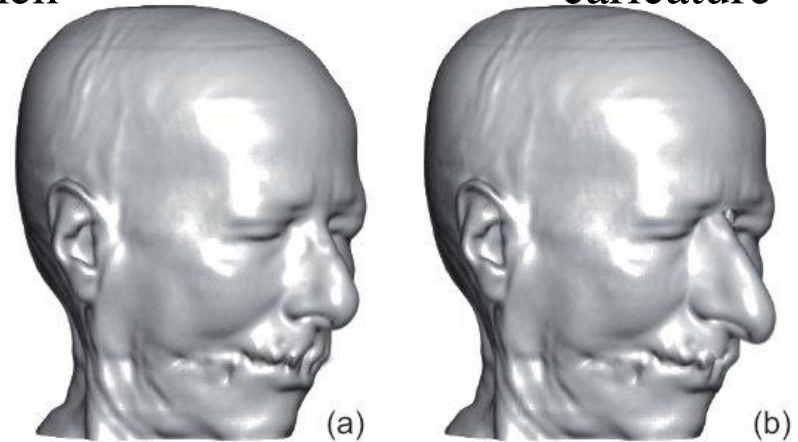
reference model

specimen

caricature

specimen

caricature

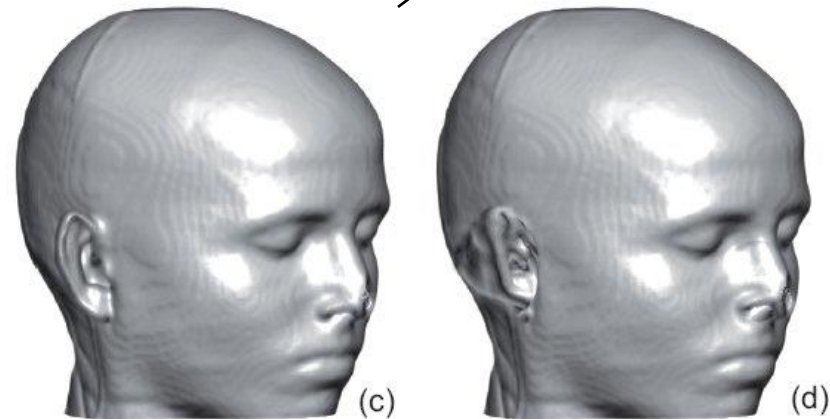


(a)

(b)

ref model

emphasize differences of the specimen
with the reference model by
exaggerating these differences

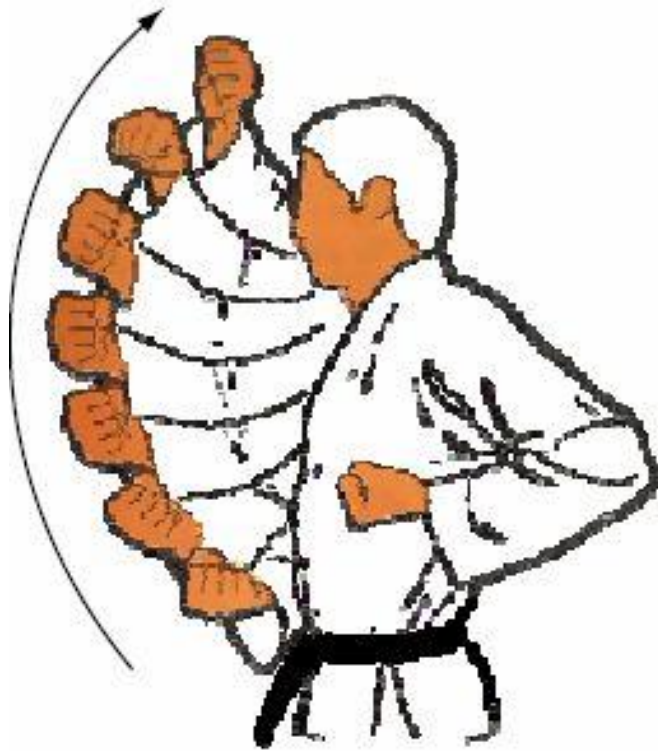


(c)

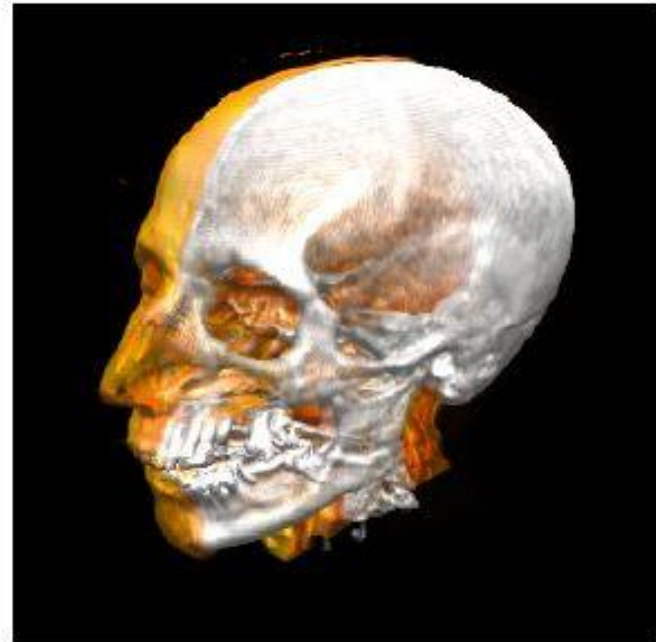
(d)

Fig. 10. A caricaturistic volume deformation. In (a) and (c) iso-surface renderings of the two datasets are shown. In (b) a caricature by volume deformation is shown using (c) as reference model. In (d) a caricature of (c) is shown using the features of (a) as reference model.

View Composition

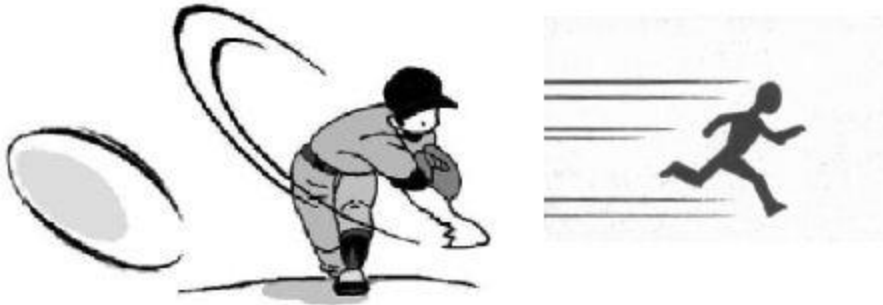


Rendering Mode Composition

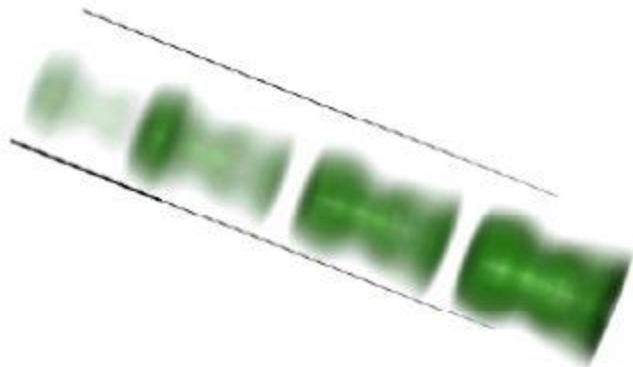


Time-Varying Data

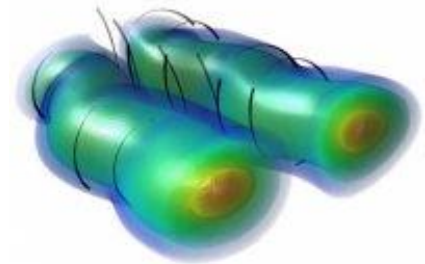
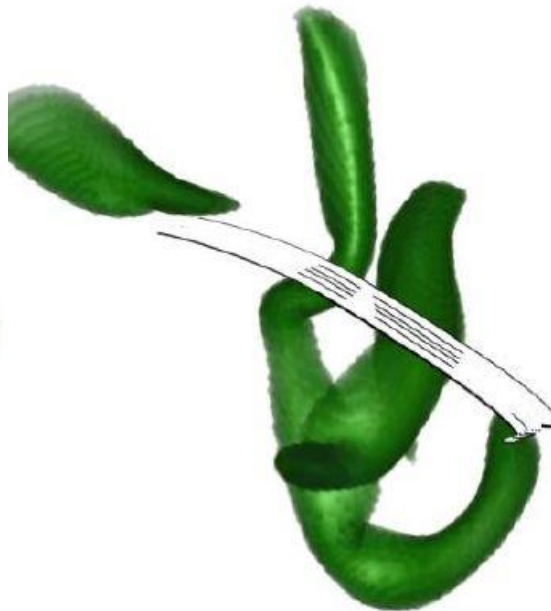
The goal is to depict the time-varying behavior of the data in a single frame via illustrative techniques



typical illustration metaphors



applied in visualization



Time-Varying Data

Use ideas from flash photography to illustrate motion hints:

