CSE 564
Visualization & Visual Analytics

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

Computer Mouse

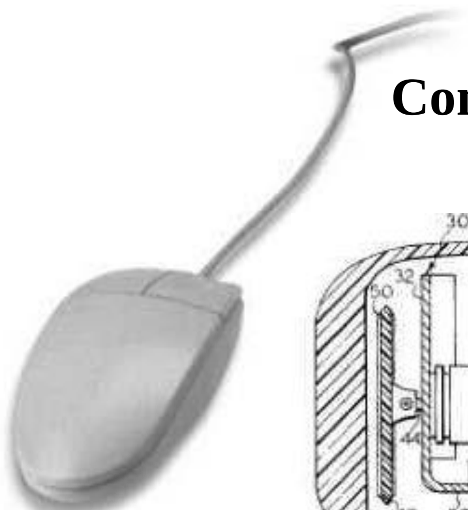
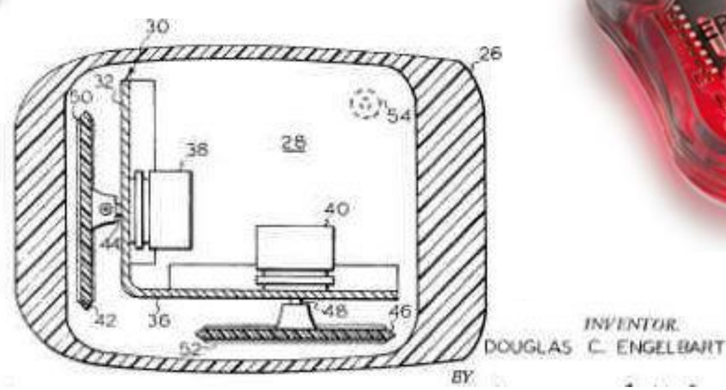
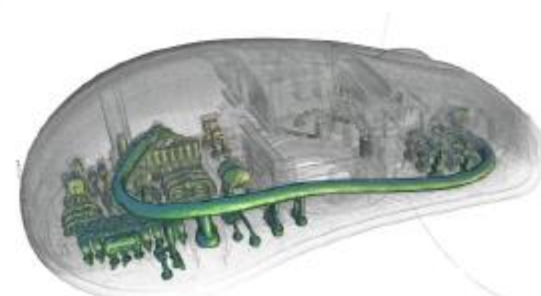


photo-realistic, opaque



technical drawing

photo-realistic, transparent

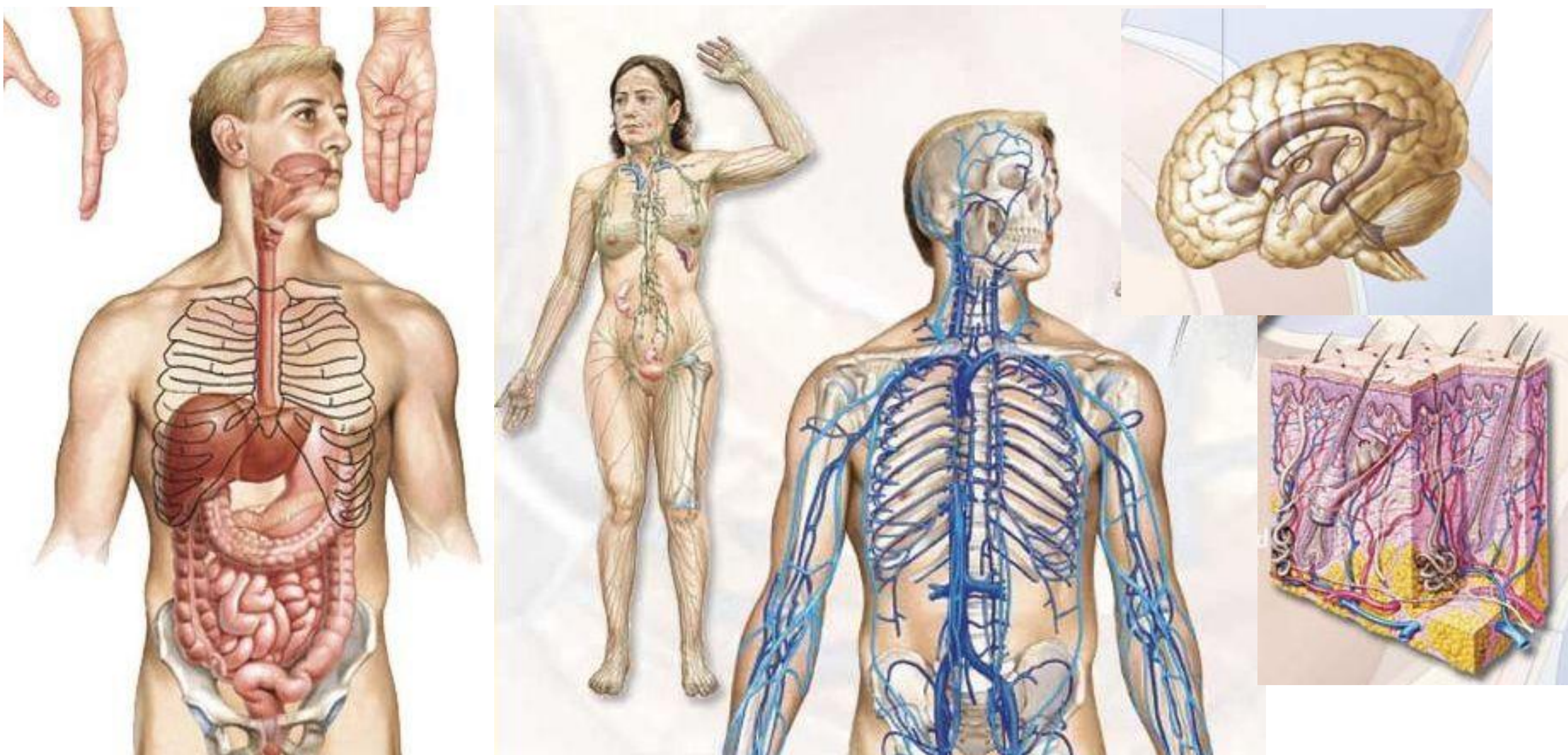


illustrative, transparent

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"

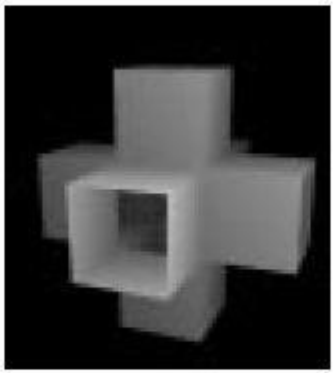
"Hide that data which does not make a difference in what you are trying to depict"

"Minimize clutter"

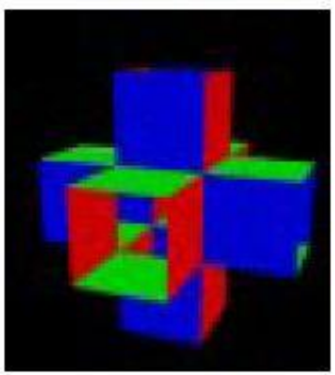
"Separate figure and background"

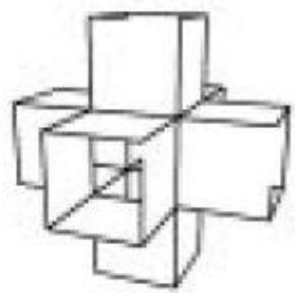
Basic Techniques: Contours and Outlines

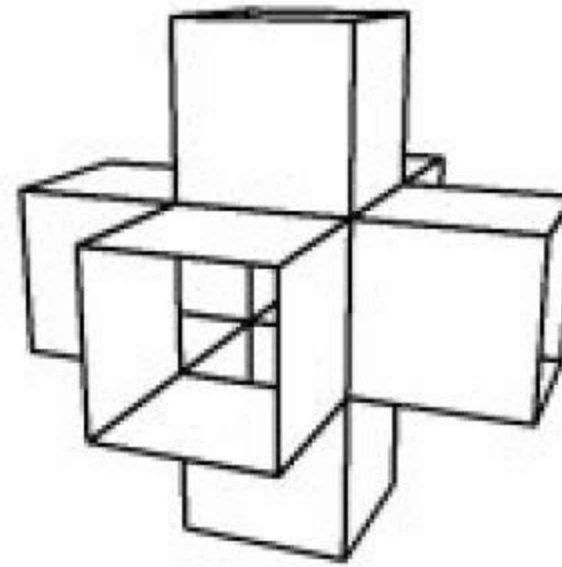
depth-map (edges are due to C_0 discontinuities)



normal-map (edges are due to C_1 discontinuities)





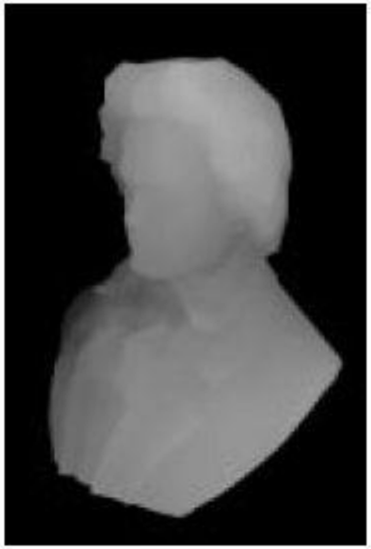


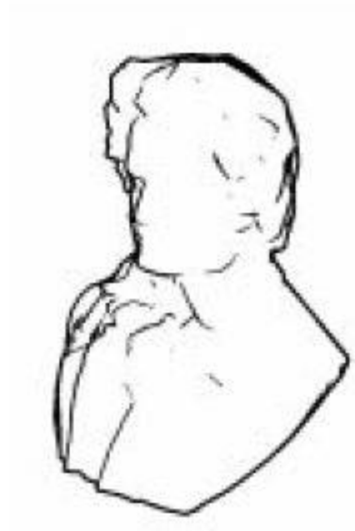
combined

Gooch and Gooch, 2001

Basic Techniques: Contours and Outlines

depth-map

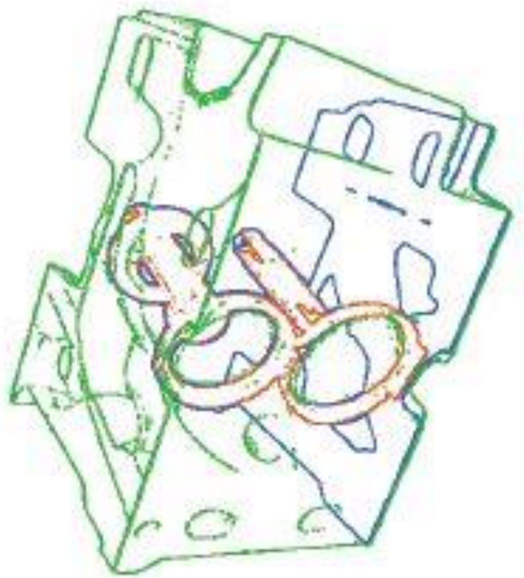


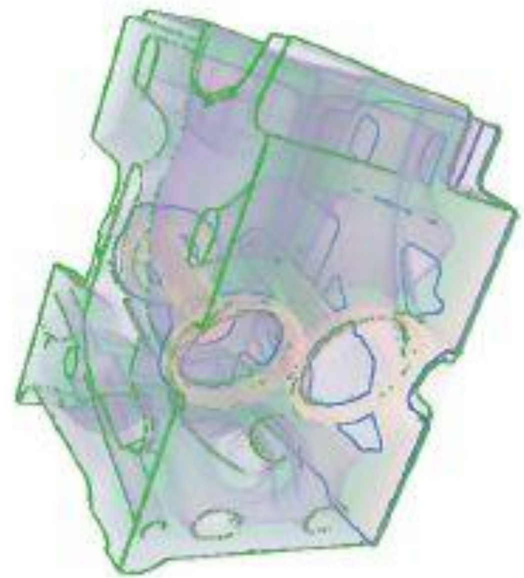


normal-map

combined

Basic Techniques: Contours and Outlines

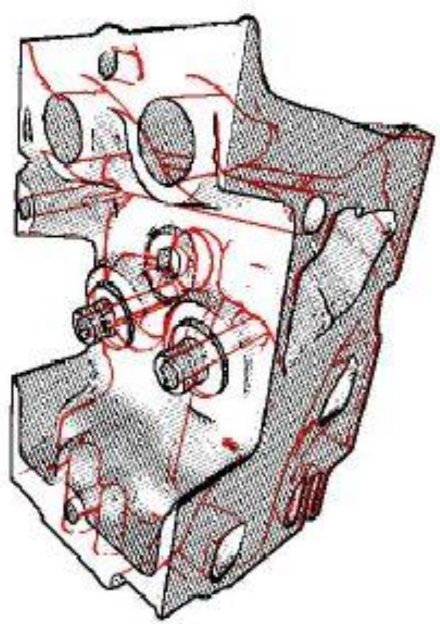


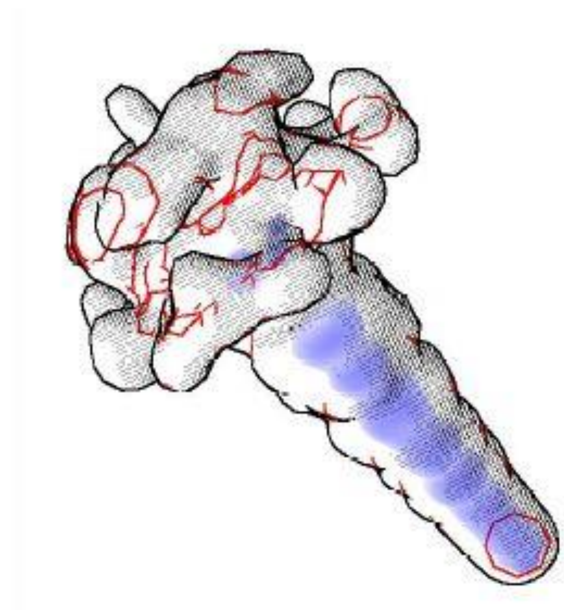


mixing outlines with
volume rendering

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

rendering interior structures as contours



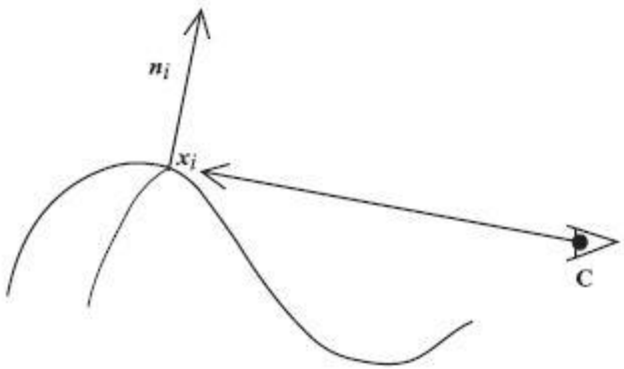


Fischer et al., 2005

Basic Techniques: Silhouettes

Not an image-space method

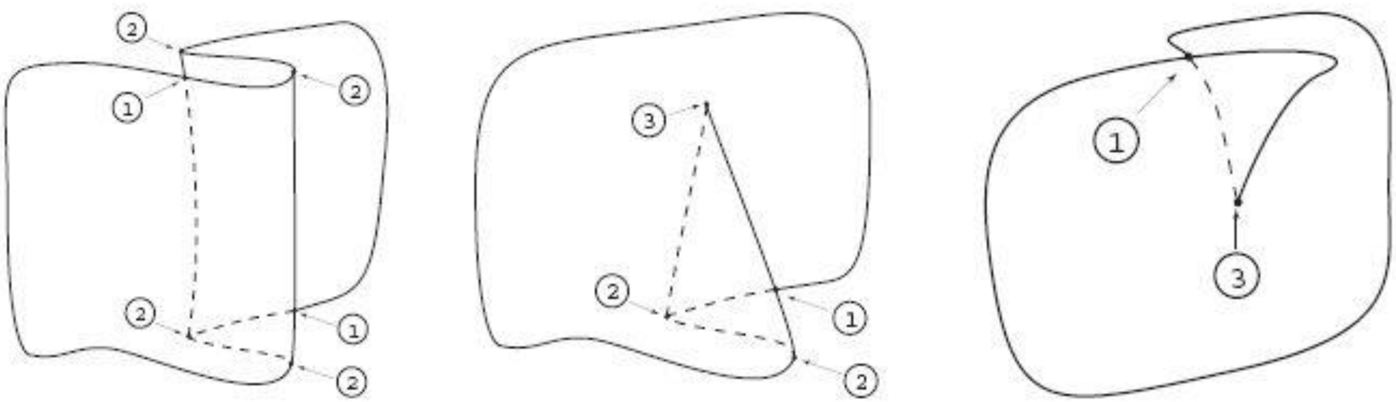
- uses dot product V·N=0 criterion
- V: view vector
- N: surface normal



Finds curves and creases at higher quality

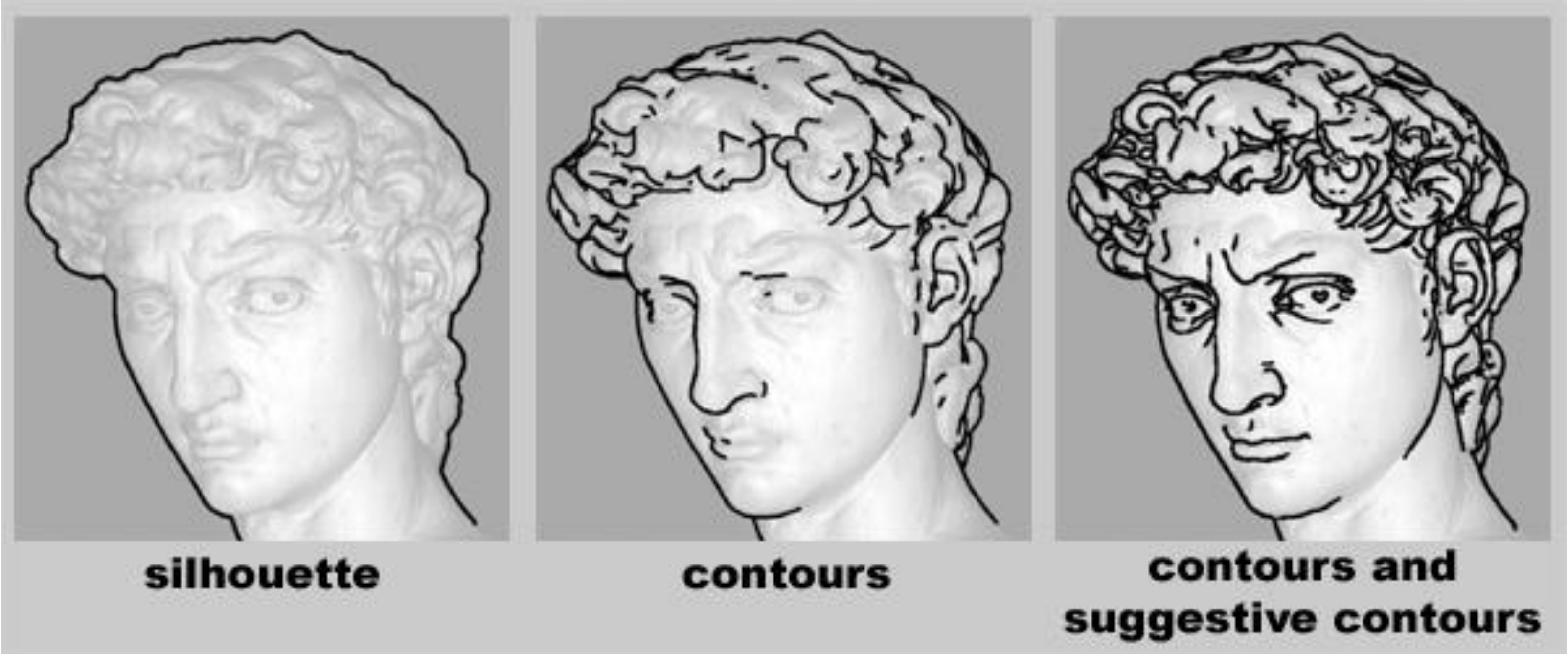
Allows further processing of these (for example hatching)

Must disambiguate occlusions



Suggestive Contours

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



DeCarlo et al., 2003

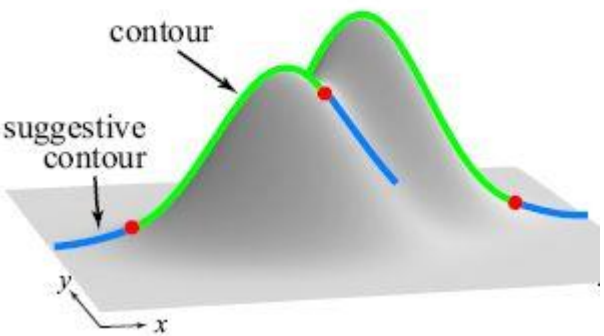
Suggestive Contours

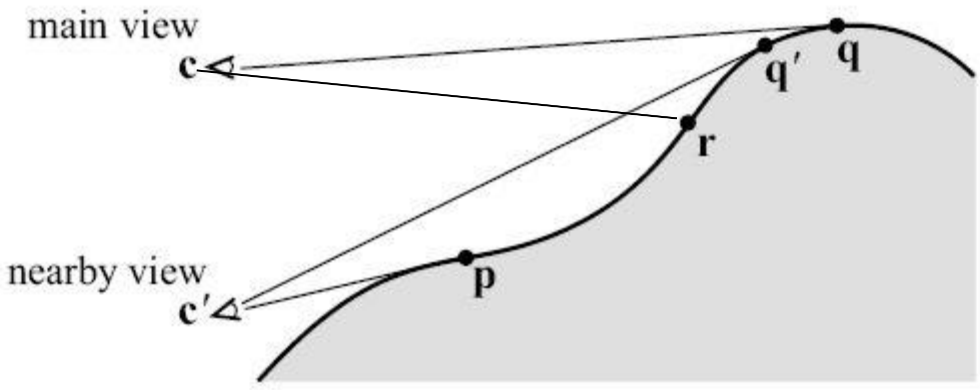
Those locations at which the surface is *almost* in contour, from the original viewpoint

- where the radial curvature (1/curve radius) is zero (inflection point)
- the curve switches from being convex - like a mountain - to concave – (like a valley)

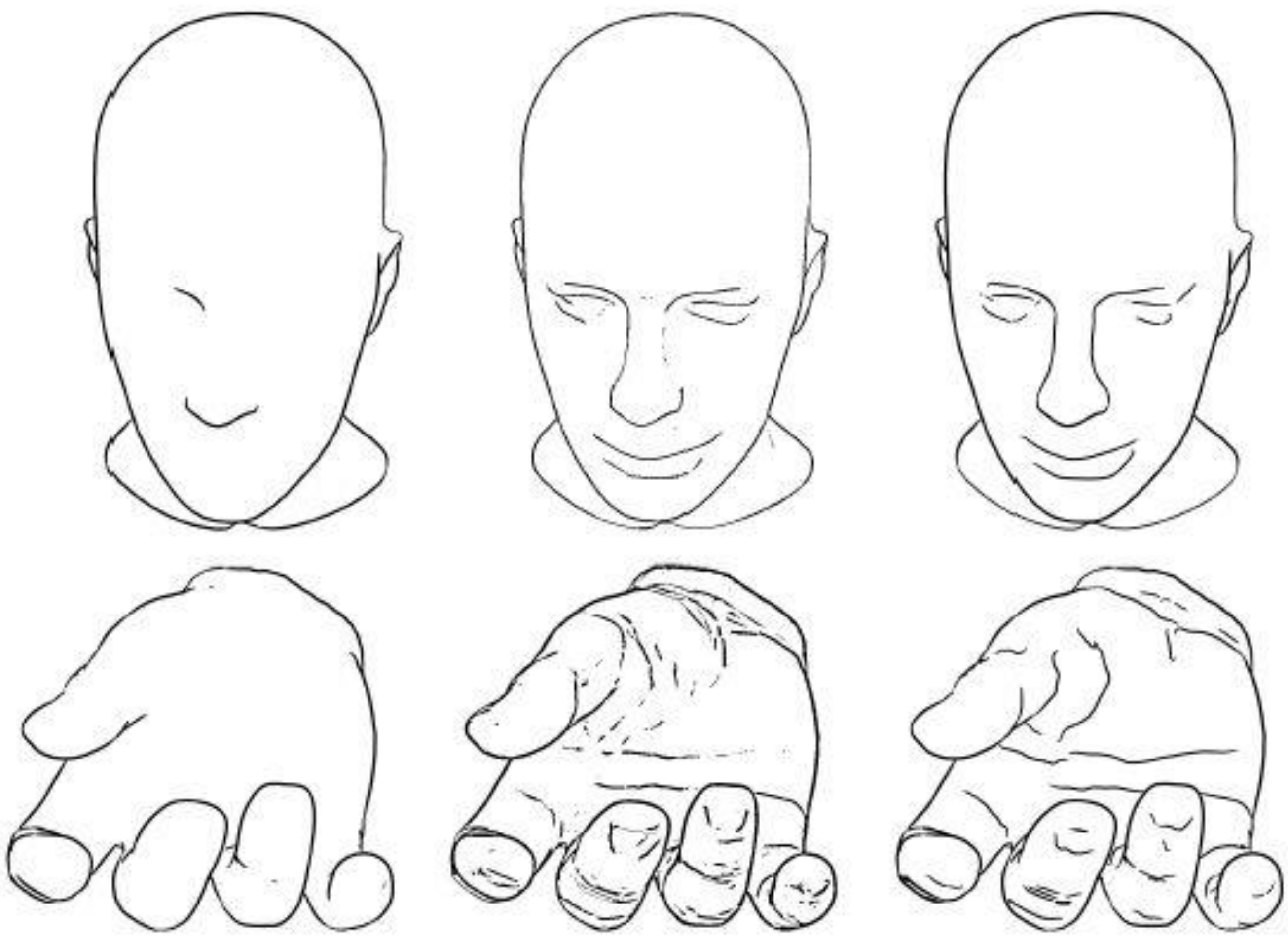
- where V·N is a positive local minimum rather than zero
- the second derivative is zero
- correspond to true contours in relatively nearby viewpoints.

- p is such a suggestive contour point
- q is a contour point





Suggestive Contours



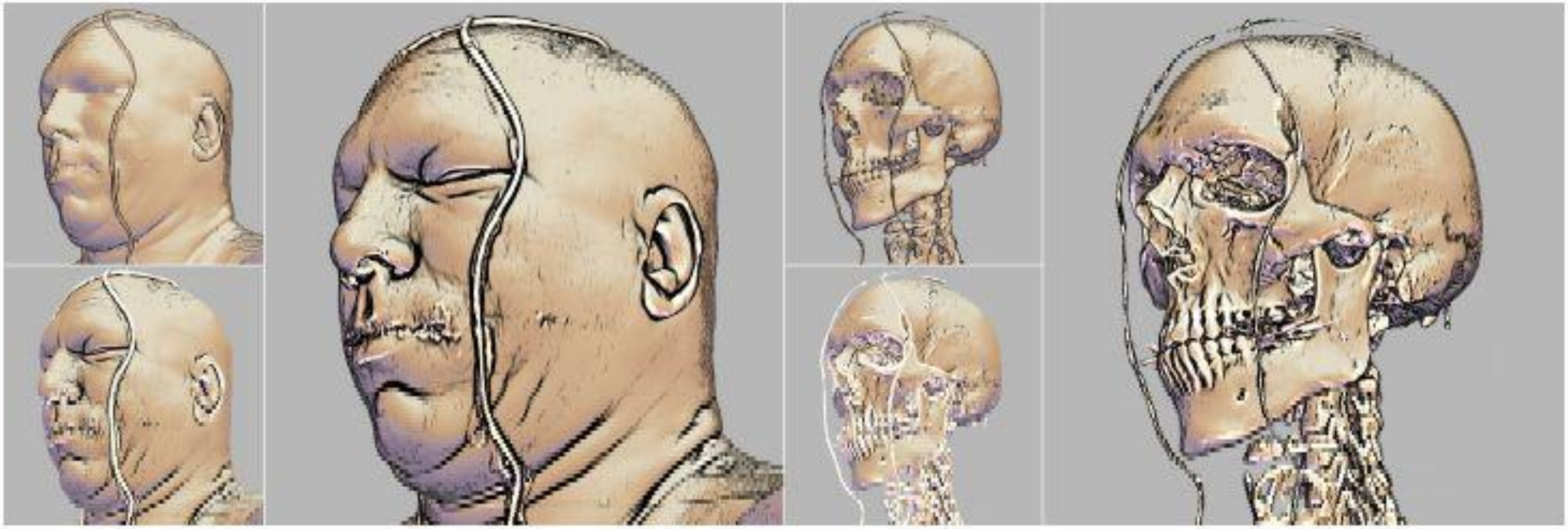
contours

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

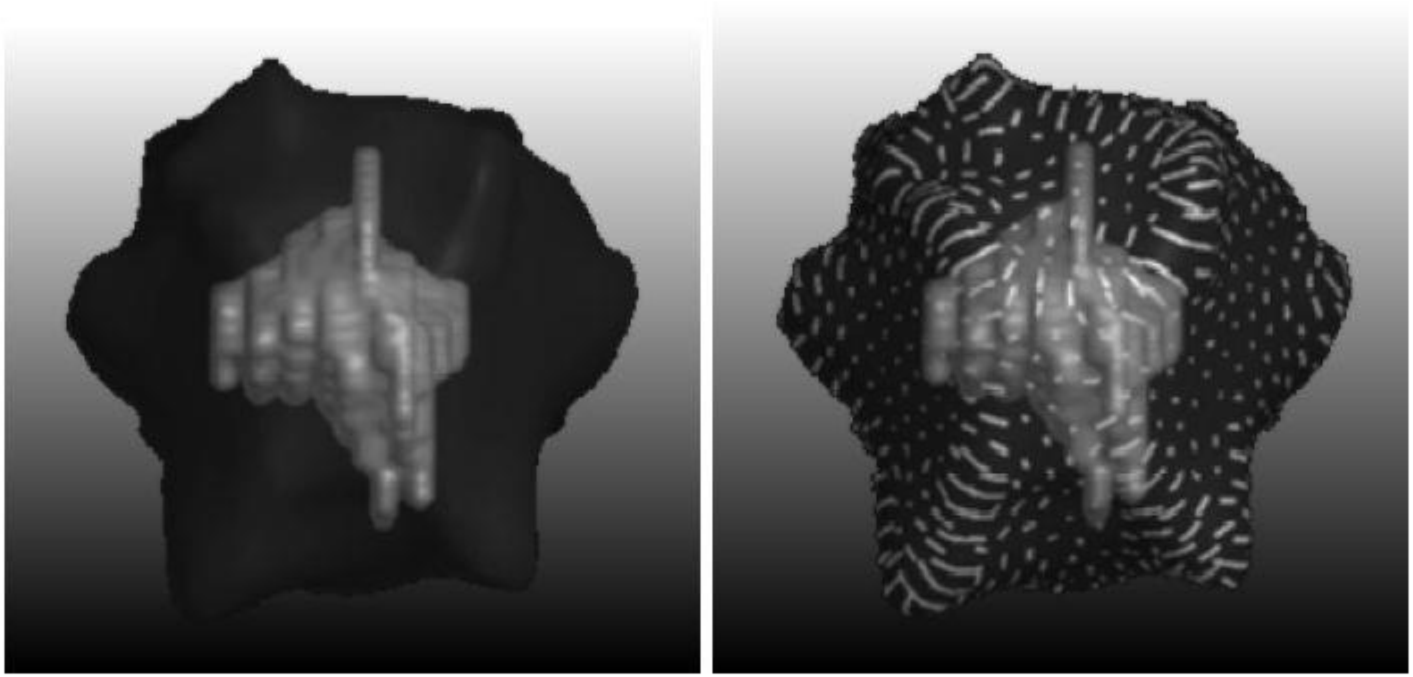


Kindlmann et al., 2003

Curvature Stroke Lines

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

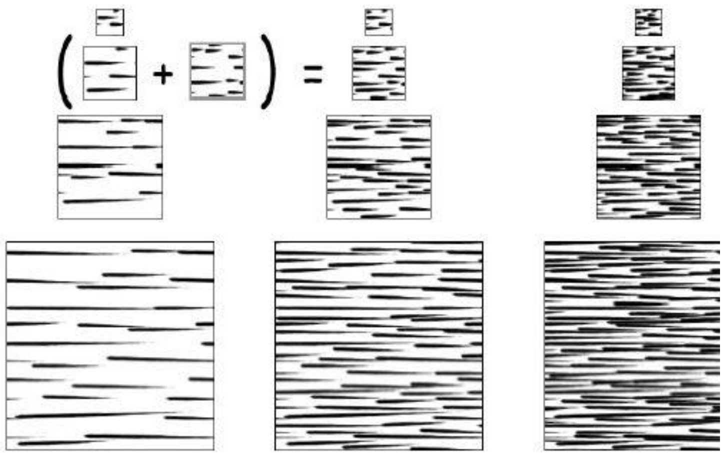
Right: Strokes along the principal curvature are added to convey shape



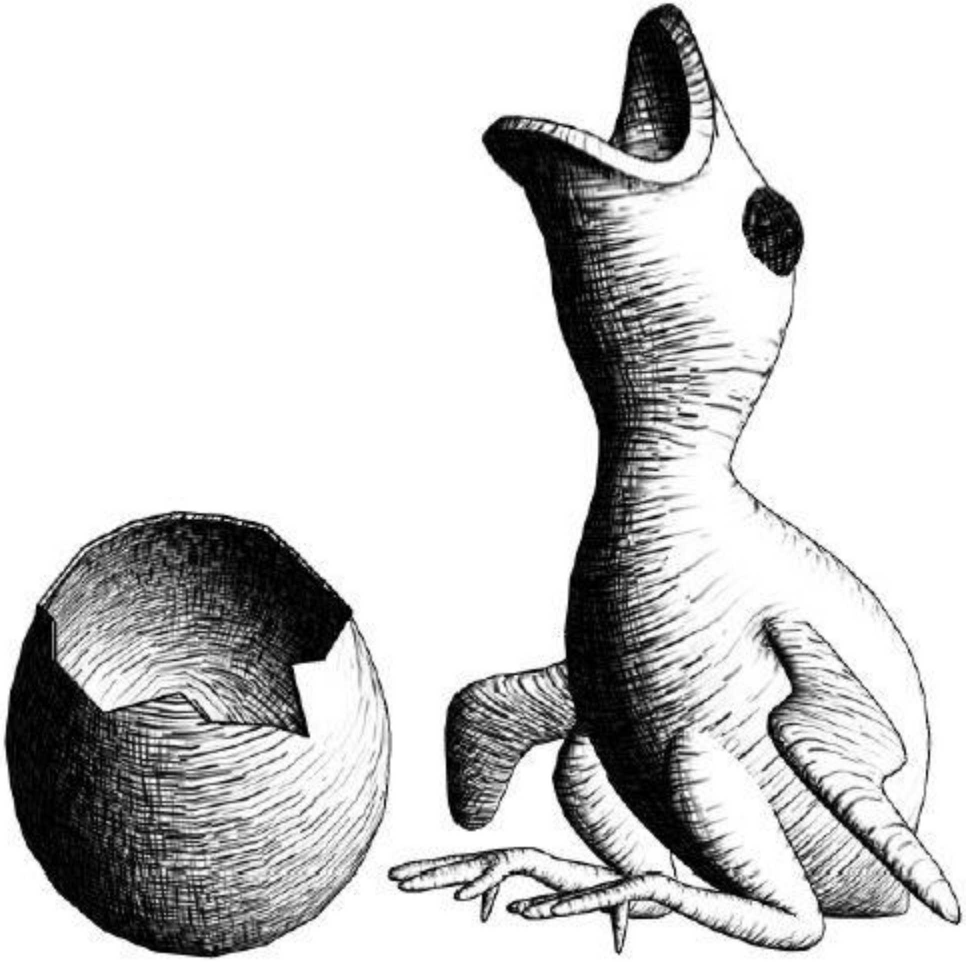
Interrante et al., 1996

Hatching

Applies this illustration style as a function of illumination and others



portion of the tonal art map

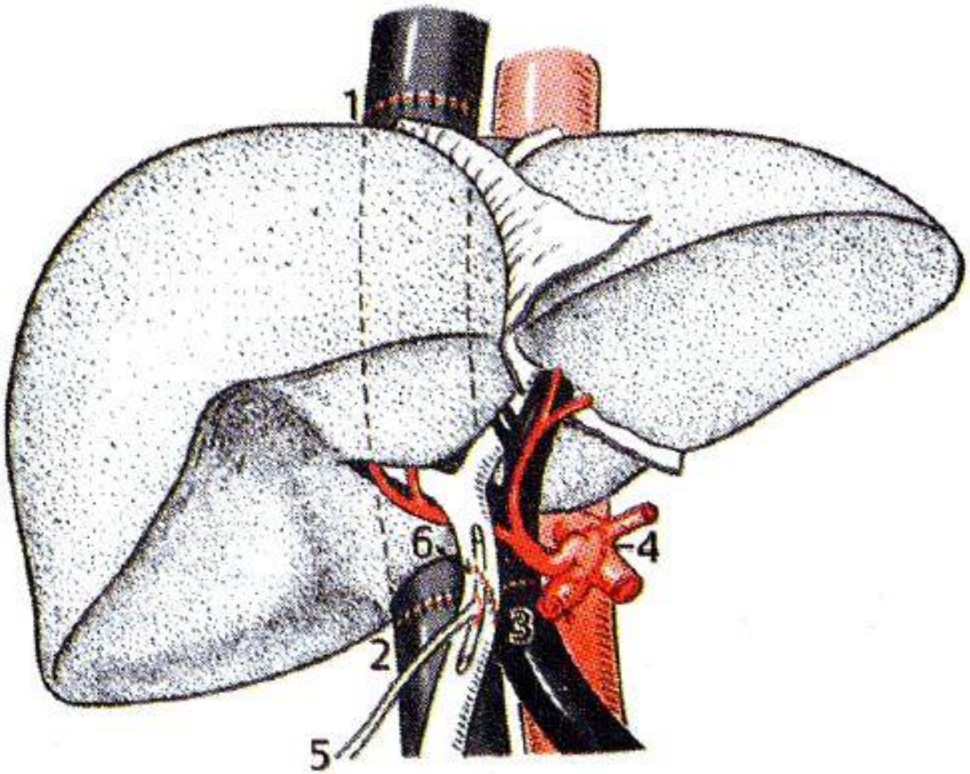


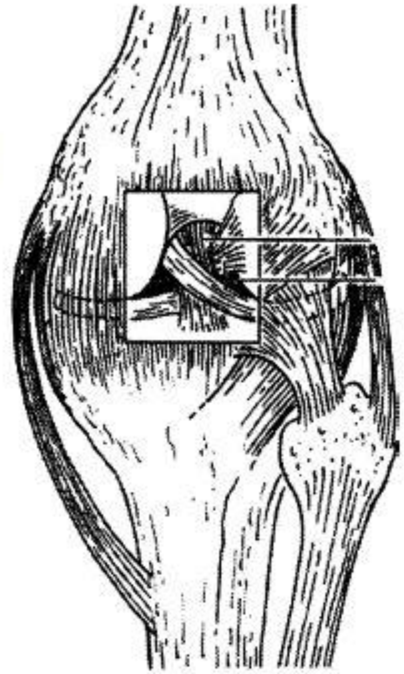
Salisbury et al., 1997

Stippling

Stippling is yet another illustration technique

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



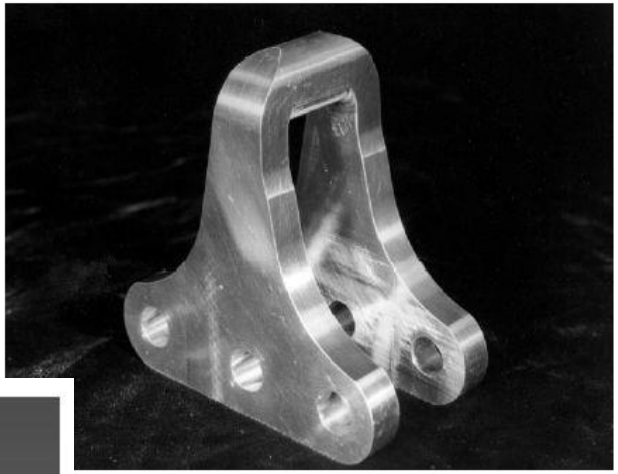


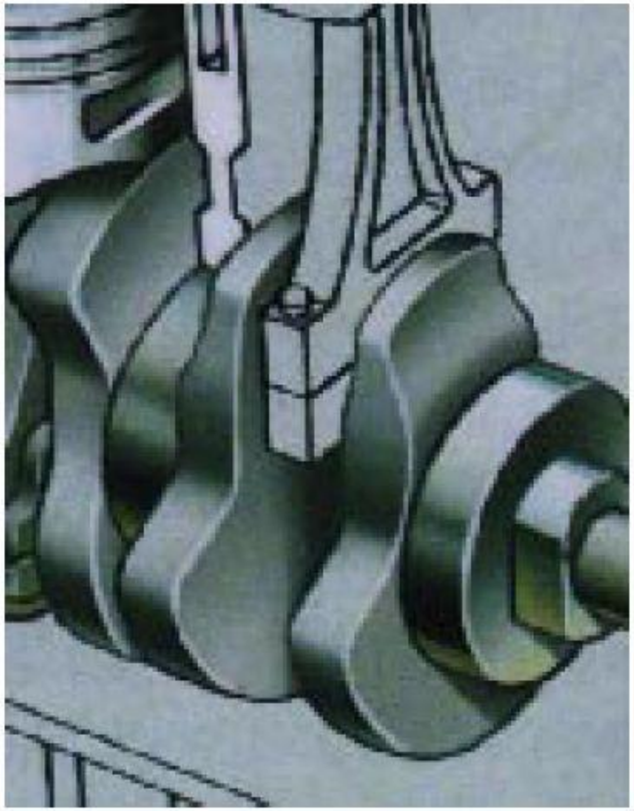
Preim and Bartz, 2007

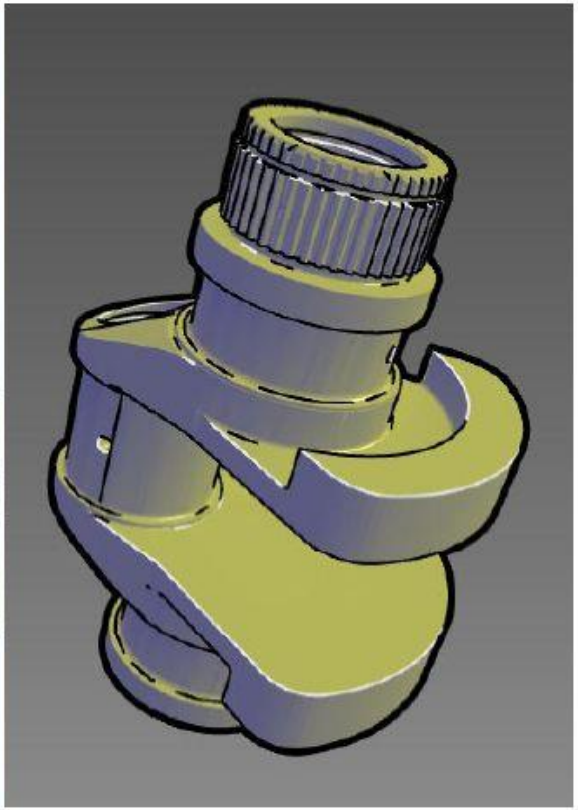
Highlighted Edges

Color interior edges white

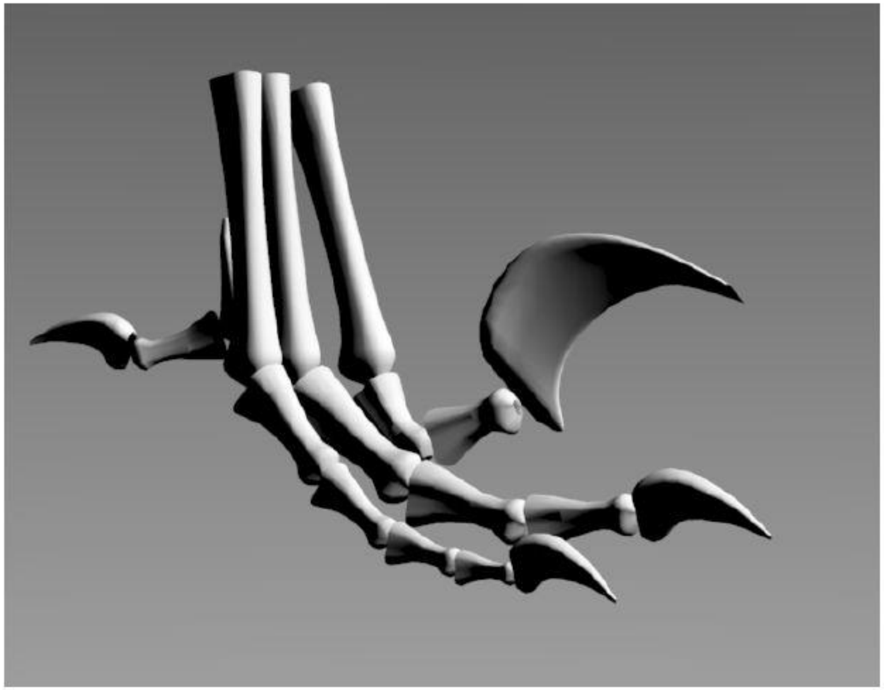
- simulates anisotropic reflections at edges



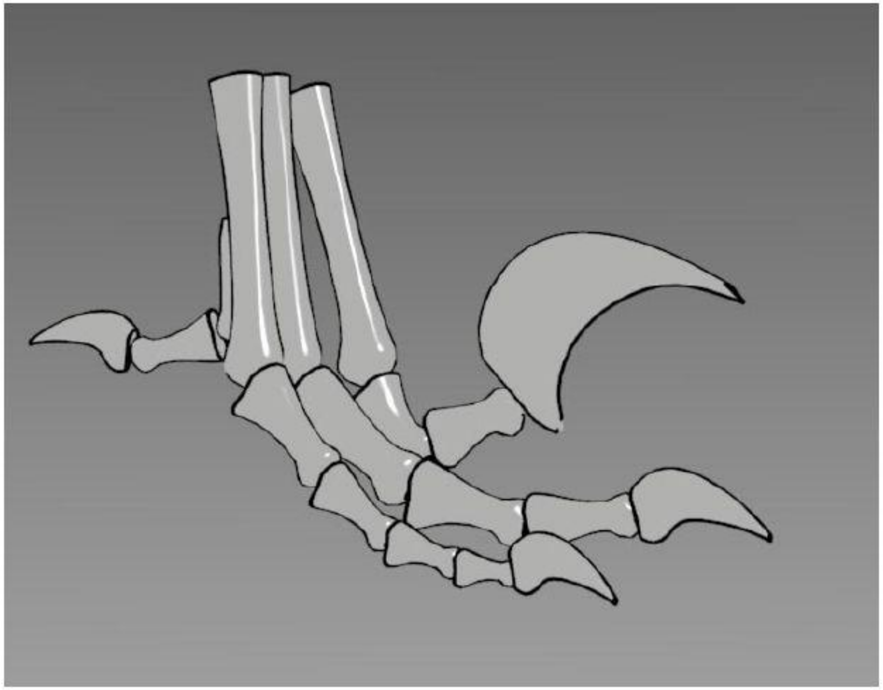




Tone Shading



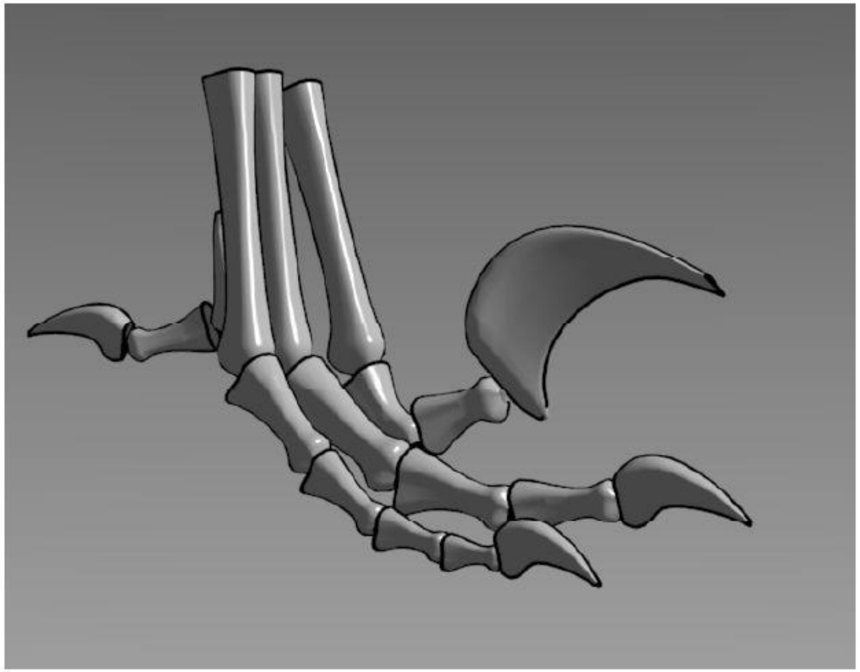
Typical photo-realistic image: diffuse shading removes detail in dark and white areas



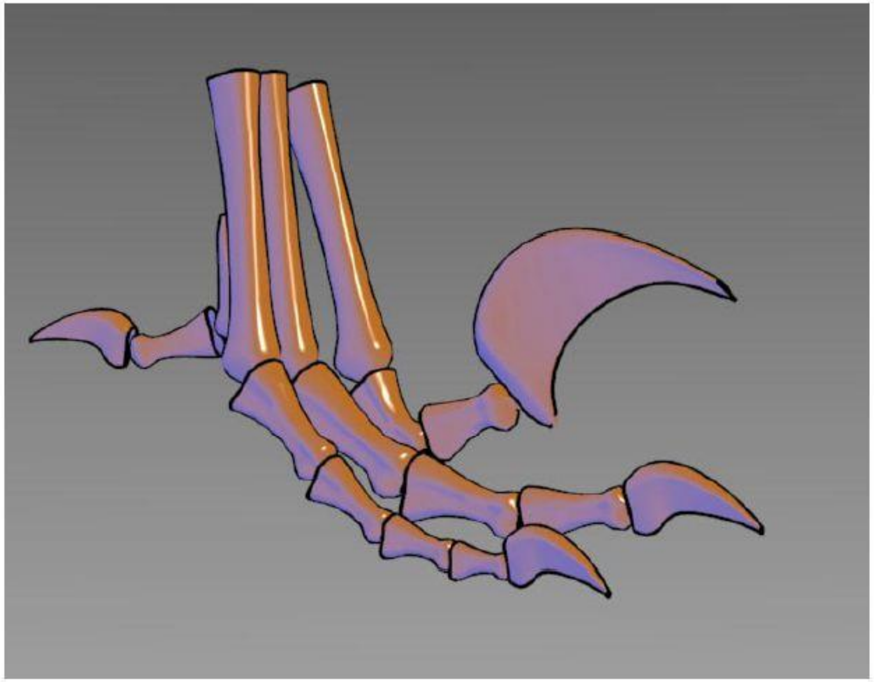
Now with highlights and edges, but without diffuse shading:
shape information is lost

Gooch et al., 1998

Tone Shading



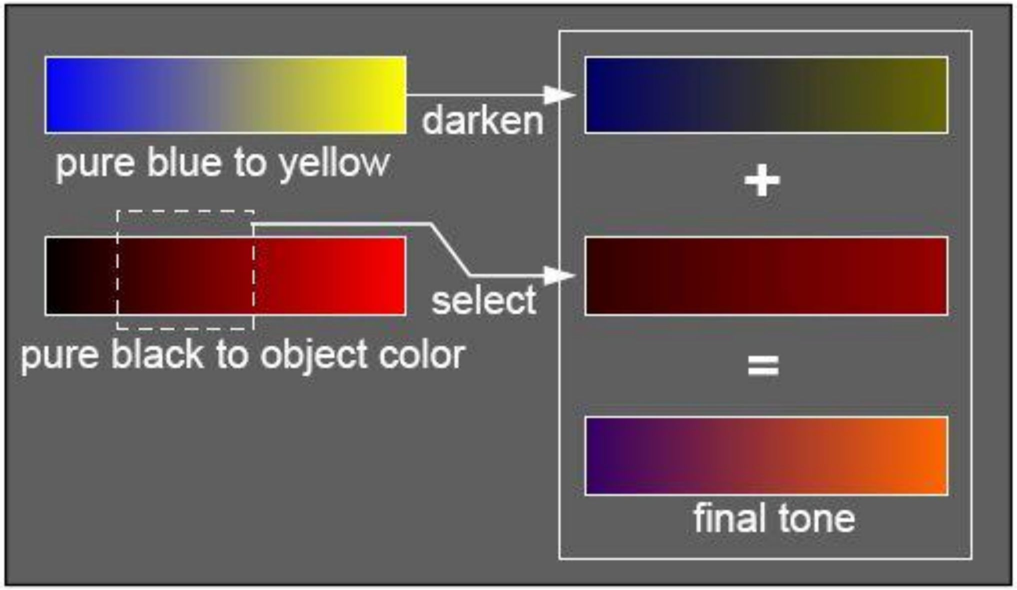
With edge lines and highlights: better, but still detail is lost in dark areas

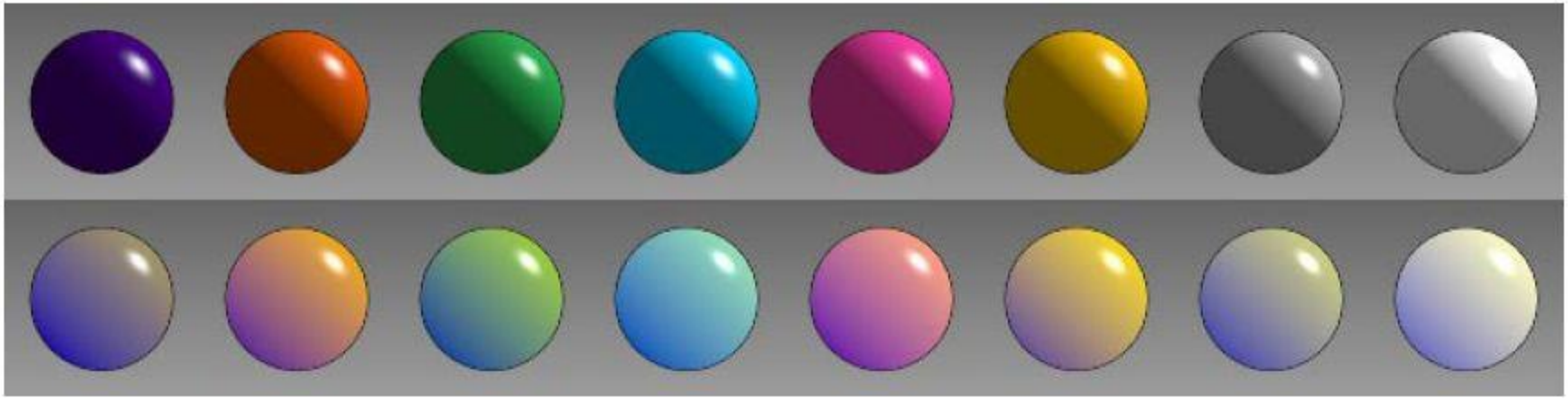


No luminance variations, instead use tonal shading (cool-to-warm shift), along with highlights and edges

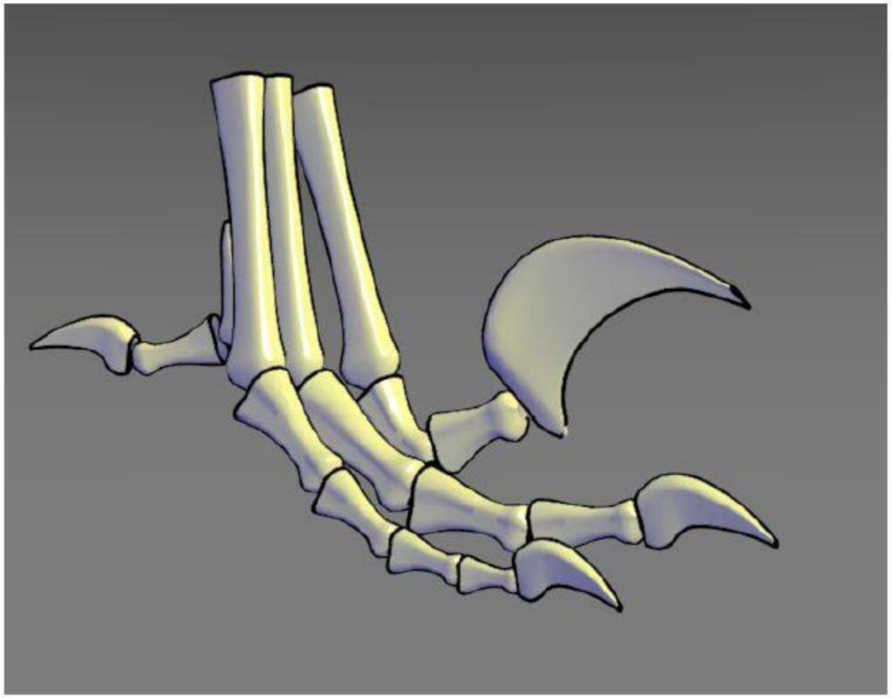
Tone Shading

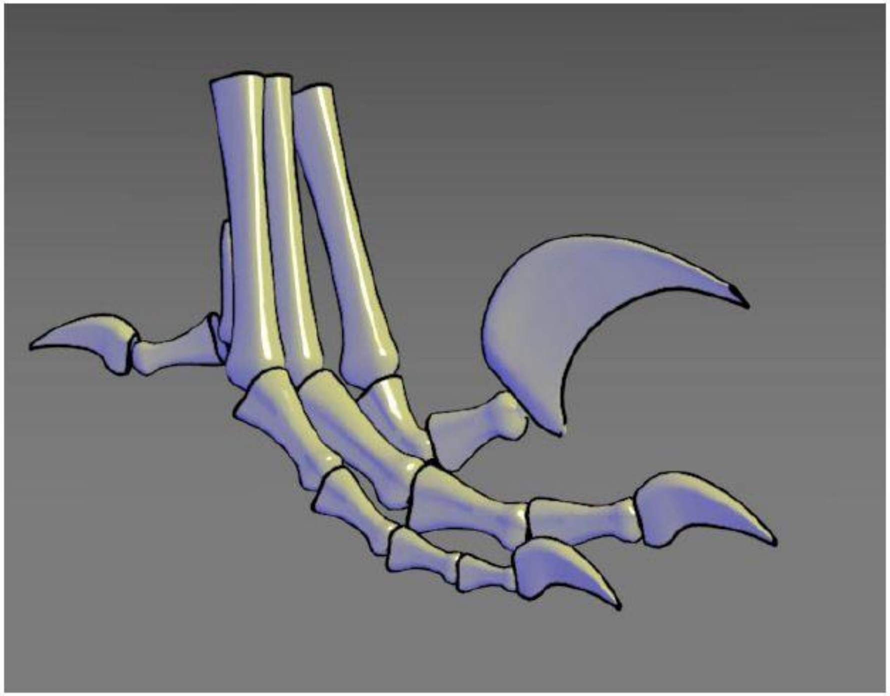
Mix luminance shift and tonal shift with a weighted sum





Tone Shading





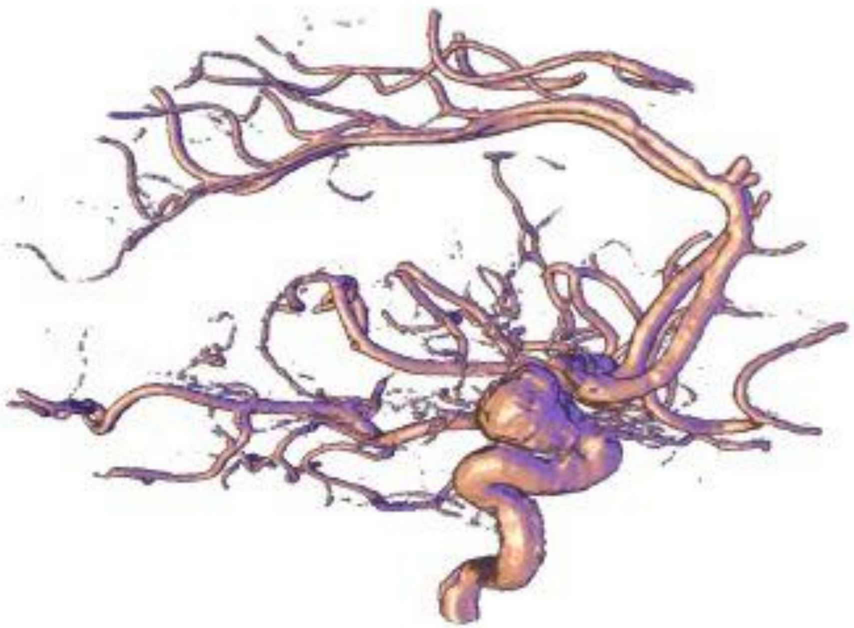
Different settings for weighted luminance/hue tone rendering.
Combines two effects with edges and highlights

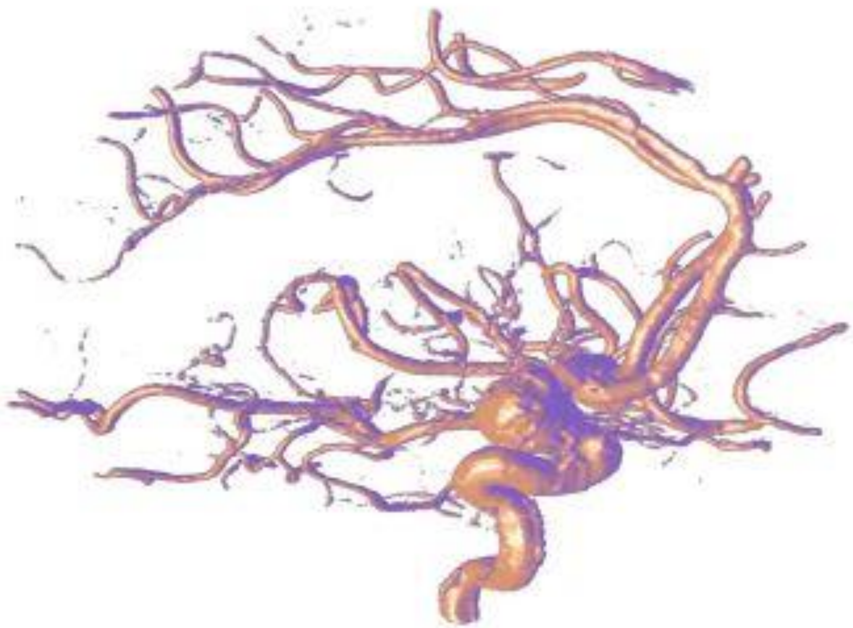
Tone Shading

Specifically for volume visualization

Tone Shading

Specifically for volume visualization



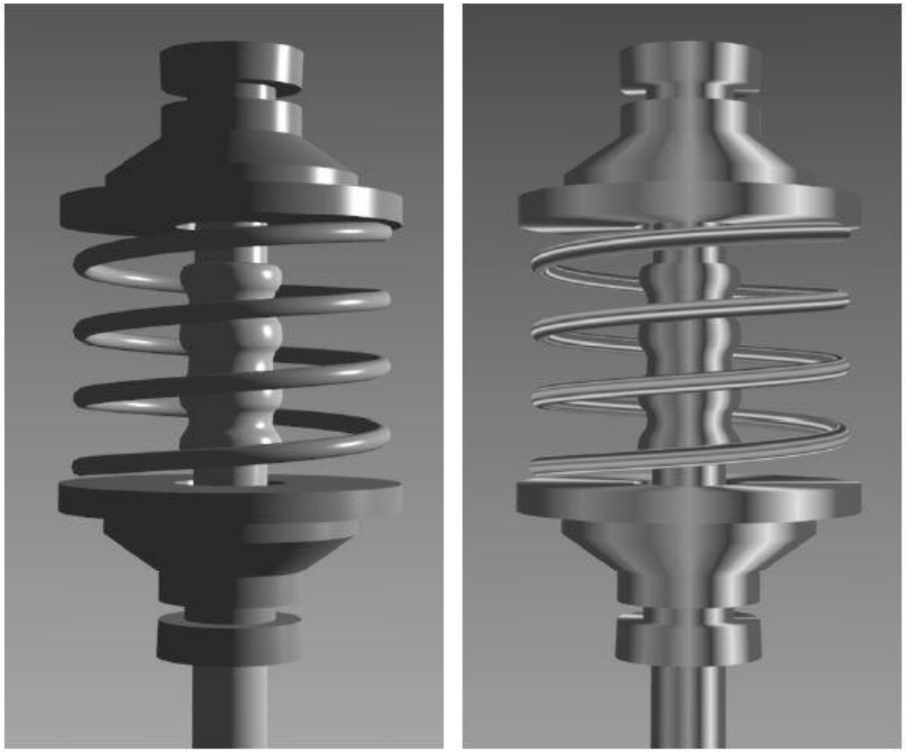


Metal Shading

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.

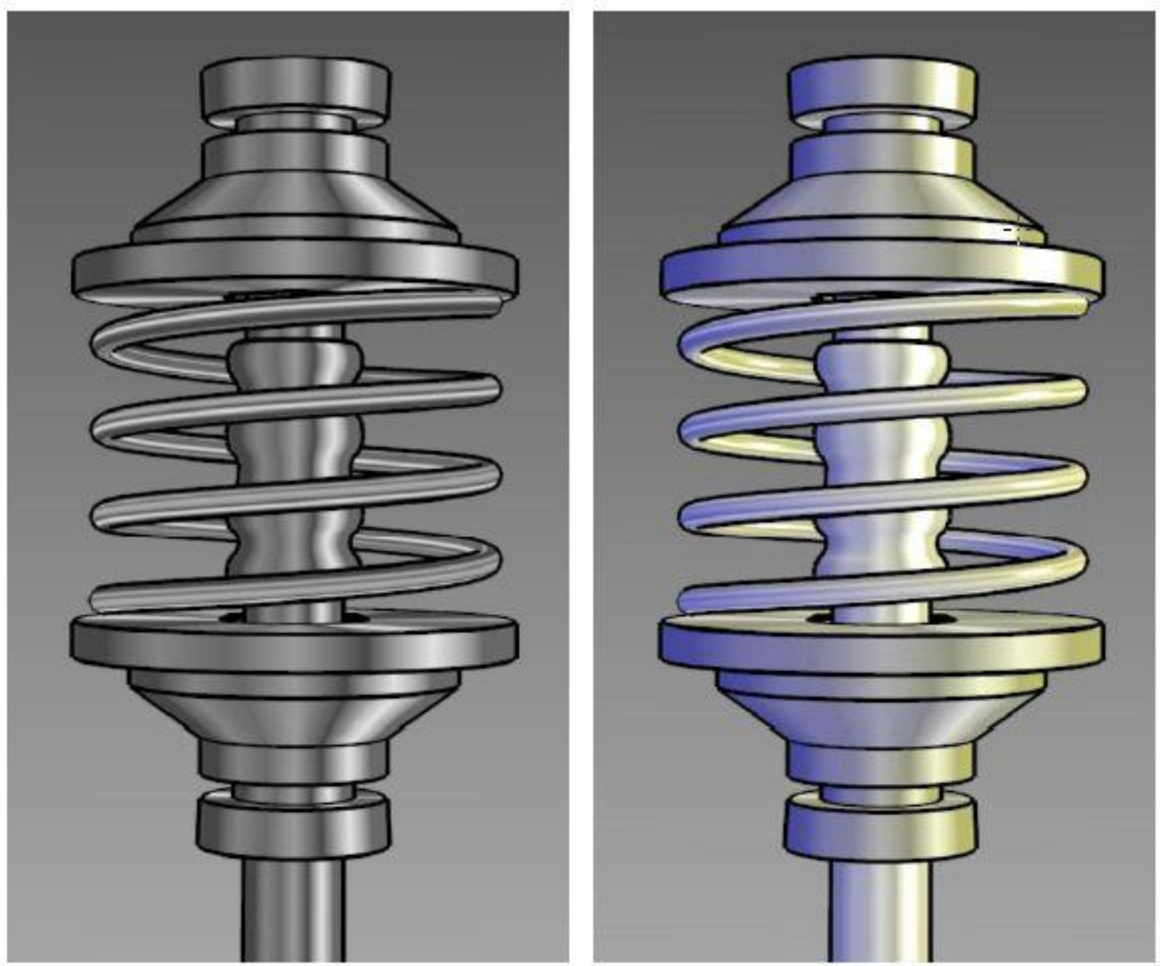
To simulate a milled object, Gooch et al. map a set of 20 stripes of varying intensity (random) along the parametric axis of maximum curvature.



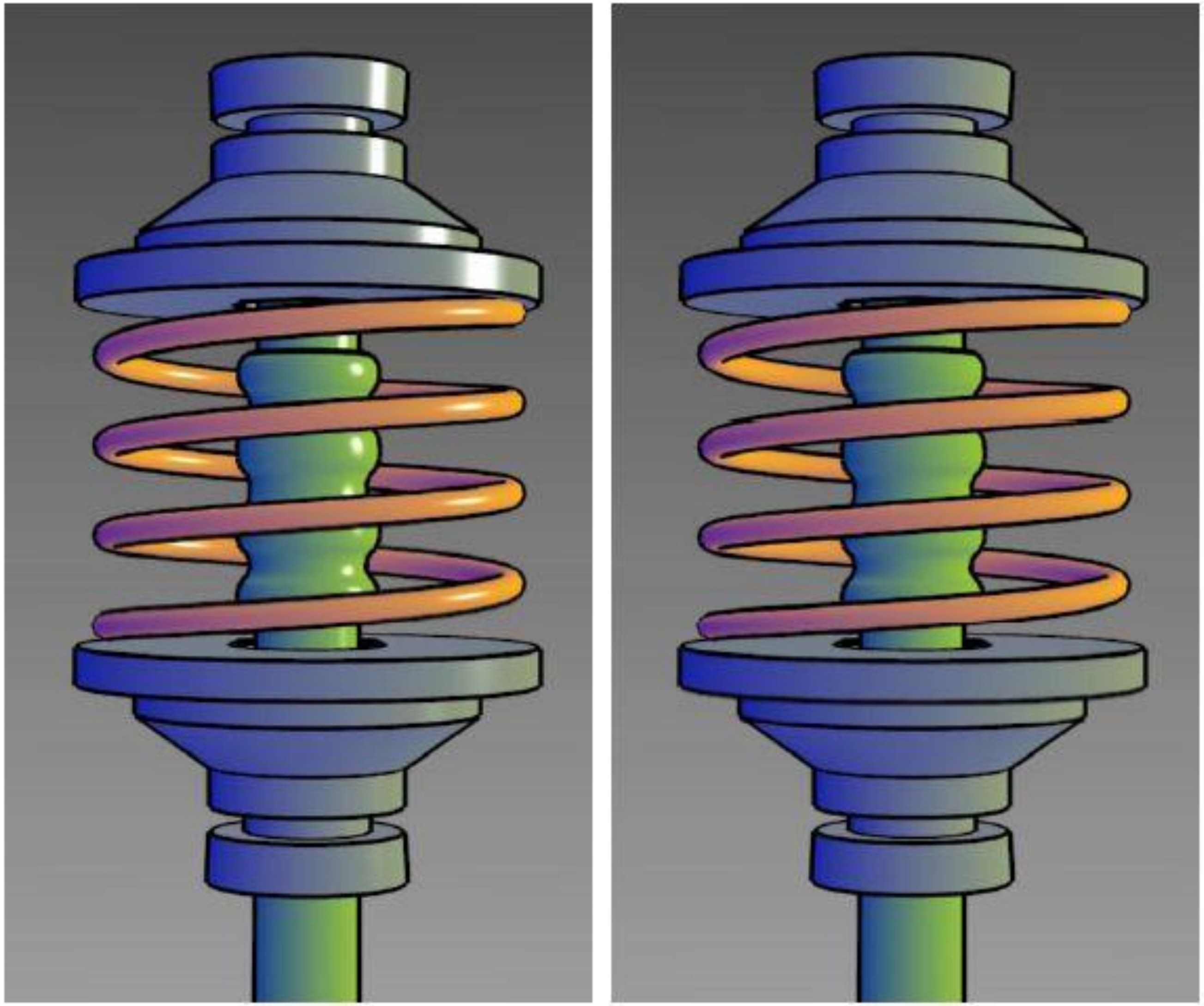
left: no metal
right: metal rendering

Metal Shading

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



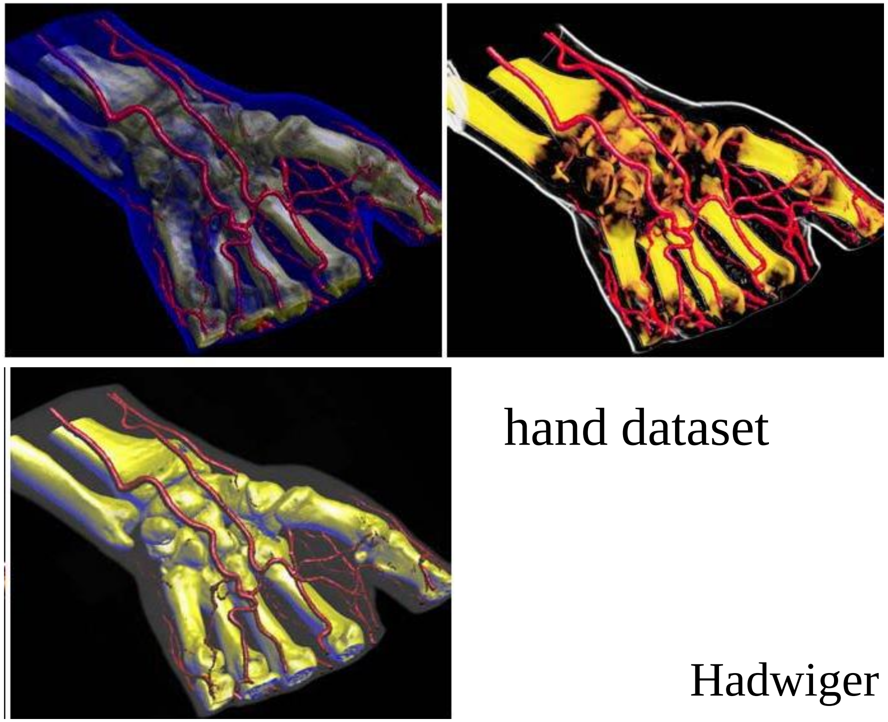
Metal Shading



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

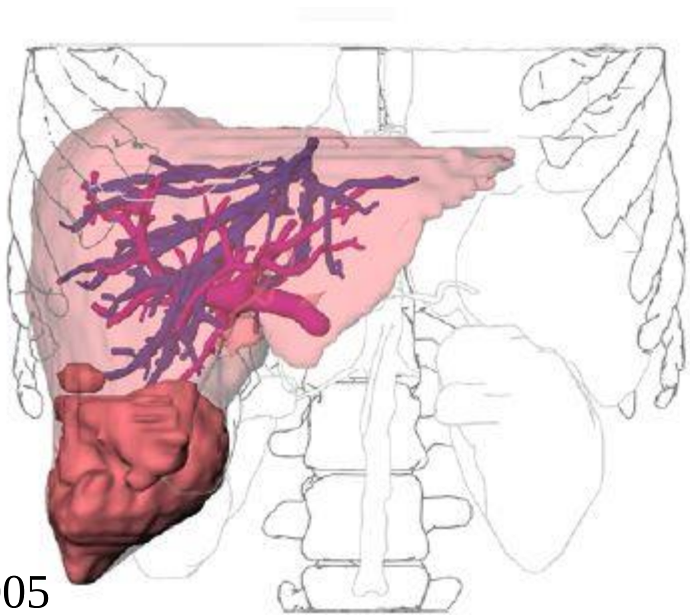
Hadwiger et al. 2003

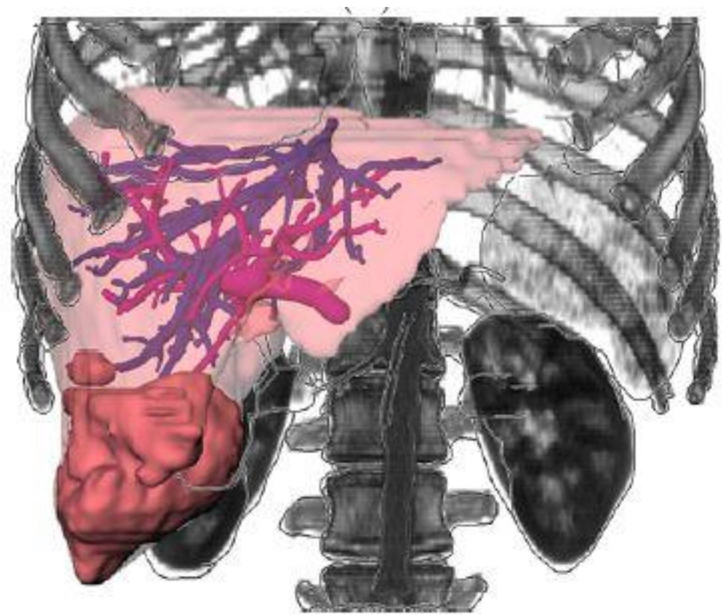
Mixing Rendering Styles

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.

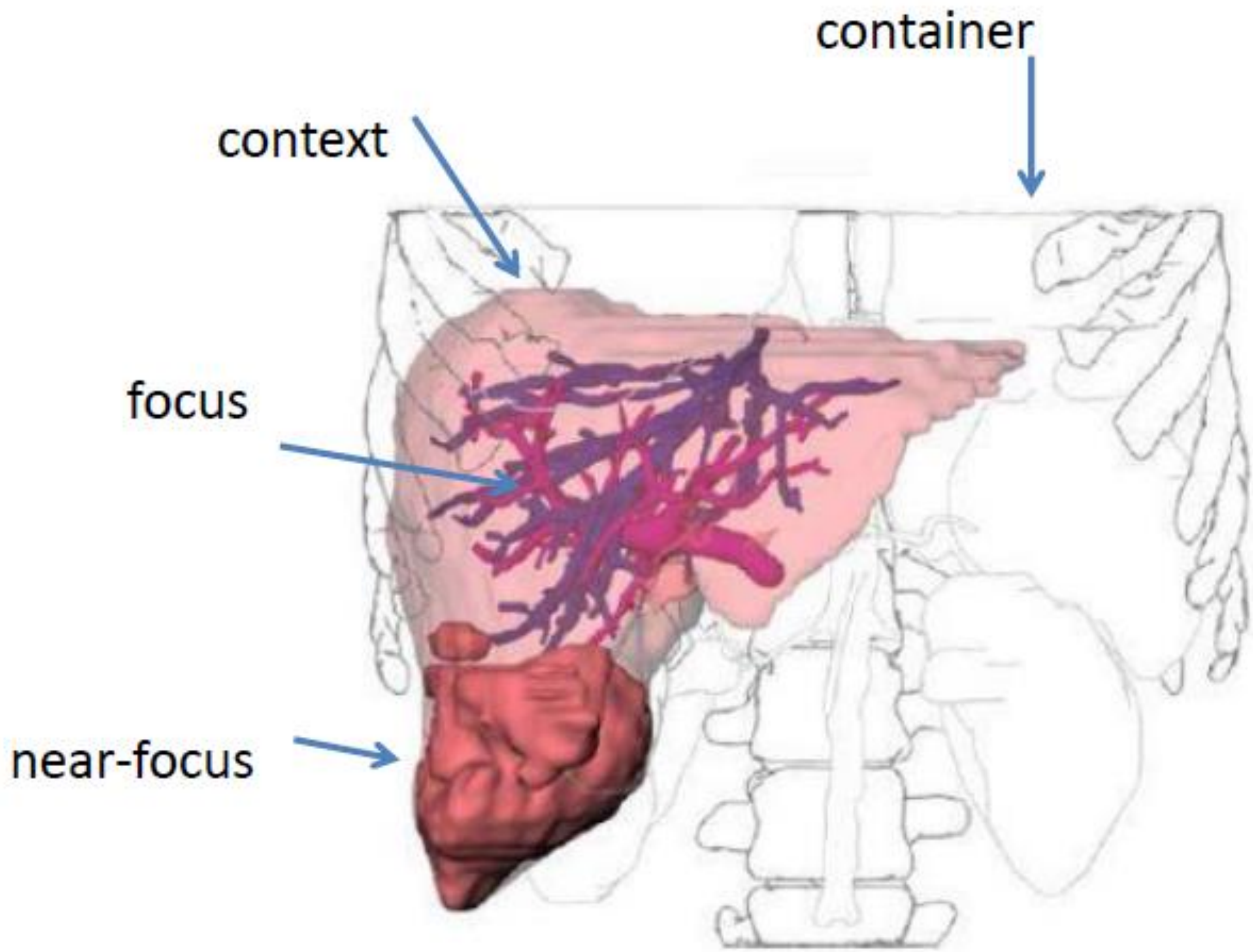
Render these in a certain order to ensure visual consistency





Tietjen et al., 2005

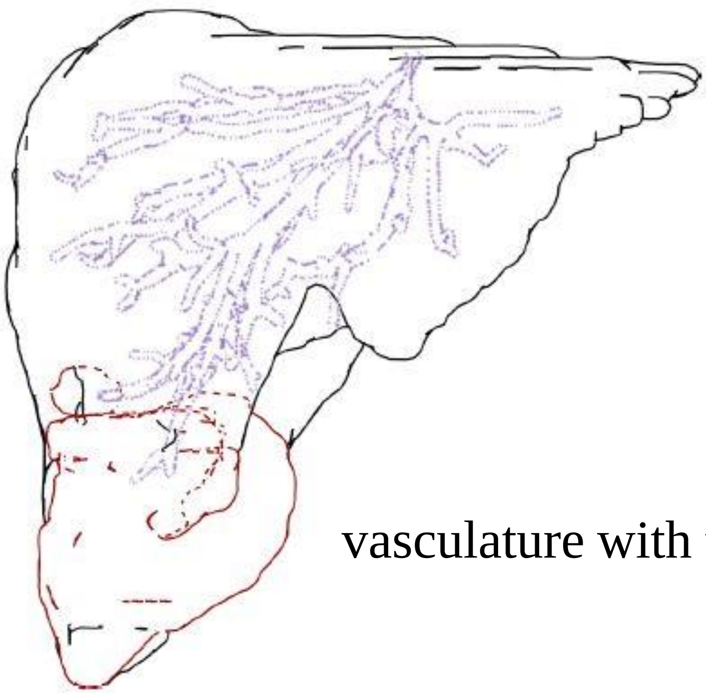
Definitions



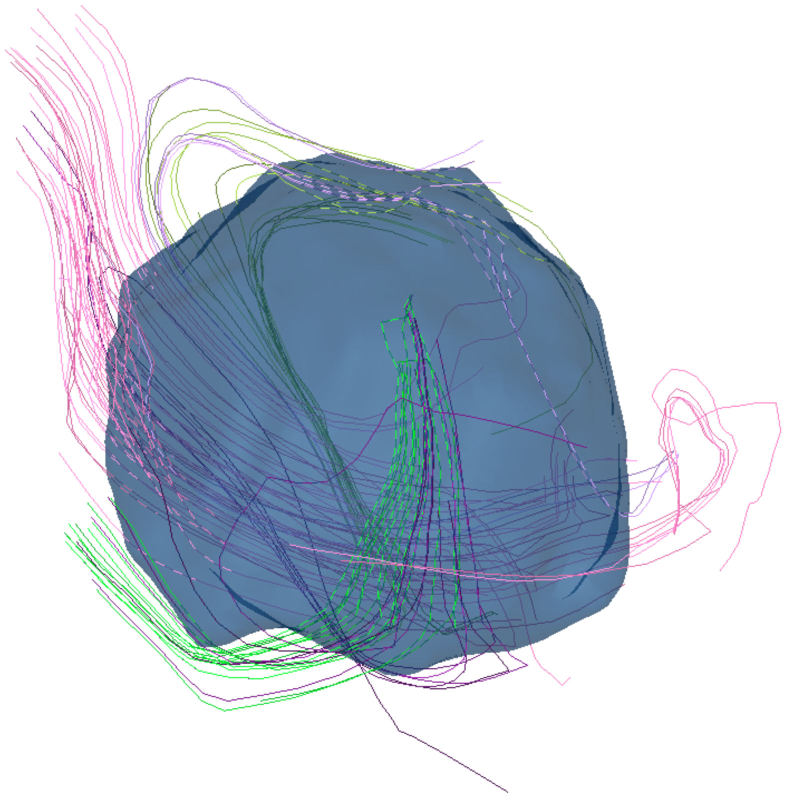
Hidden Structures

Show with different rendering style

- dotted lines, faint lines



vasculature with tumor

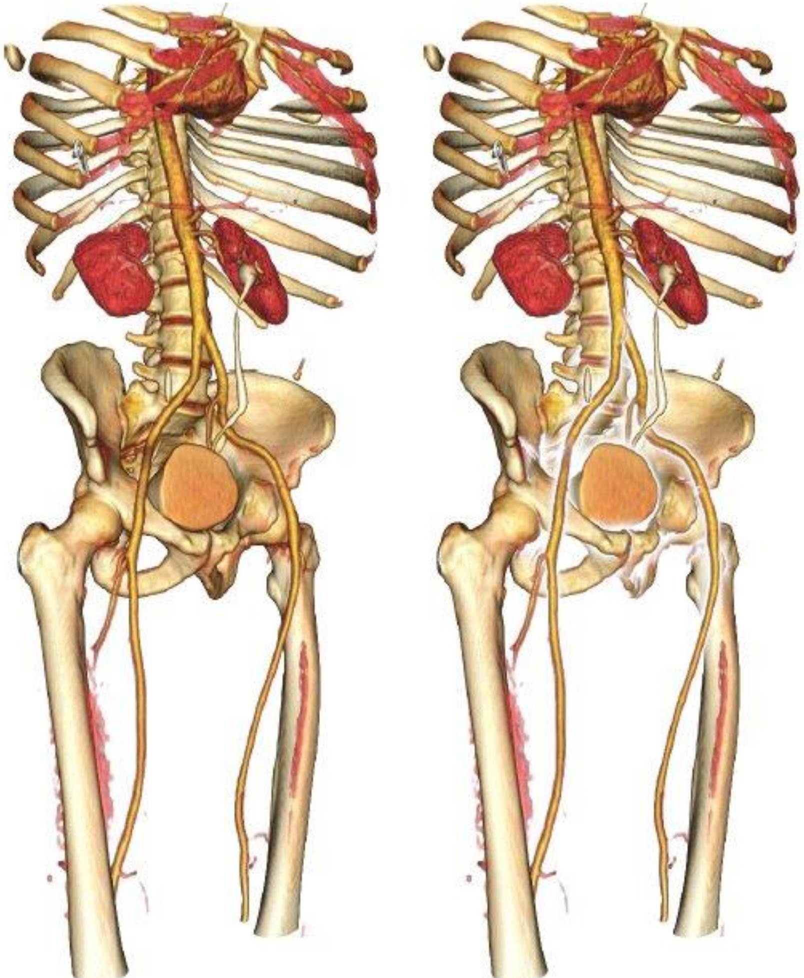


MRI DTI lines inside a tumor

Xin et al., 2006

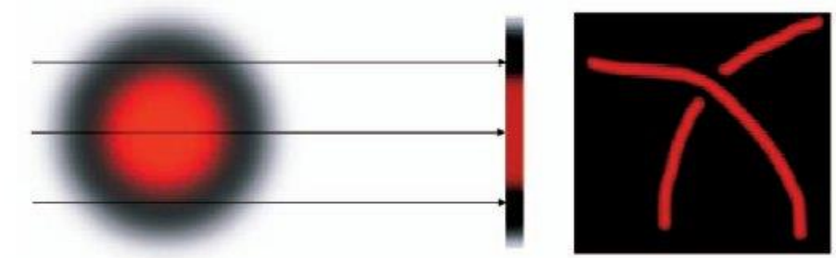
Halos

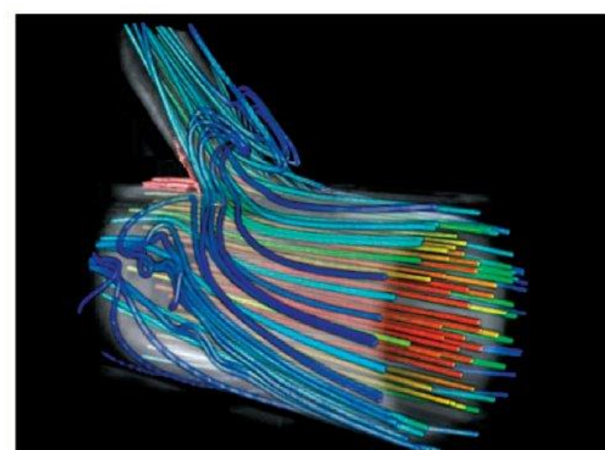
Can enhance depth perception



no halos with halos

Bruckner et al., 2006

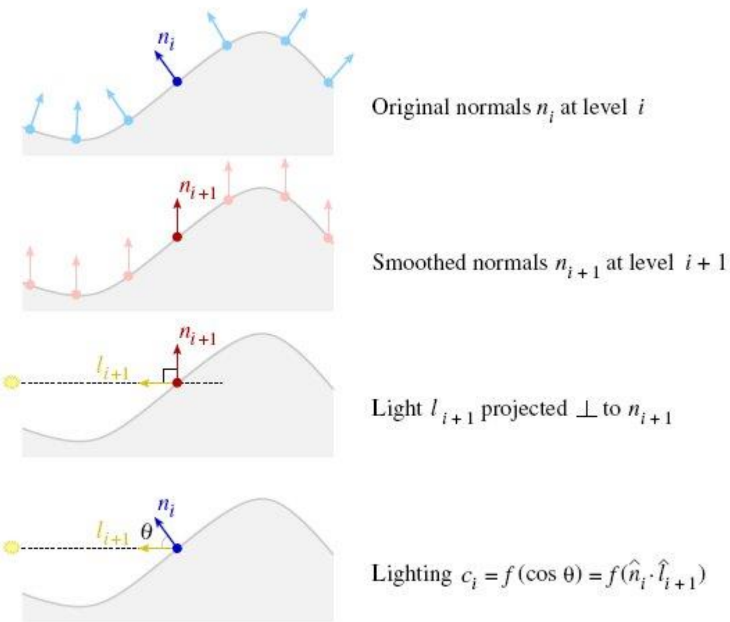


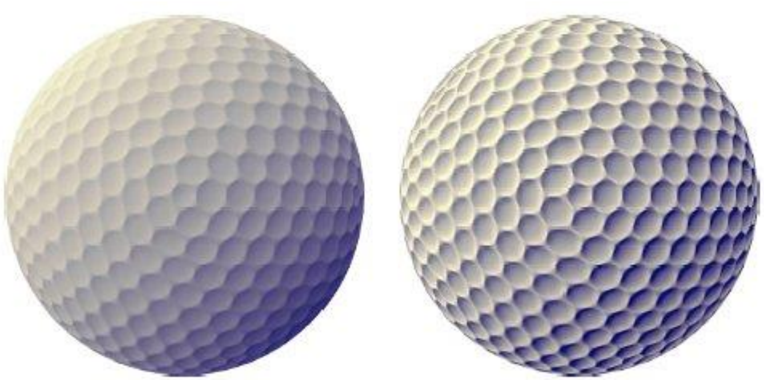


Wenger et al., 2006

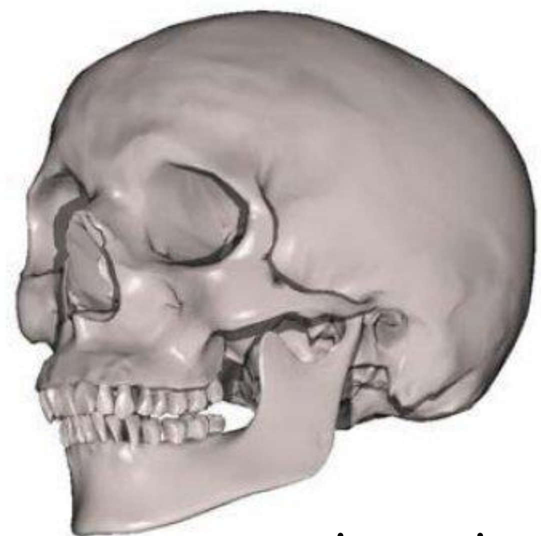
Illustrative Lighting Effects

Inconsistent shading to show depth:





consistent



inconsistent

Rusinkiewicz et al., 2006

Lee et al., 2006

Illustrative Lighting Effects

Bryce Canyon
early morning

Inconsistent
shading

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

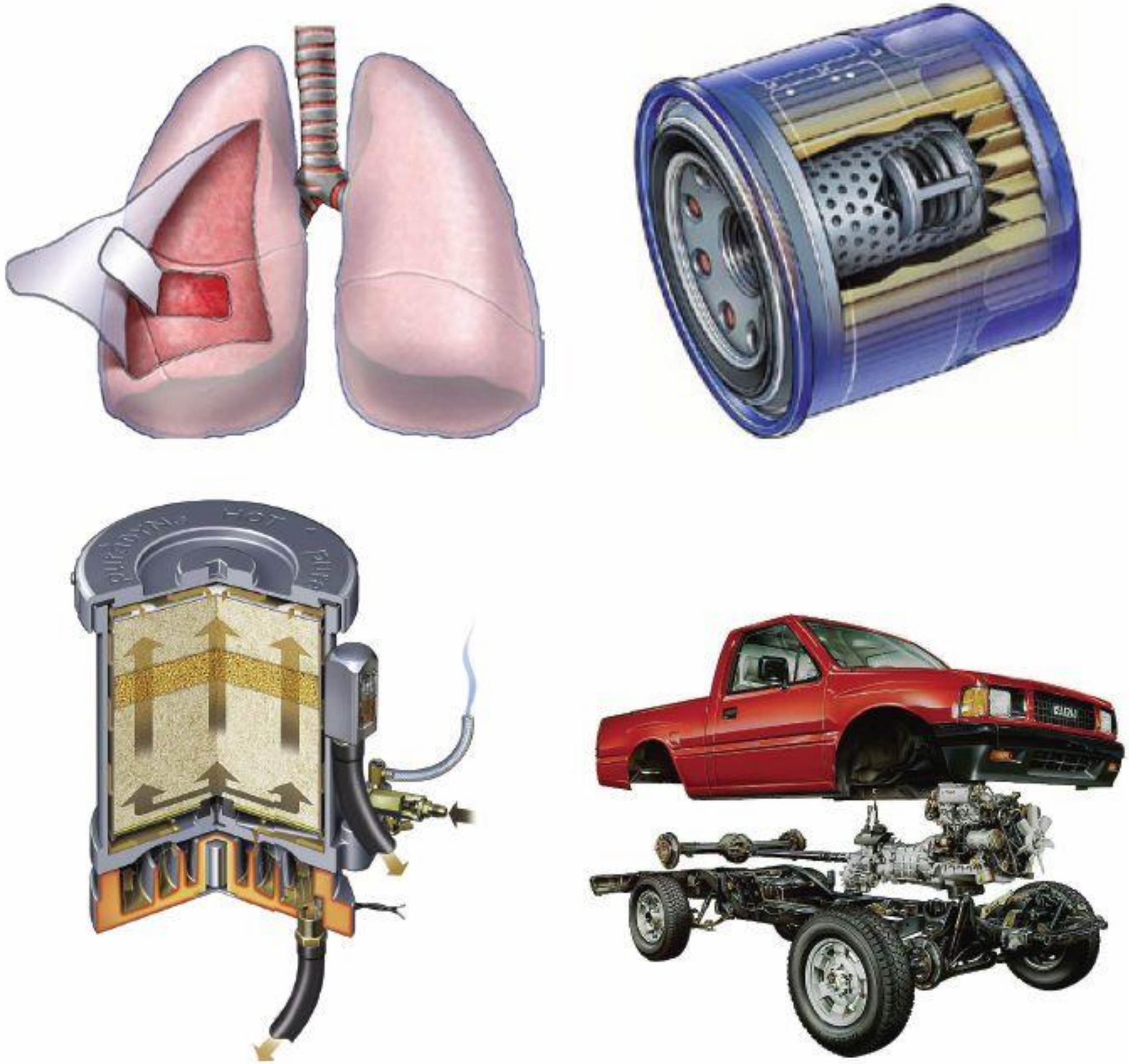
Low-level abstraction:

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

High-level abstraction

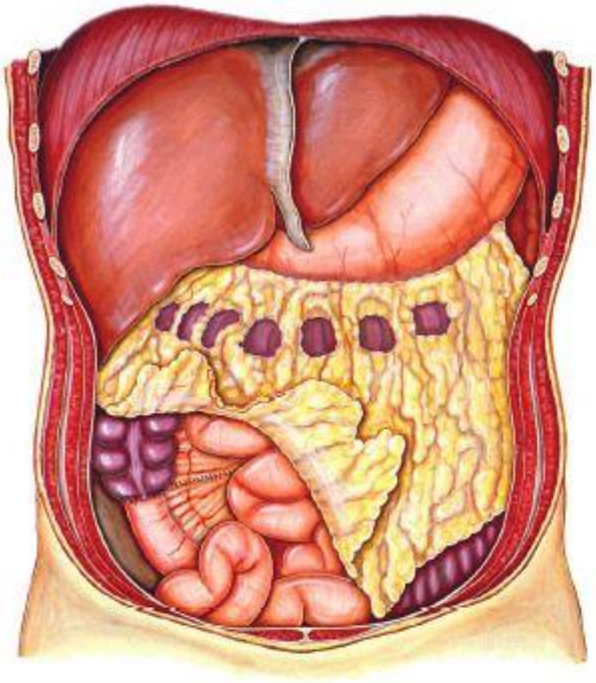
- deal with what should be visible and recognizable and at what level of detail
- this should be importance-driven, that is, the current visualization goal controls feature rendering style and visibility
- we will discuss these next
- smart visibility: cutaways, breakaways, ghosting, exploded views

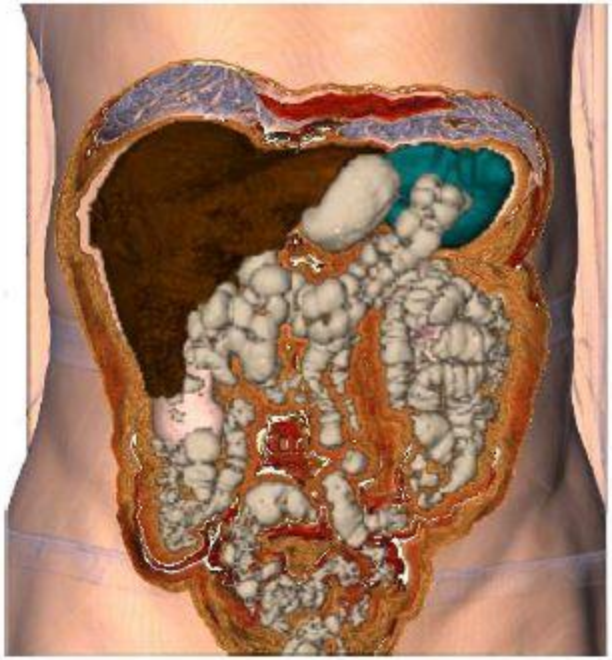
Cut-Aways



Viola et al., 2005

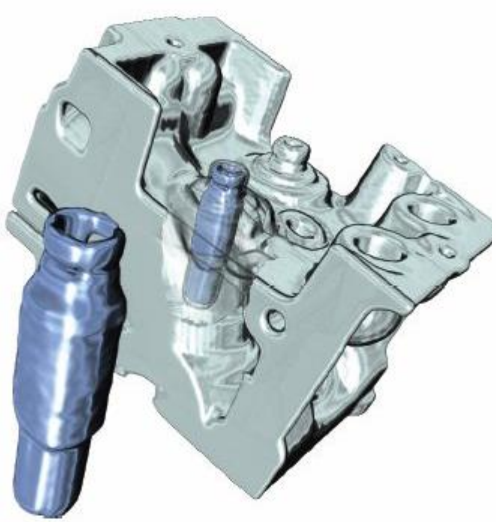
Cut-Aways

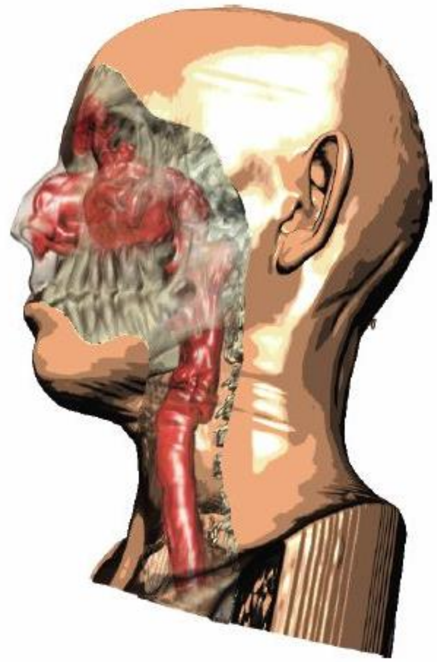




Viola et al., 2005

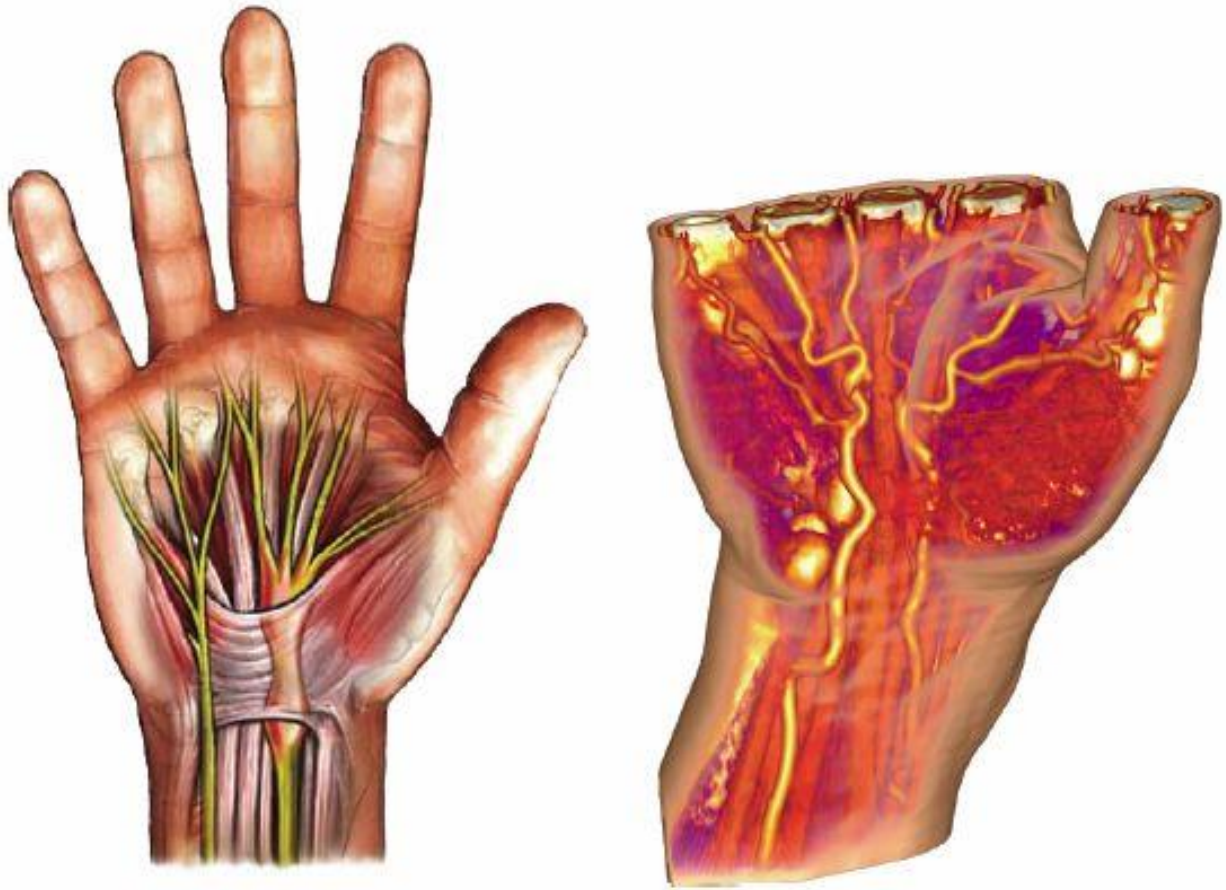
Ghosting





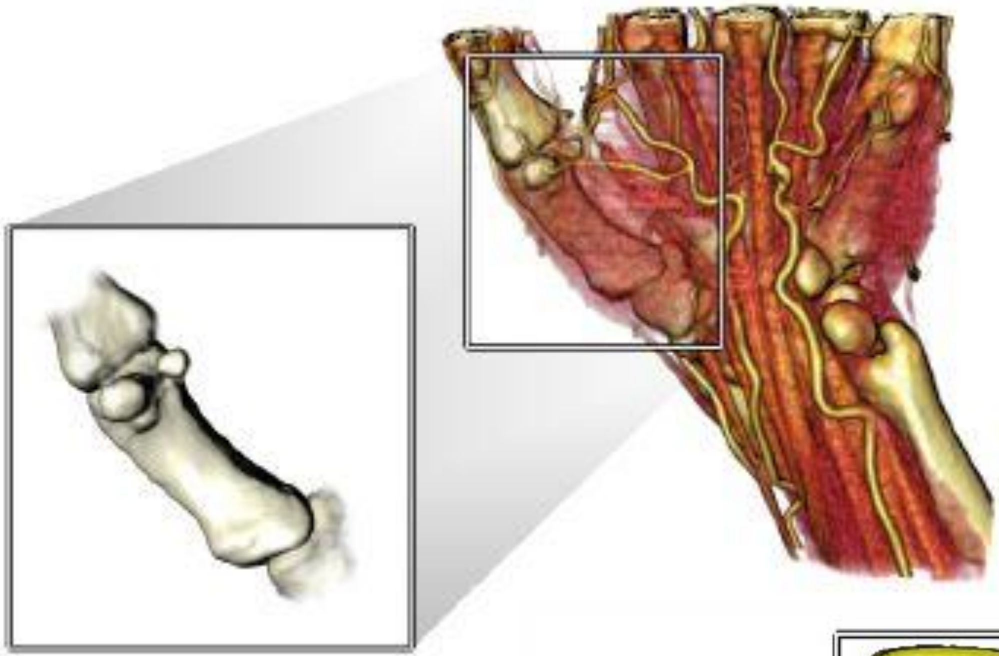
Bruckner et al., 2006

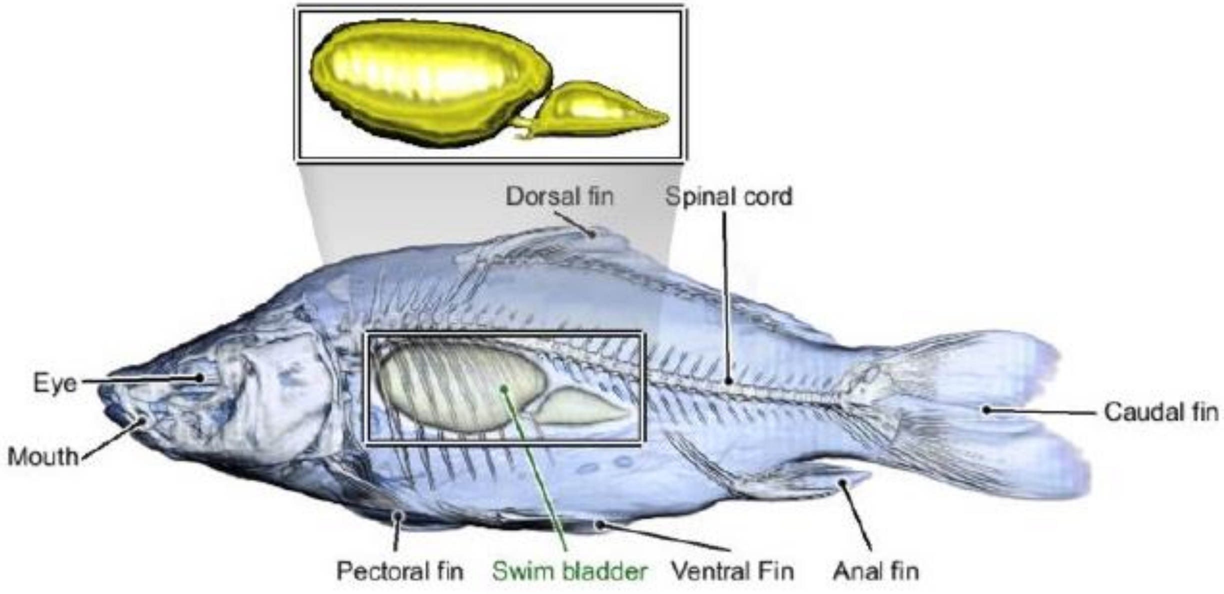
Focus + Context



Bruckner et al., 2006

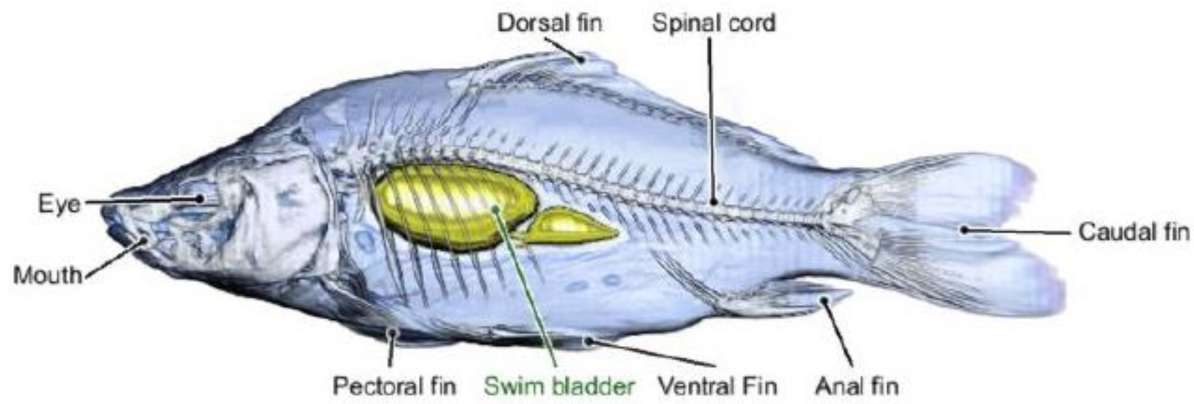
Fans





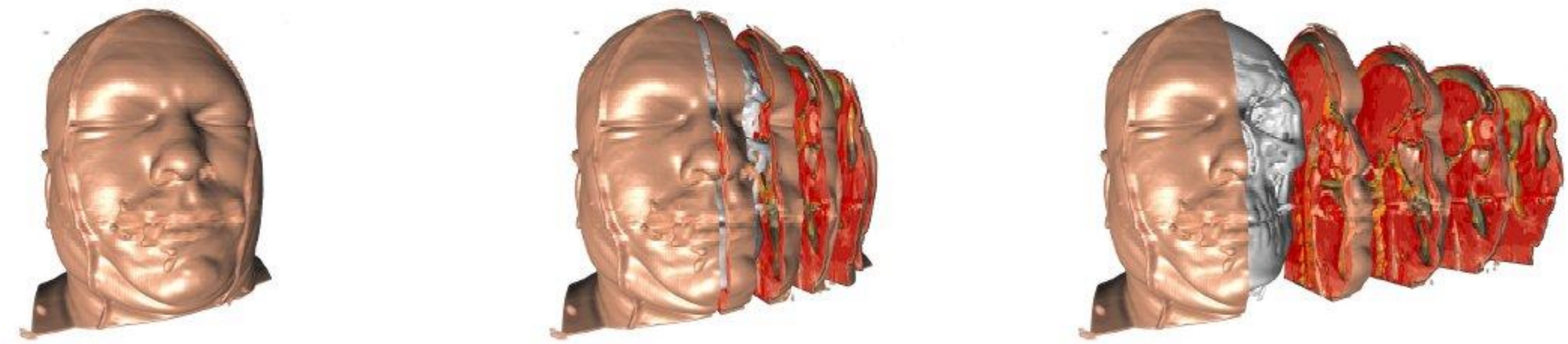
Bruckner et al., 2005

Labeling And Other Abstractions



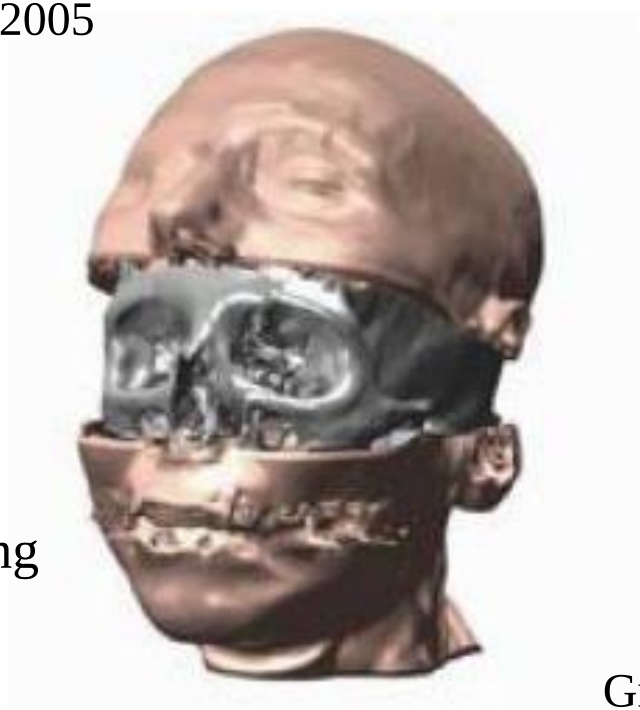
Bruckner et al., 2005

Displacement With Context



exploded views

Bruckner et al., 2005



volume splitting

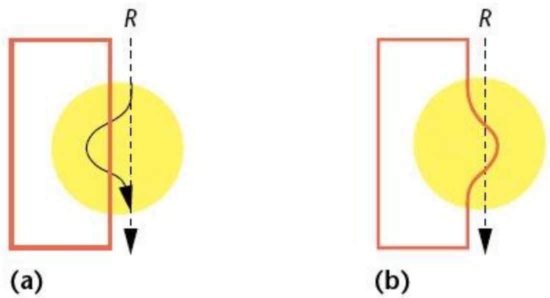
Islam et al., 2004

dynamic multi-volumes

Grimm et al., 2004

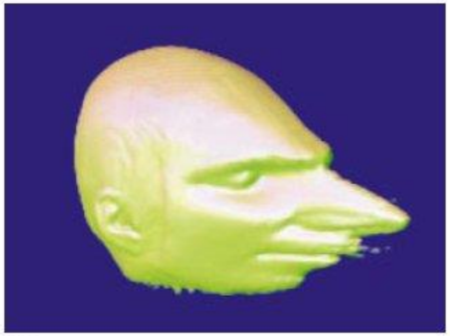
Distortion Techniques

Ray deflectors:



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)

Kurzion et al., 1997

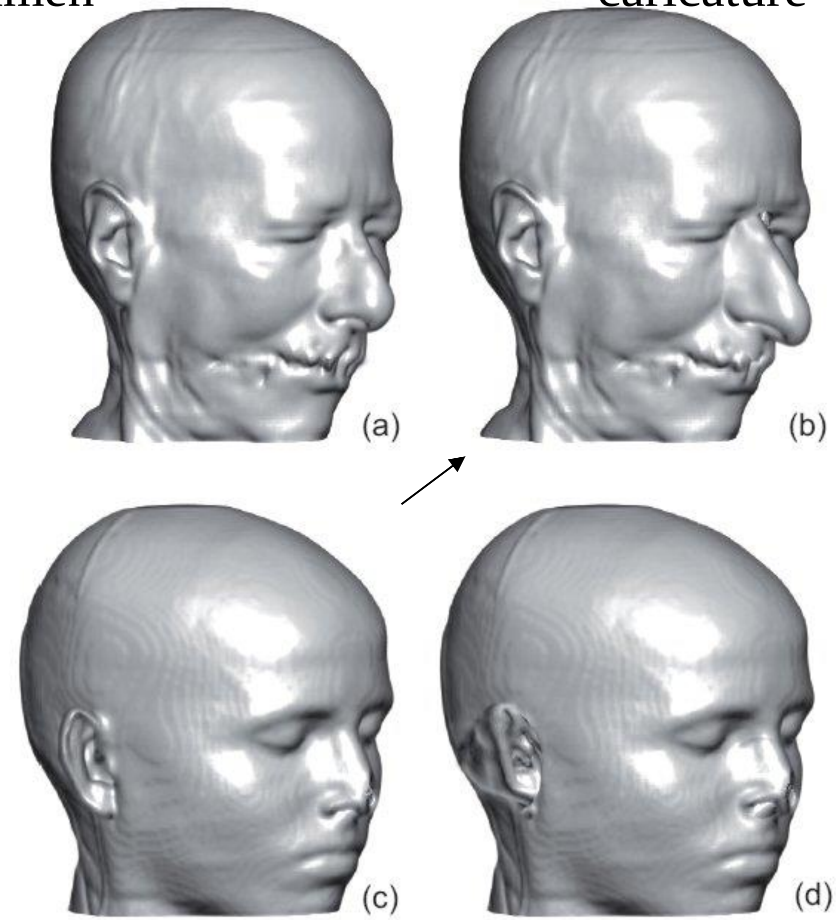
Correa et al., 2006

Explaining Differences Via Exaggerations

Caricature visualization

reference model | specimen | caricature

specimen | caricature



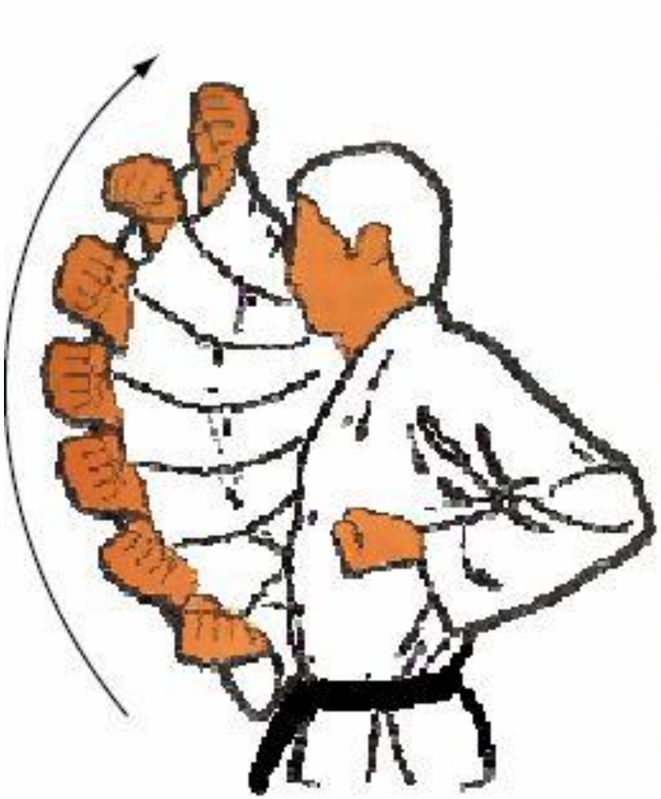
ref model

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

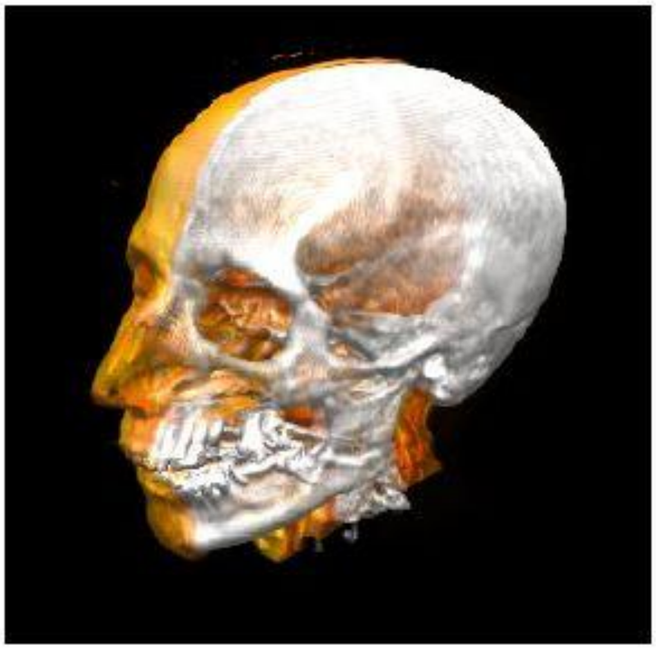
Fig. 10. A caricaturistic volume deformation. In (a) and (c) iso-surface renderings of the two datasets are shown. In (b) a caricature by volume deformation is shown using (c) as reference model. In (d) a caricature of (c) is shown using the features of (a) as reference model.

Rautek et al., 2006

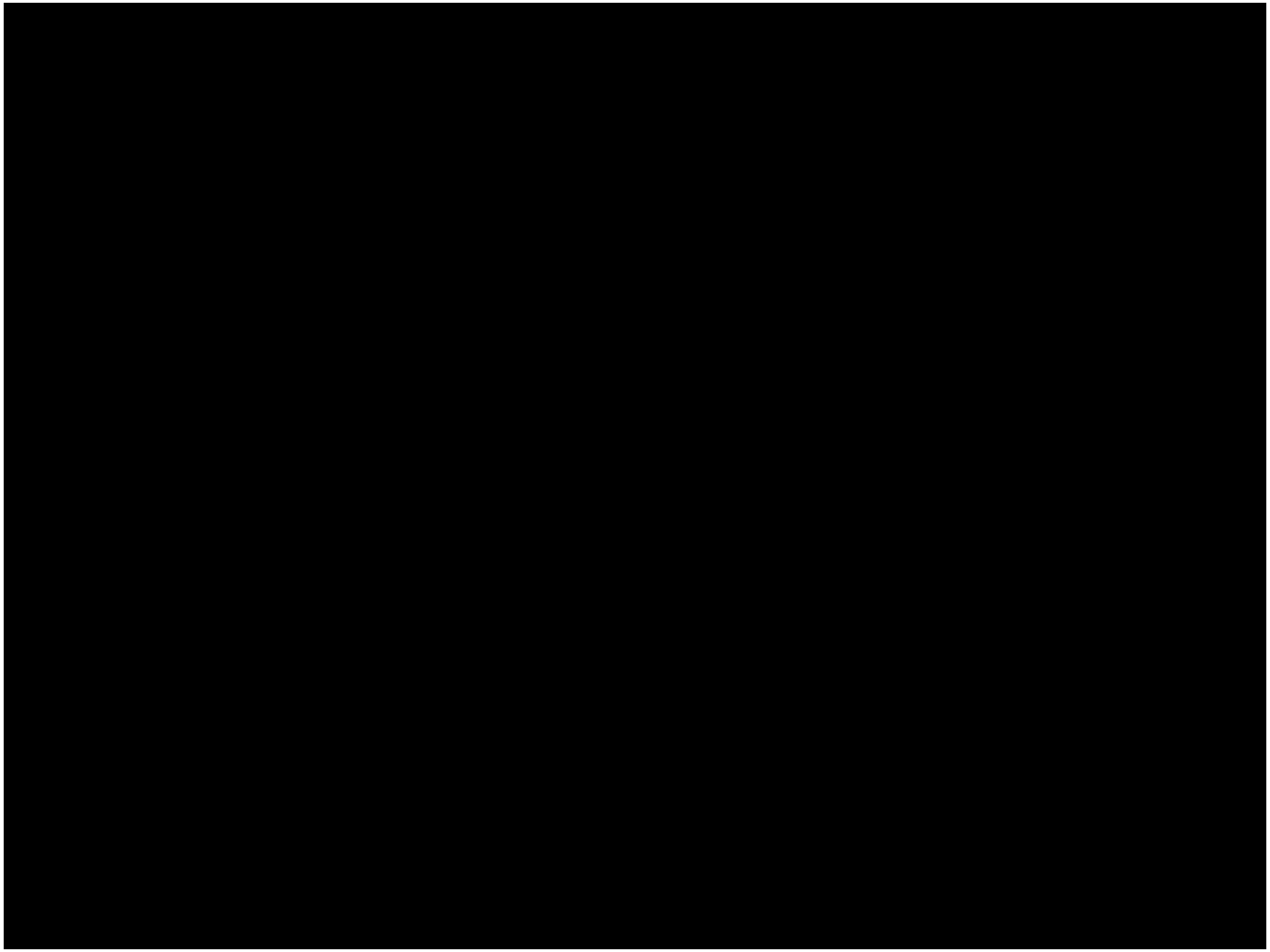
View Composition



Rendering Mode Composition

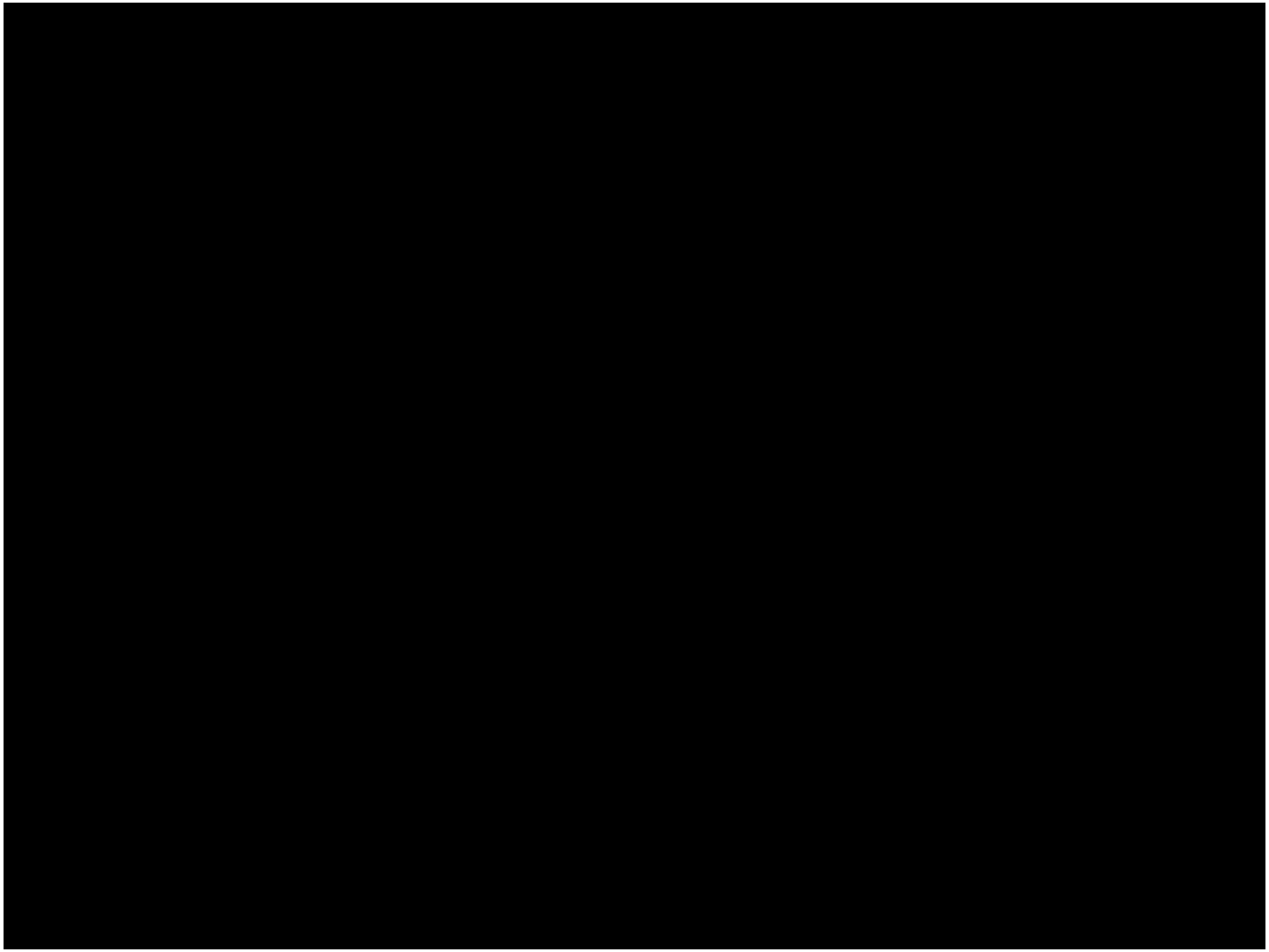


Importance-Driven Visualization



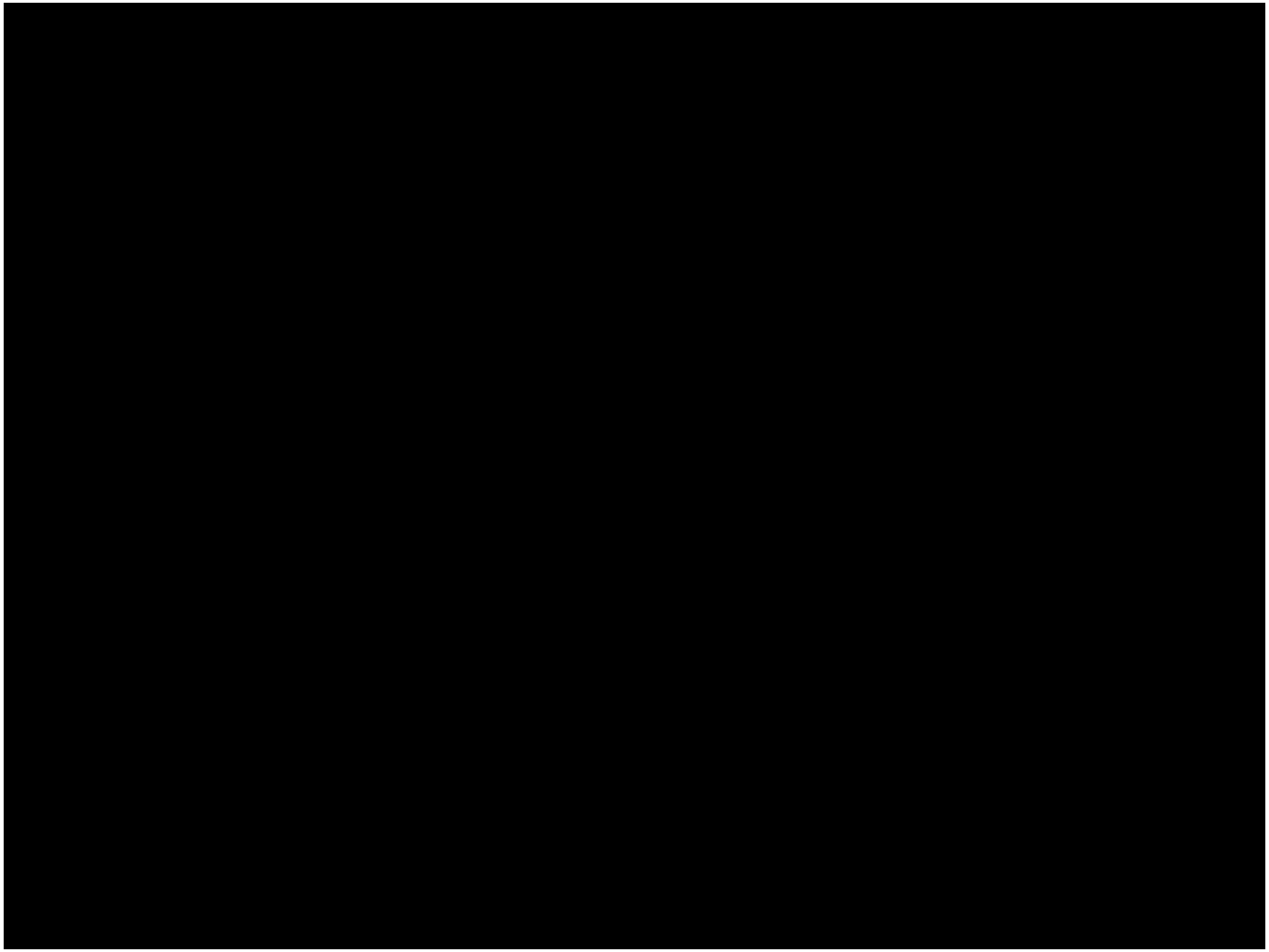
Viola et al., 2005 (colorOpacity)

Importance-Driven Visualization



Viola et al., 2005 (conicalMImP)

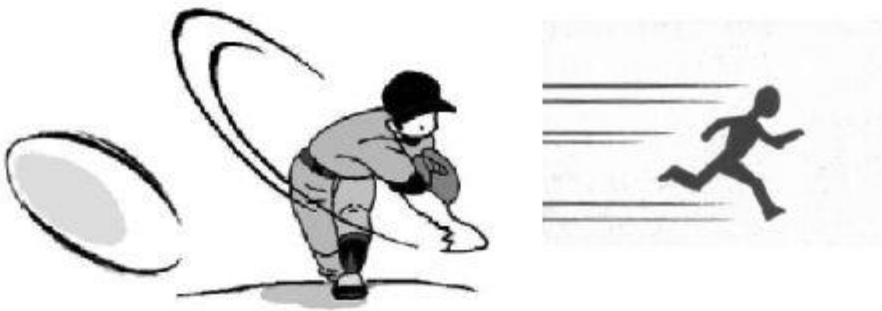
Importance-Driven Visualization



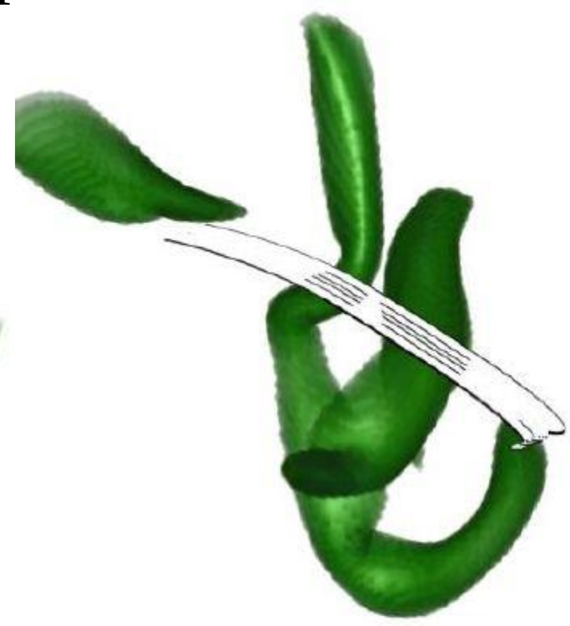
Viola et al., 2005 (animMonsterAbdomenMImP)

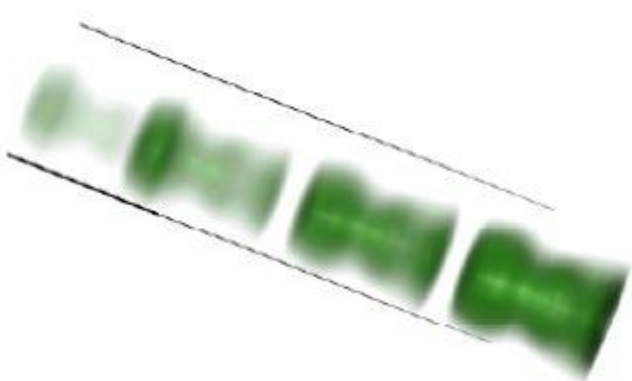
Time-Varying Data

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



typical illustration metaphors





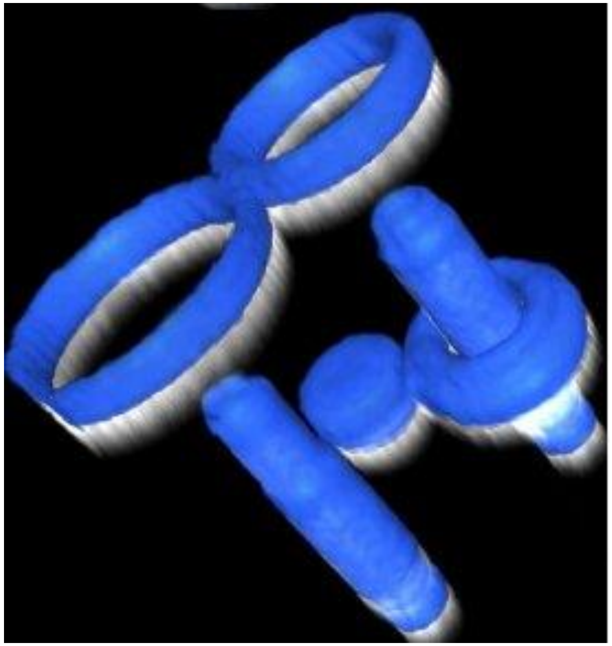
applied in visualization

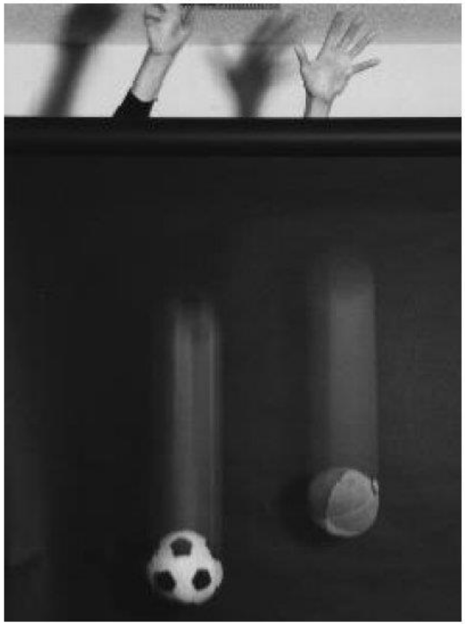
Joshi et al., 2005

Stompel et al. 2002

Time-Varying Data

Use ideas from flash photography to illustrate motion hints:





Guan et al., 2005