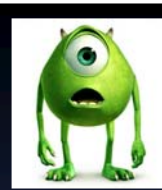
ITS 102: Visualize This!

Lecture 7: Illustrative Visualization



Klaus Mueller

Computer Science Department

Stony Brook University

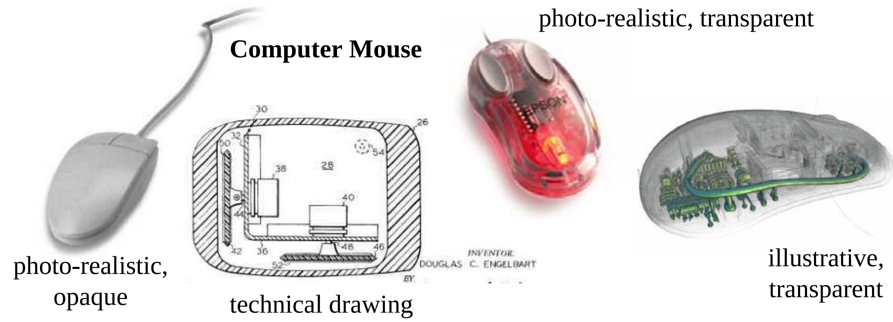
Introduction

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

- we shall use these terms here interchangeably

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

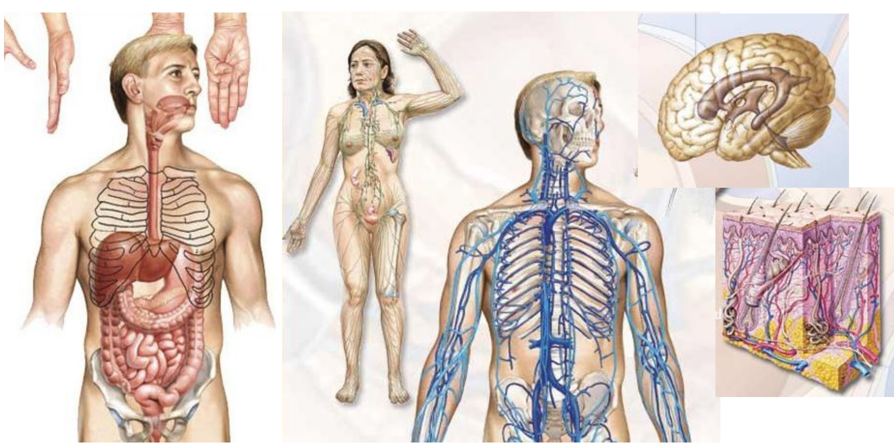
Compare these renderings of a computer mouse:



Recall Your Medical Textbooks…

Frank Netter (1906 – 1991)

- often referred to as "Medicine's Michelangelo"
- illustrative rendering was key to understanding



The Power of Illustrative Rendering

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* (illustrative) 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

NPR Follows Ed Tufte's Famous 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"

This Talk…

Frank Netter spent many hours, or even days, on a single illustration

His work required:

- drawing skill
- imagination
- creativity
- many hours in the cadaver lab

Using computers, everyone can be Frank Netter, using:

- various digital interactive tools (facilitated by graphics hardware GPU)
- automated, goal-oriented processing

Illustrative rendering can be a tool for:

- interactive medical text books
- surgery / intervention / treatment planning
- patient education

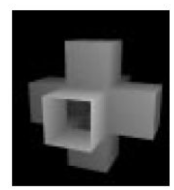
This Talk…

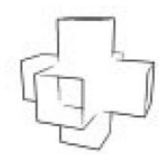
Agenda:

- some technical detail (only some) on basic techniques
- lots of examples and applications
- mostly in medicine, but also in science an engineering

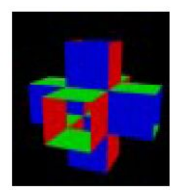
Basic Techniques: Contours and Outlines

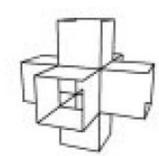
depth-map (edges are due to C_0 discontinuities)

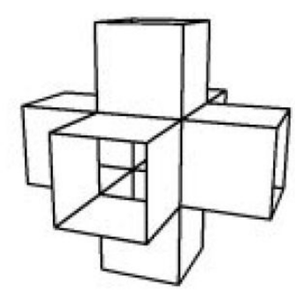




normal-map (edges are due to C_1 discontinuities)



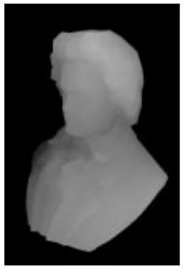




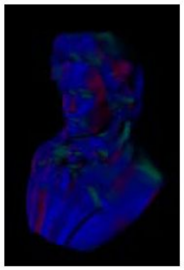
combined

Basic Techniques: Contours and Outlines

depth-map

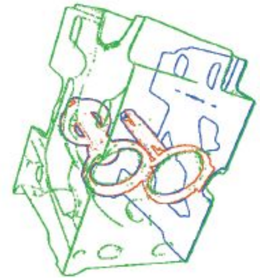


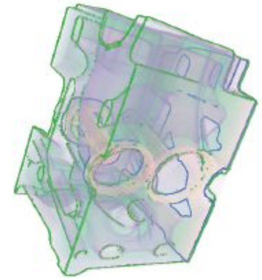
normal-map



combined

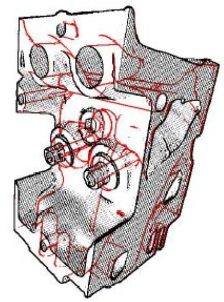
Basic Techniques: Contours and Outlines

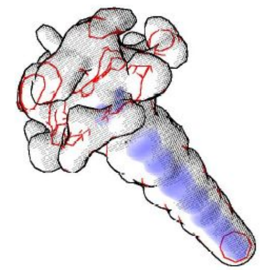




mixing outlines with volume rendering

rendering interior structures as contours



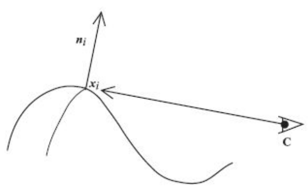


J. Fisher, D. Bartz

Basic Techniques: Silhouettes

Not an image-space method

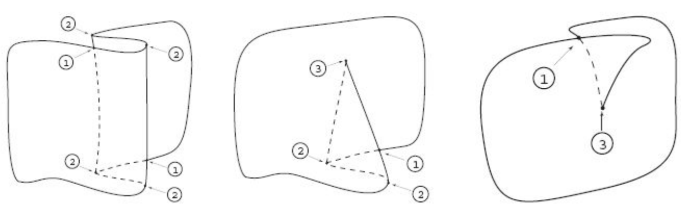
- uses dot product V·N=0 criterion
- V: view vector
- N: surface normal



Finds curves and creases at higher quality

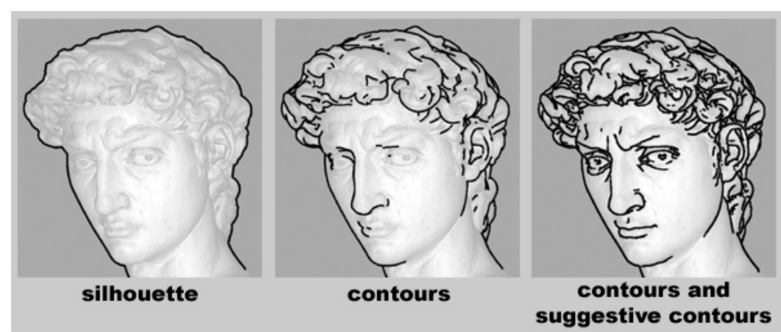
Allows further processing of these (for example hatching)

Must disambiguate occlusions



Suggestive Contours

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

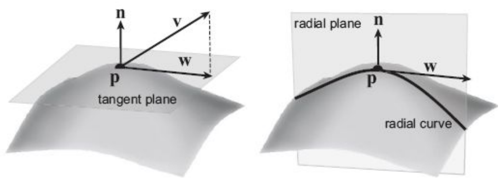


D. DeCarlo

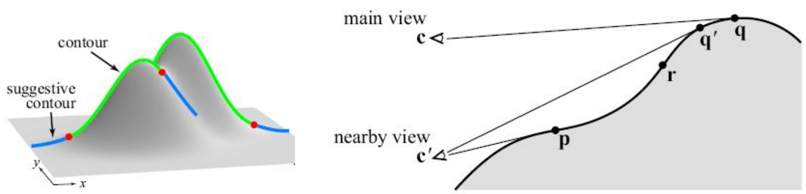
Suggestive Contours

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

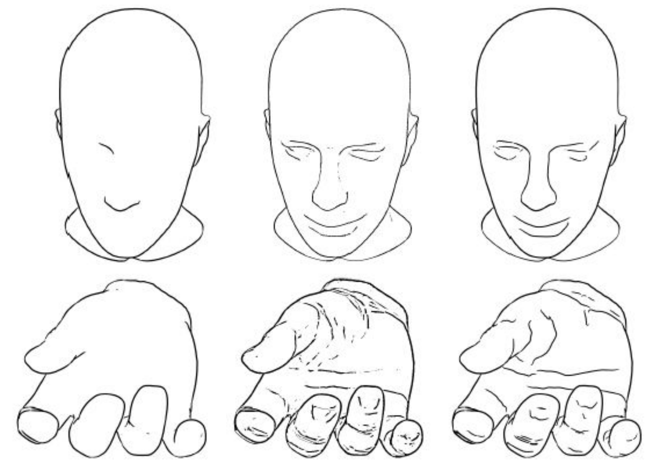
- where the radial curvature (1/curve radius) is zero (w is the projection of V onto the tangent plane)



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



Suggestive Contours



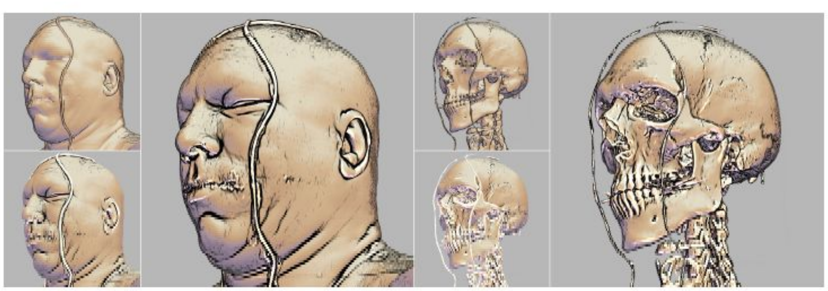
contours

suggestive contours
(image space vs. object space method)

Suggestive Contours

Require the computation of the second derivative at high accuracy

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

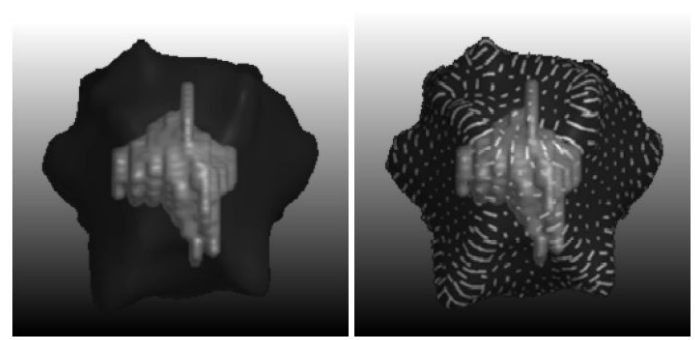


G. Kindlmann

Curvature Stroke Lines

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

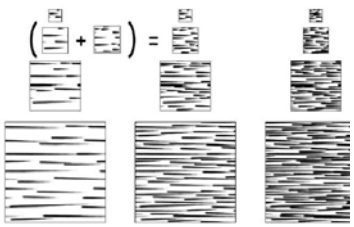
Right: Strokes along the principal curvature are added to convey shape



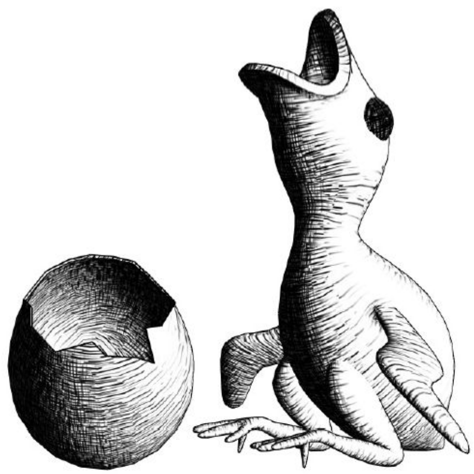
V. Interrante

Hatching

Applies this illustration style as a function of illumination and others



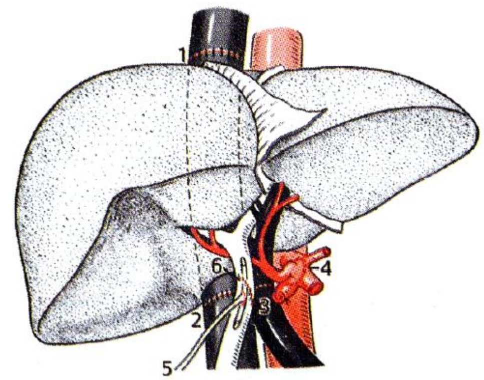
portion of the tonal art map

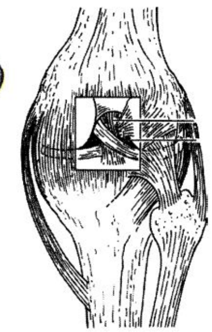


Stippling

Stippling is yet another illustration technique

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

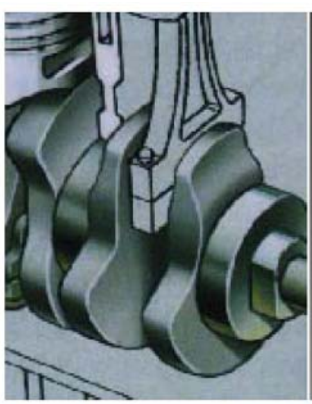


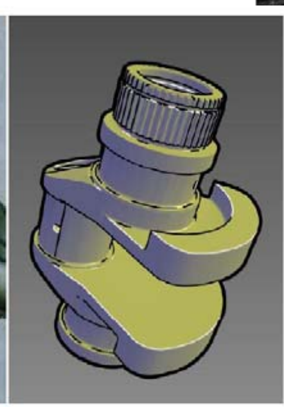


Highlighted Edges

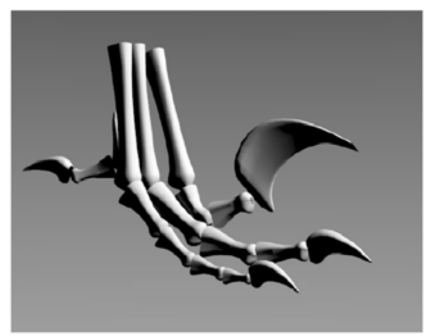
Color interior edges white

- simulates anisotropic reflections at edges

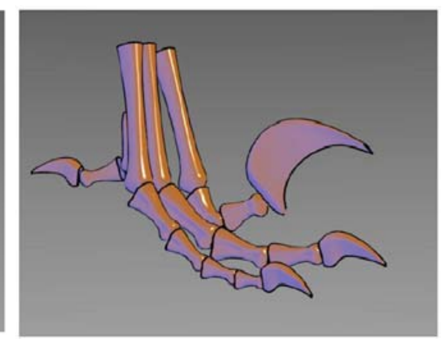




Tone Shading



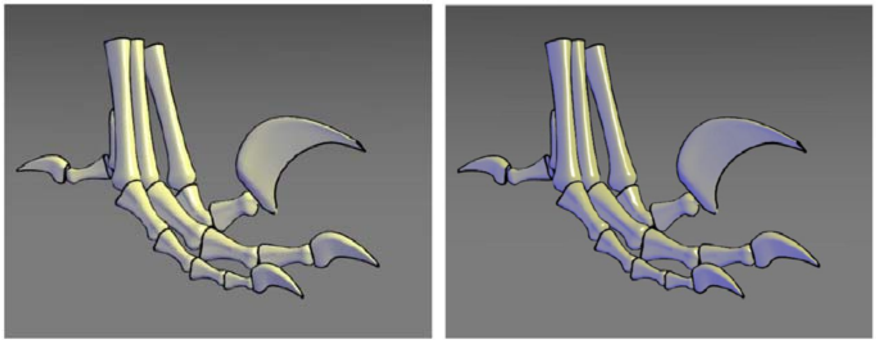
Standard Computer Graphics



Tonal shading (cool-to-warm shift), along with highlights and edges

B. & A. Gooch

Tone Shading



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

B. & A. Gooch

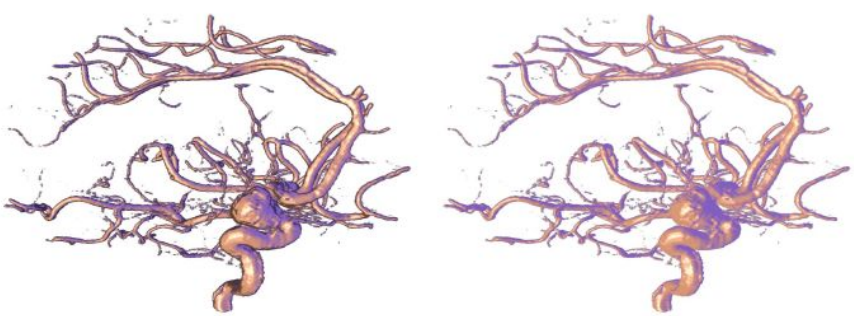
Tone Shading

Specifically for volume visualization

B. & A. Gooch

Tone Shading

Specifically for volume visualization



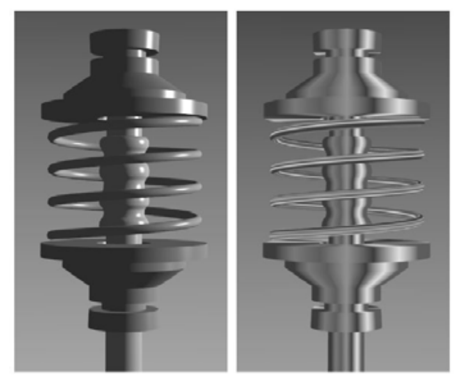
B. & A. Gooch

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, one can map a set of stripes of varying intensity (random) along the parametric axis of maximum curvature.

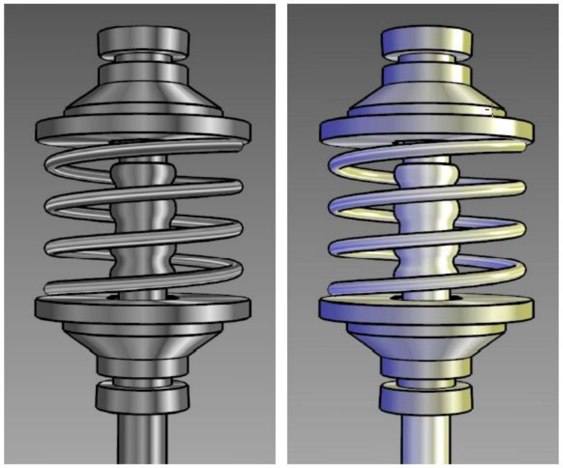


left: no metal
right: metal rendering

B. & A. Gooch

Metal Shading

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

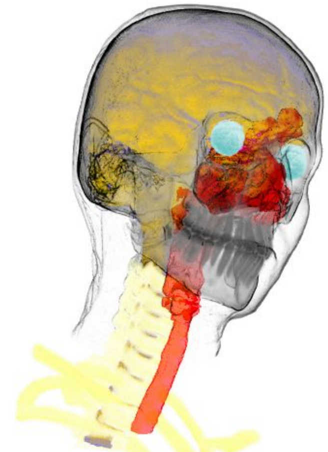


B. & A. Gooch

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



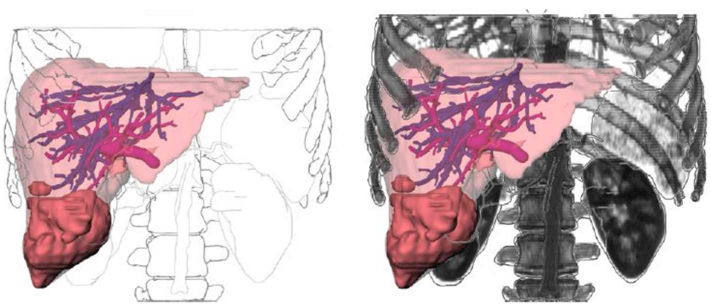
M. Hadwiger

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

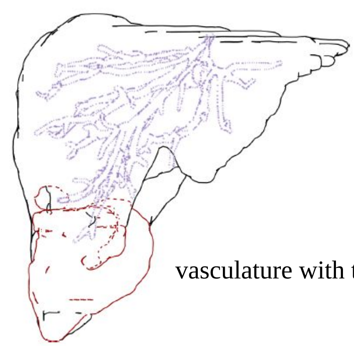


B. Preim

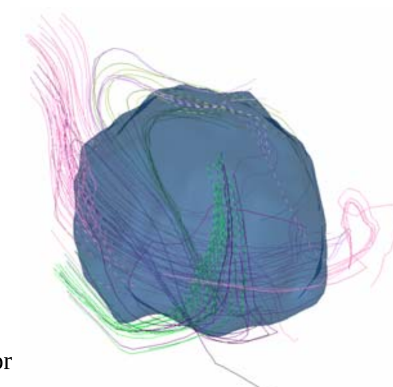
Hidden Structures

Show with different rendering style

- dotted lines, faint lines



vasculature with tumor



MRI DTI lines inside a tumor

X. Guan

User-Defined Parameters

κ_t controls *depth of cut*

- Higher values → remove more occluding structures
- Zero → results in conventional direct volume rendering

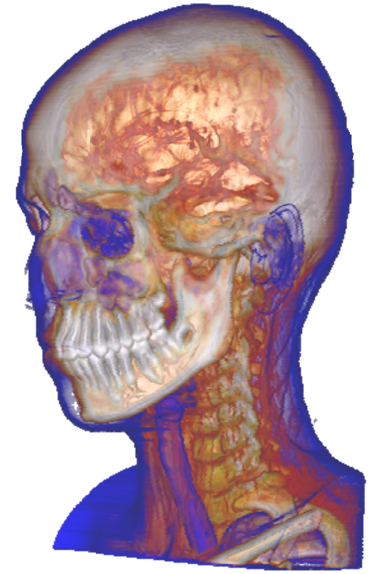
κ_s controls *sharpness of cut*

- Higher values → less smooth transition in opacity
- Zero → pure gradient-magnitude opacity modulation

Ivan Viola, Stefan Bruckner and M. Eduard Gröller

User-Defined Parameters

Effect of κ_t



$\kappa_t=8.6$

$\kappa_s=0.4$

I. Viola

User-Defined Parameters

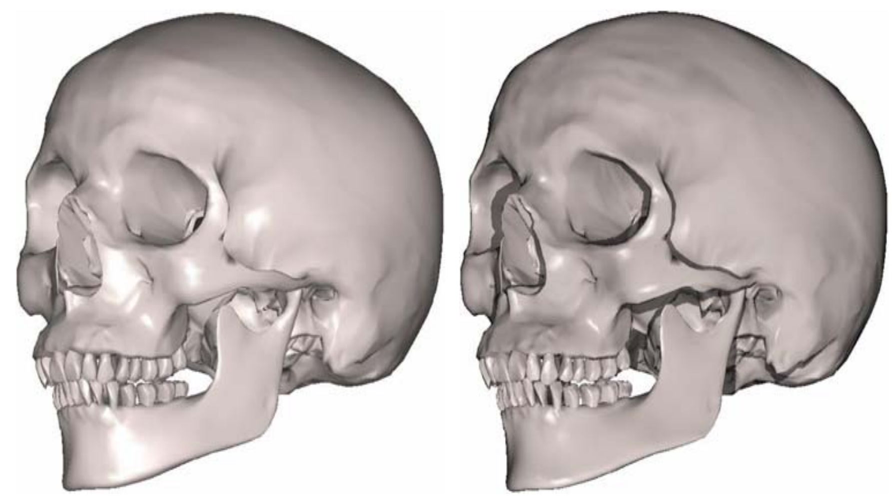
Effect of κ_s

$\kappa_t=6.0$

$\kappa_s=0.8$

I. Viola

Inconsistent Lighting



C. Lee

Two Levels Of Abstraction

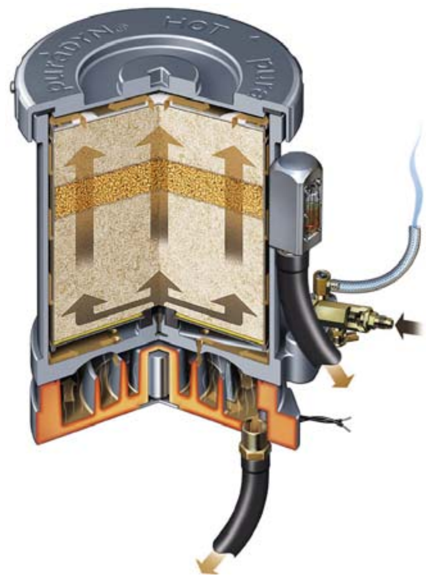
Low-level abstraction:

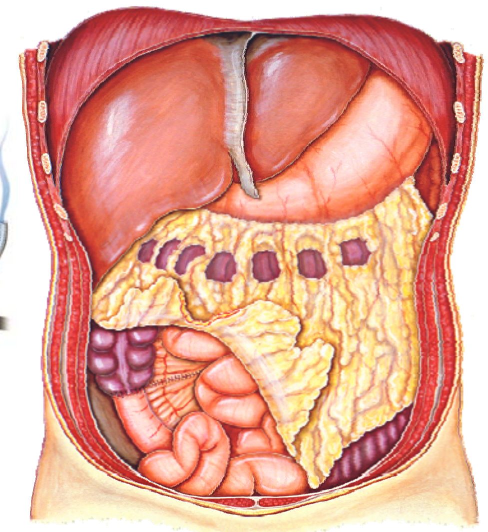
- concerned with **how** objects are represented
- stylized depiction: silhouettes, contours, pen+ink, stippling, hatching, etc.
- we have seen this just now

High-level abstraction

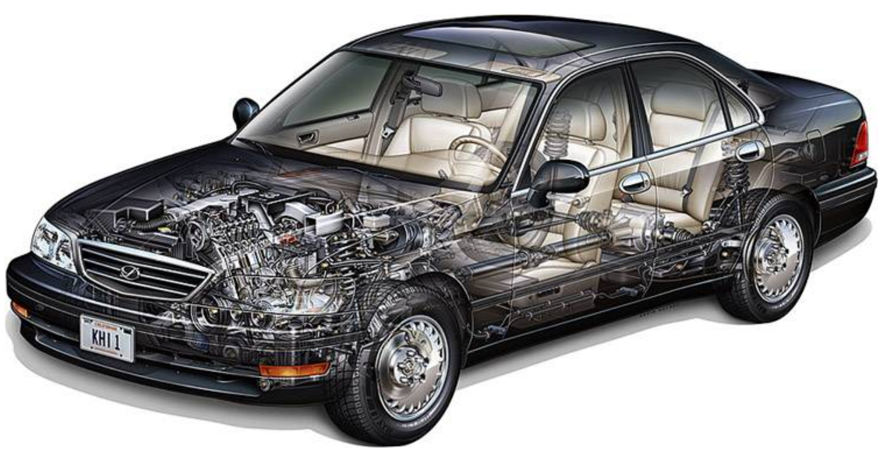
- deal with **what** should be visible and recognizable and at what level of detail
- this should be importance-driven, that is, the current visualization goal controls feature rendering style and visibility
- smart visibility: cutaways, breakaways, ghosting, exploded views
- we will discuss these next

Cut-Aways

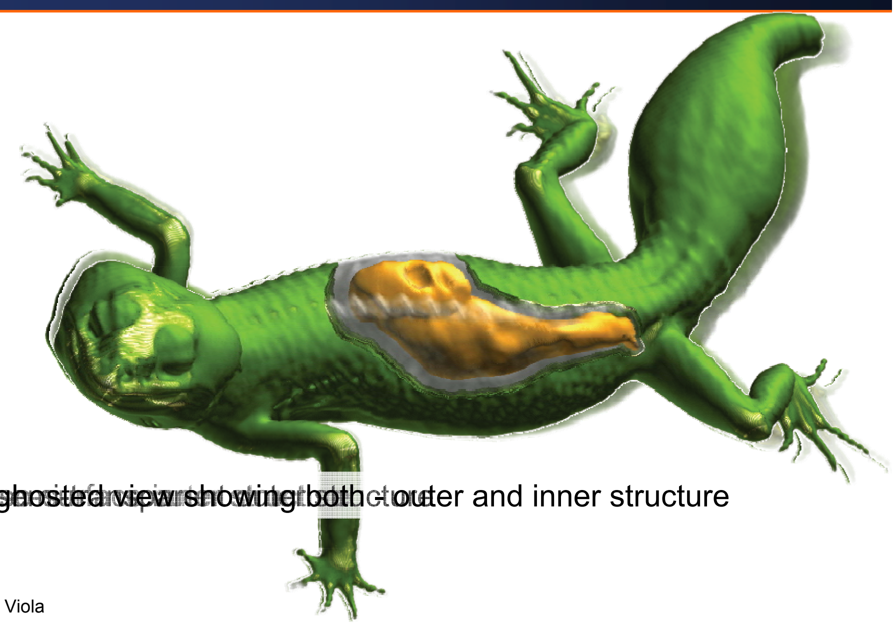




Ghosting



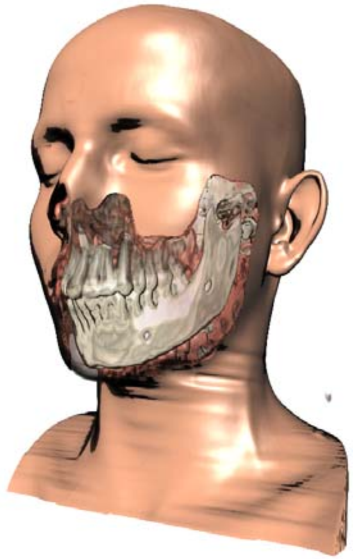
Ghosting: Procedure



ghosted view showing both outer and inner structure

I. Viola

Ghosting

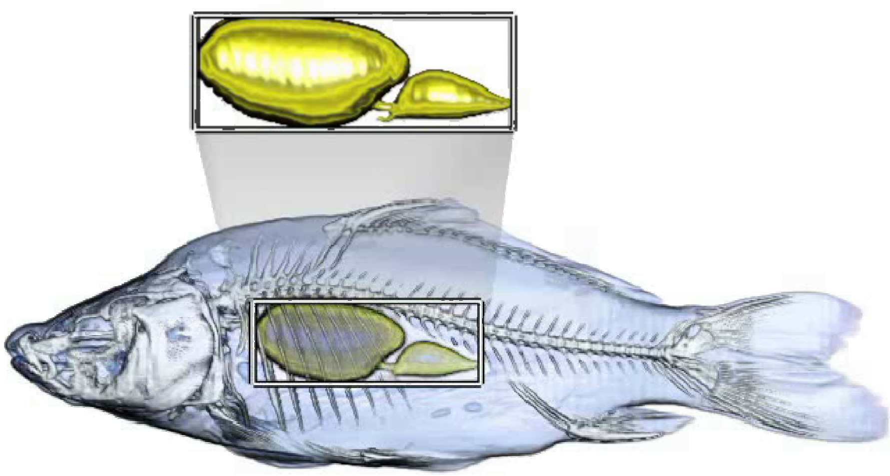


S. Bruckner

Context Preserving

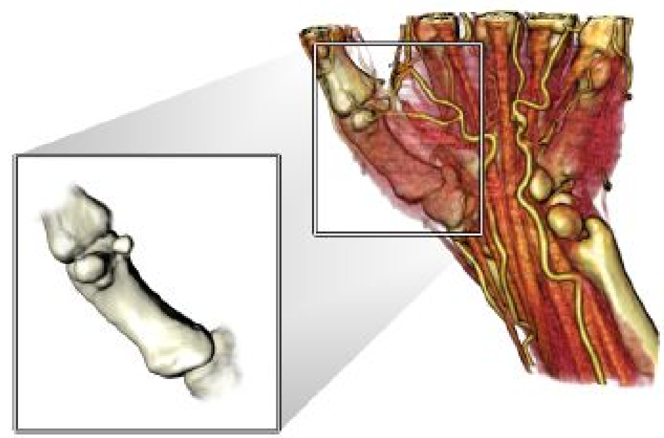
I. Viola

Fans



S. Bruckner

Fans



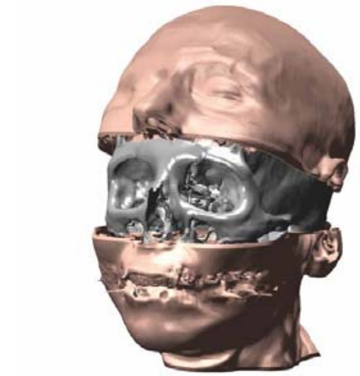
S. Bruckner

Labeling And Other Abstractions

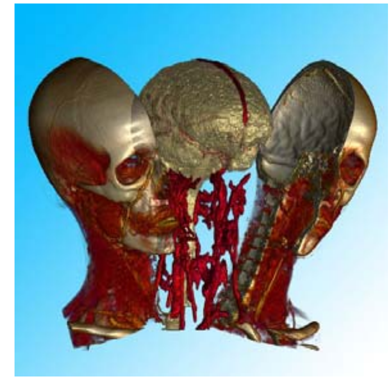
S. Bruckner

Spatial Exploding

Volume Splitting

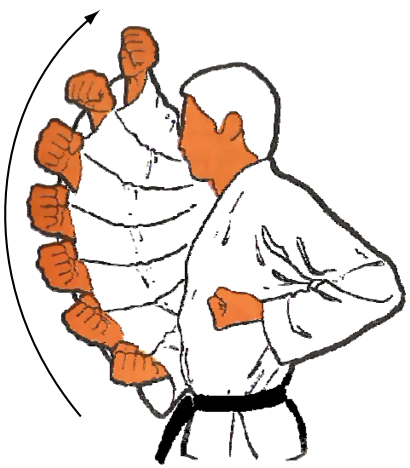


Dynamic Multi-Volumes

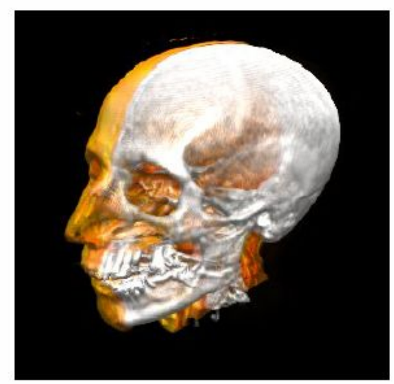


Islam, S. Grimm

Temporal Exploding



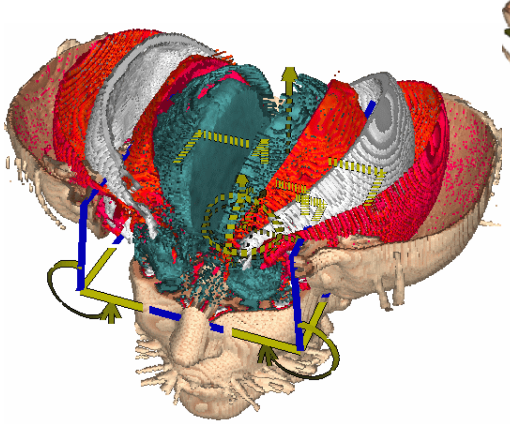
Rendering Mode Composition

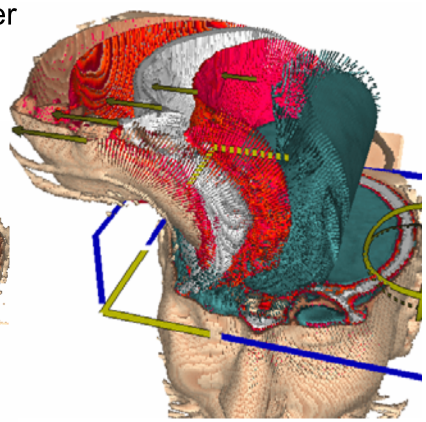


Browsing

Peeler

Leafer

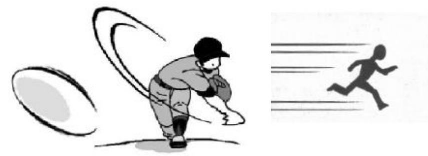




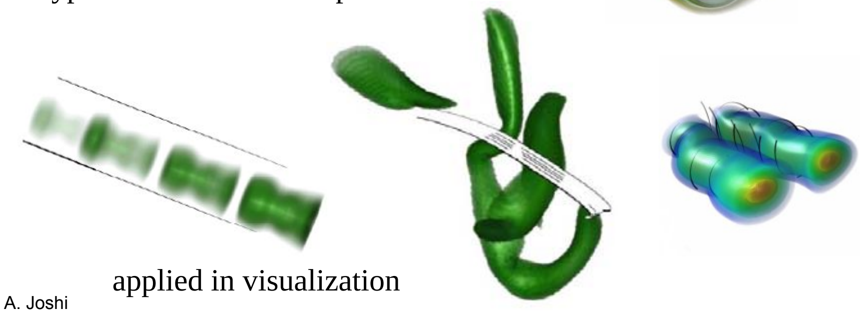
McGuffin

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



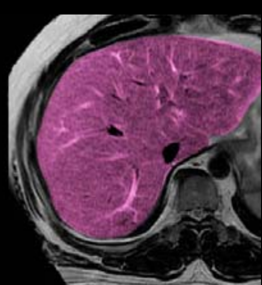
applied in visualization

A. Joshi

Semantic Zooms: Introduction

Ever tried to zoom into a volumetric dataset?

What do you get?



L. Wang

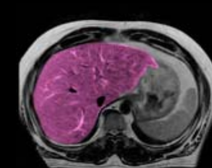
Semantic Zooms: Overview

But there is a solution:

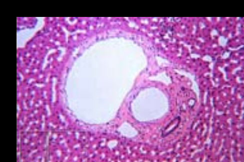
- augment with detail from other sources, such as histology, microscopy, micro-tomography, etc

Use these sample images to synthesize missing detail

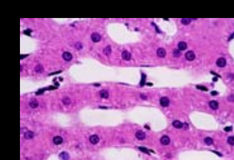
- when needed
- into the right places



MRI level



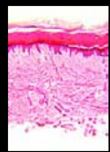
histology level

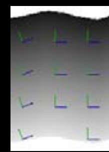


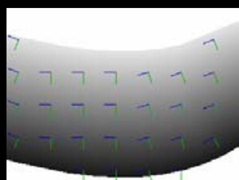
cell level

Sample Images

Semantic Zooms: Example (Skin Synthesis)


Sample image


Distance and gradient fields


Reference distance and gradient fields


Synthesized skin histology image

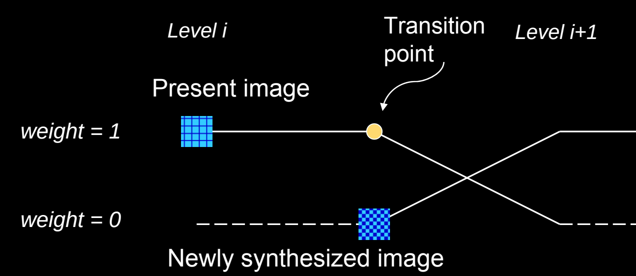
Semantic Zooms: Smooth Transitions

Magnify low resolution level image

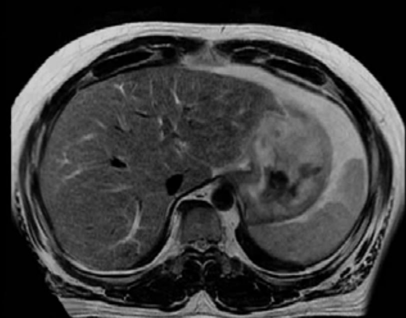
Synthesize new detail at transition point

Minify synthesized next high level image

Weighted Blending



Semantic Zooms: The Infinite Microscope

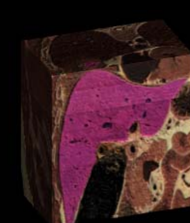


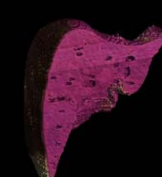
L. Wang

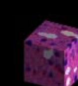
Semantic Zooms in 3D

Visible human liver

- Colorization
- Segmentation

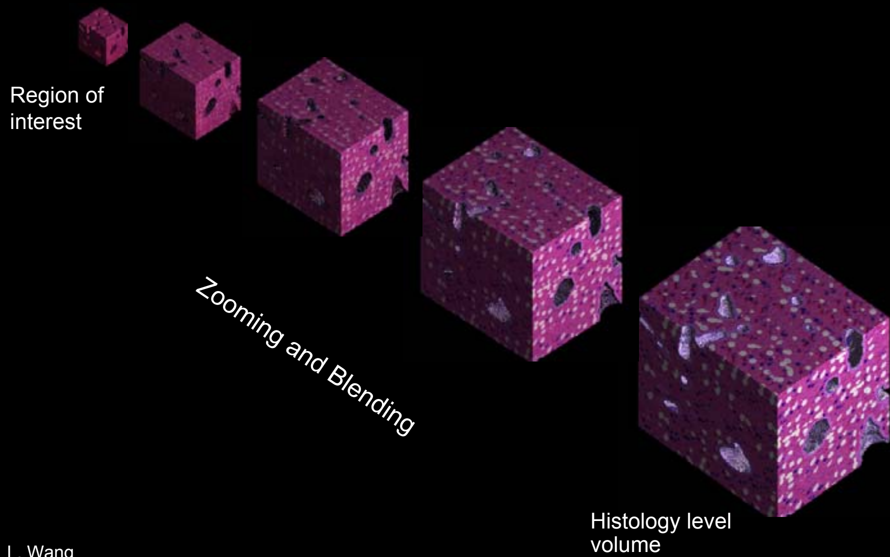



Liver


Histology Sample Volume

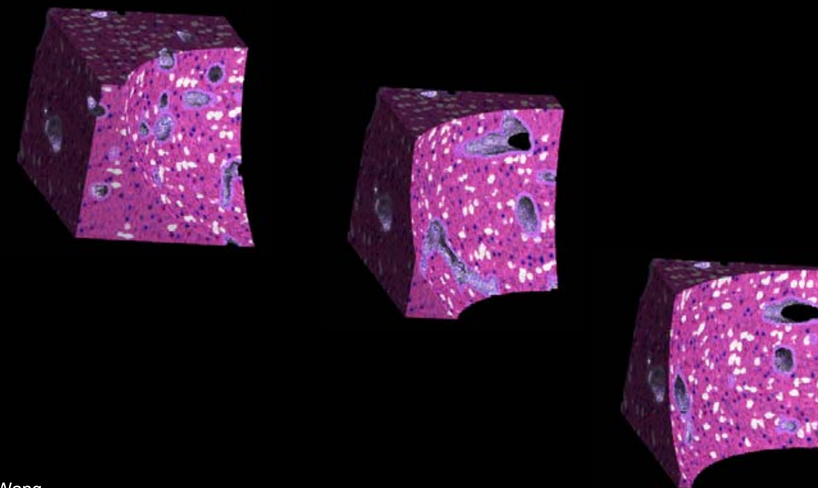
L. Wang

Semantic Zooms in 3D



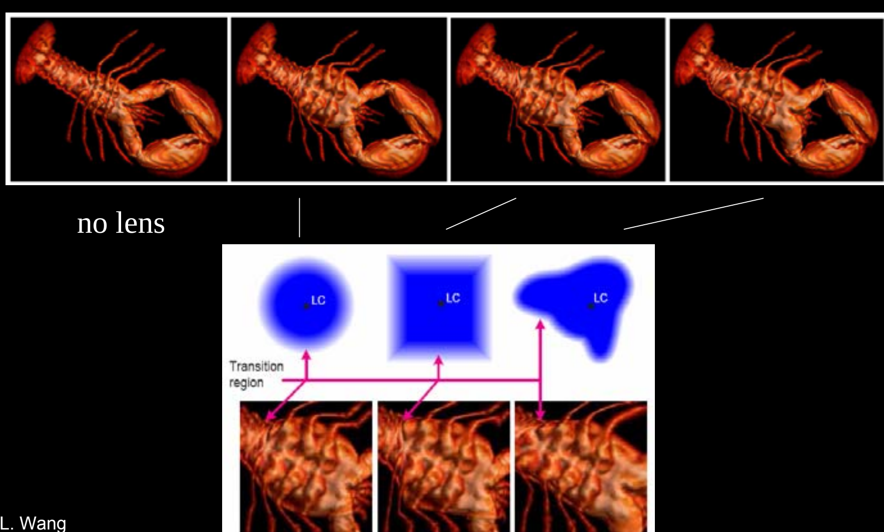
L. Wang

Semantic Zooms in 3D



L. Wang

Generalized Lenses



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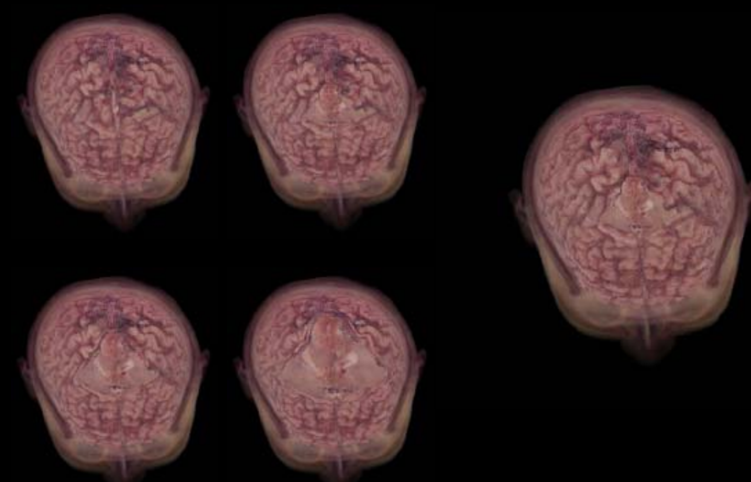
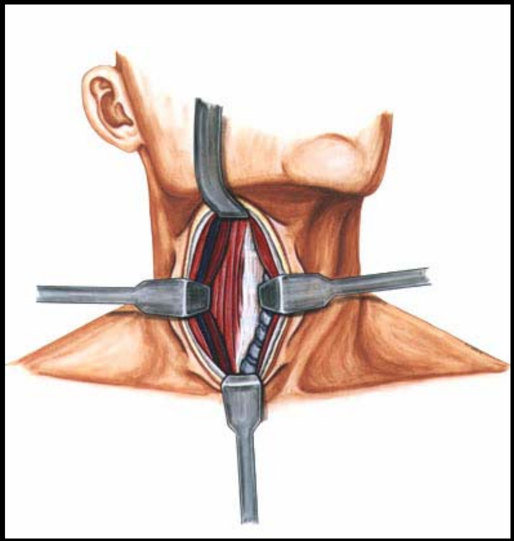
Generalized Lenses

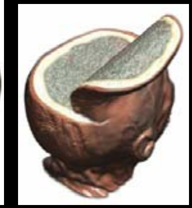


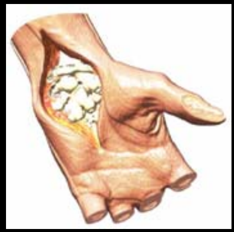
L. Wang

Deformations: Illustration



Interactive Deformations





C. Correa