CSE 591: Visual Analytics

Lecture 4: Visual Importance and Saliency

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Attention

The cognitive process of selectively concentrating on one thing while ignoring other things

- detecting features in visual clutter (CAPTCHA, next slide)
- detecting coherent speech in noisy environments (cocktail party effect)
- ignore features while concentrating on others (recall gorilla)
- can also have divided attention (example: cell phone + driving)
- heavily studied in psychology and neuroscience
- closely tied to perception

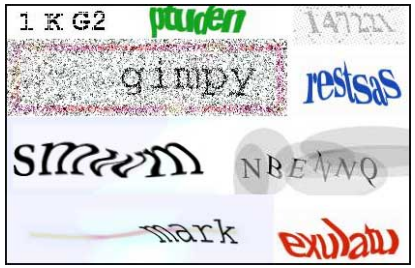
Attention theory is important for visualization as well

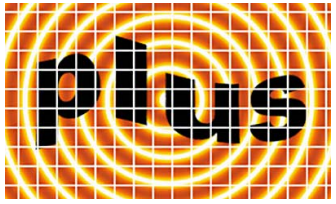
- in contrast to computer vision, WE design/create the scene
- this design guides the attention of the viewer
- guidance determined by visualization goals

Therefore it is important to understand mechanism of attention

CAPTCHA

CAPTCHA: noisy and vastly distorted patterns that are difficult to recognize by machines





CAPTCHA

But computer vision algorithms have become more sophisticated at CAPTCHA *character* recognition

- the latest approach is *object* recognition

Visual Recognition and Attention

Two opposing theories:

- Gestalt
- Feature integration

Gestalt theory

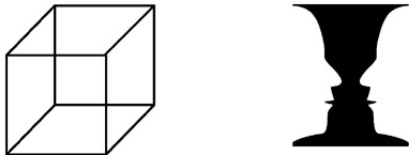
- top-down approach
- proposes that the operational principle of the brain is holistic, parallel, and analog, with self-organizing tendencies
- important in user interface design (button grouping, etc)

Feature integration theory

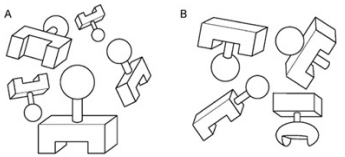
- bottom-up approach
- primary visual features are processed and represented with separate **feature maps**
- these are later integrated in a **saliency map** that can be accessed in order to direct attention to the most conspicuous areas

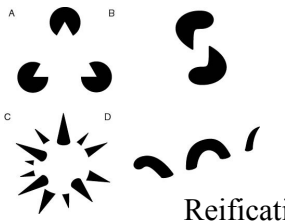
Gestalt Theory: Confirming Examples

Emergence



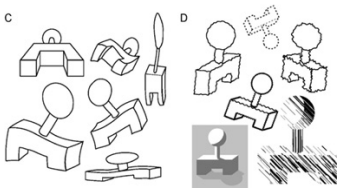
Multi-Stability





Reification

Invariance



Gestalt Theory: Opposing Examples

Selective-Encoding:

- involving one to distinguish what is important in a problem and what is irrelevant (i.e., filtering)

Selective-Comparison:

- identifying information by finding a connection between acquired knowledge and experience

Selective-Combination:

- identifying a problem through understanding the different components and putting everything together.

Feature Integration Theory

One of the most influential influential psychological models of human visual attention in recent years

Two types of visual search mechanisms

Feature search

- can be performed fast and pre-attentively for targets defined by primitive features (such as color, orientation, intensity, etc)

Conjunction search

- serial search for targets defined by a conjunction of primitive features
- much slower
- requires conscious attention

Very promising technique for computer vision to detect partially occluded objects (SIFT)

What Does It Mean For Visualization?

Feature integration theory:

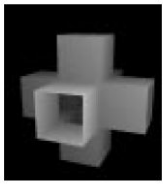
- must exploit this to guide attention
- relatively “easy” since it involves mostly local enhancements
- notion of saliency is important (recall center-surround mechanism)

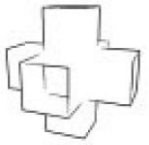
Gestalt theory:

- reminds me of ghosting techniques (mental feature completion)
- silhouettes and contours for context objects
- many techniques used now in illustrative rendering
- recall also optical illusions

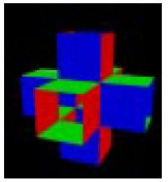
Basic Techniques: Contours and Outlines

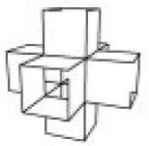
depth-map (edges are due to C_0 discontinuities)

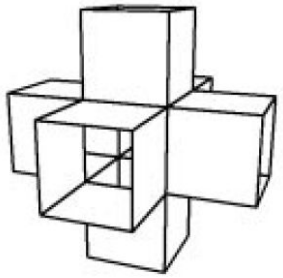




normal-map (edges are due to C_1 discontinuities)



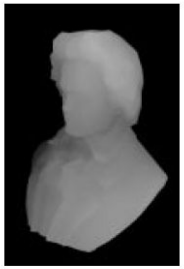




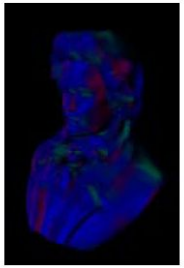
combined

Basic Techniques: Contours and Outlines

depth-map

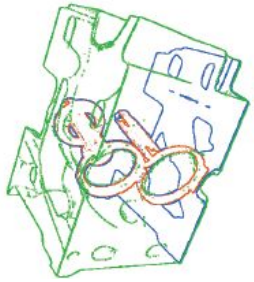


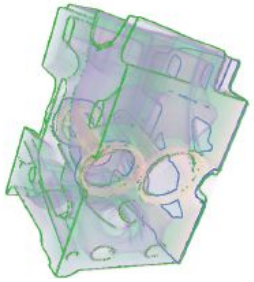
normal-map



combined

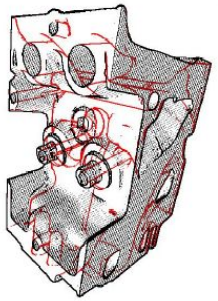
Basic Techniques: Contours and Outlines

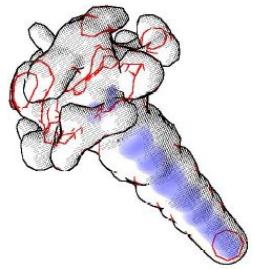




mixing outlines with volume rendering

rendering interior structures as contours



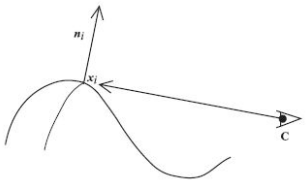


J. Fisher, D. Bartz

Basic Techniques: Silhouettes

Not an image-space method

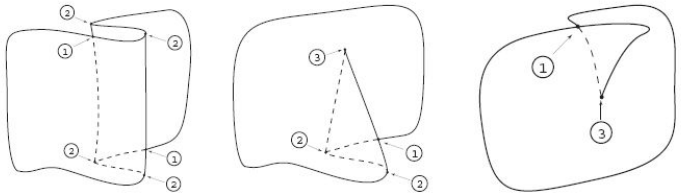
- uses dot product V·N=0 criterion
- V: view vector
- N: surface normal



Finds curves and creases at higher quality

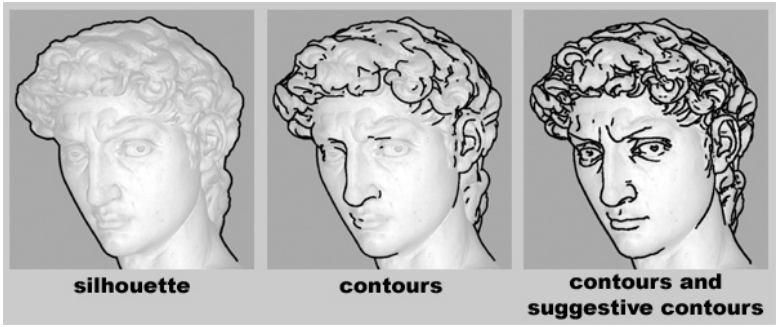
Allows further processing of these (for example hatching)

Must disambiguate occlusions



Suggestive Contours

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

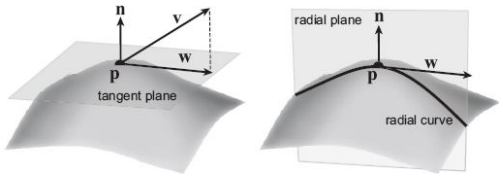


D. DeCarlo

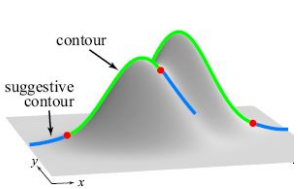
Suggestive Contours

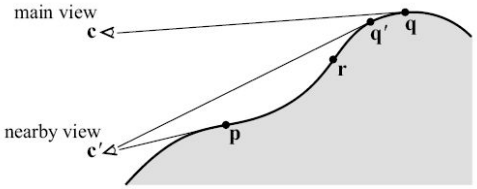
Those locations at which the surface is *almost* in contour, from the original viewpoint

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

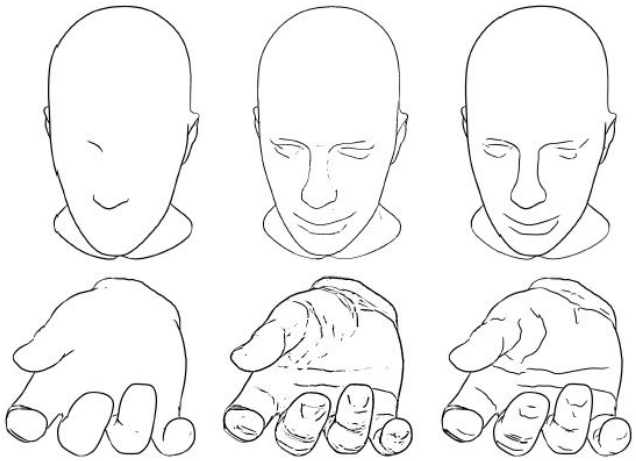


- where V·N is a positive local minimum rather than zero.
- correspond to true contours in relatively nearby viewpoints.





Suggestive Contours



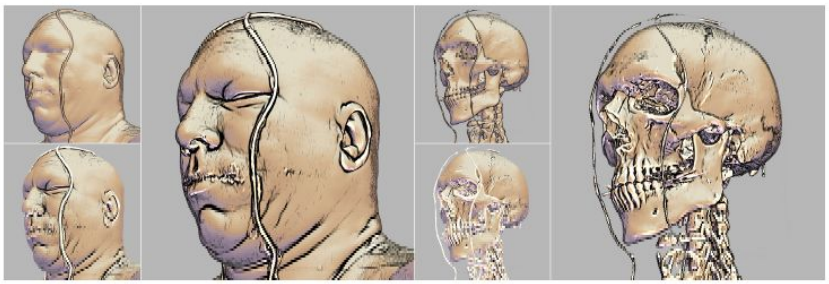
contours

suggestive contours
(image space vs. object space method)

Suggestive Contours

Require the computation of the second derivative at high accuracy

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

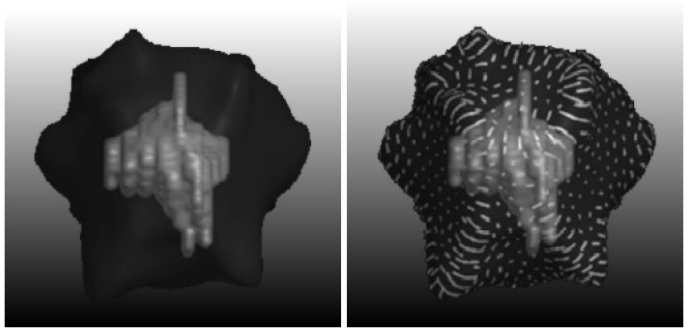


G. Kindlmann

Curvature Stroke Lines

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

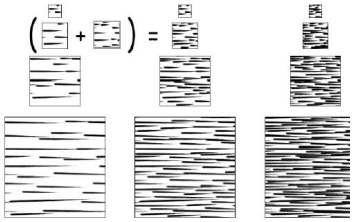
Right: Strokes along the principal curvature are added to convey shape



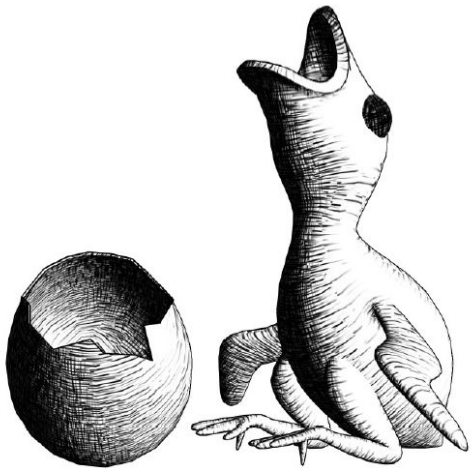
V. Interrante

Hatching

Applies this illustration style as a function of illumination and others



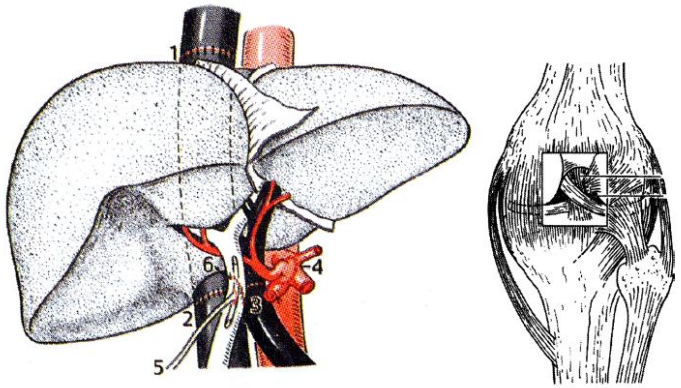
portion of the tonal art map



Stippling

Stippling is yet another illustration technique

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

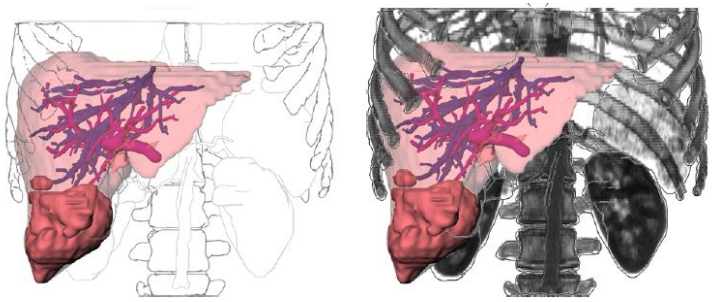


Importance-Controlled Rendering / Visualization

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.

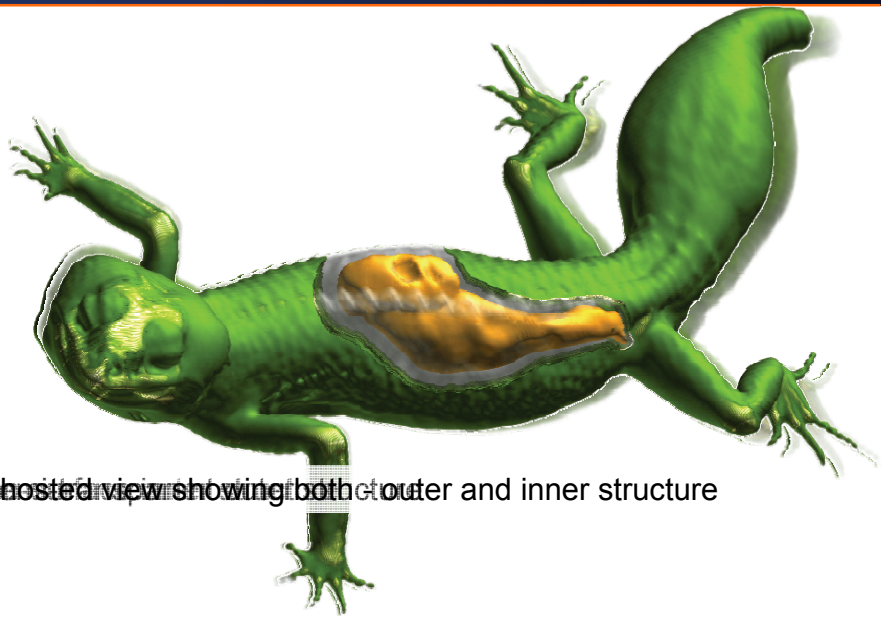
Render these in a certain order to ensure visual consistency



B. Preim

Ghosting

Ghosting: Procedure

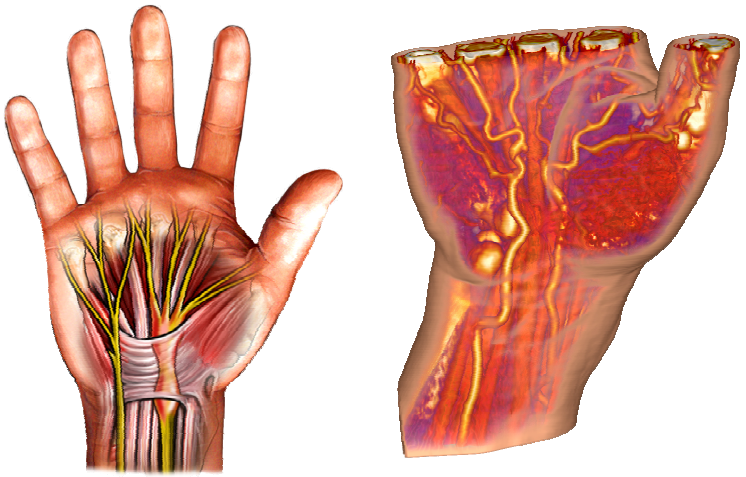


ghosted view showing both outer and inner structure

Ghosting

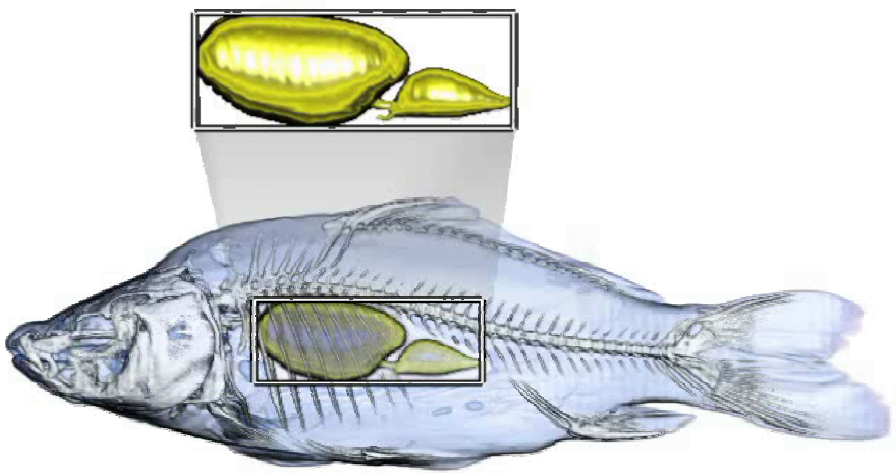
S. Bruckner

Context Preserving



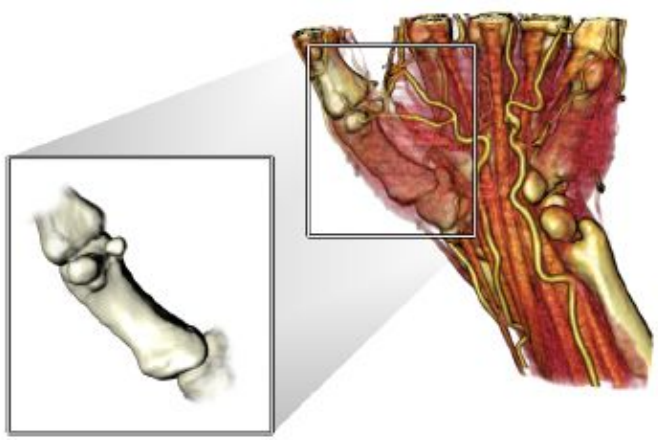
I. Viola

Fans



S. Bruckner

Fans



S. Bruckner

The 4th Dimension

Time varying effects are very difficult to perceive in detail

- recall the 7+-1 rule?

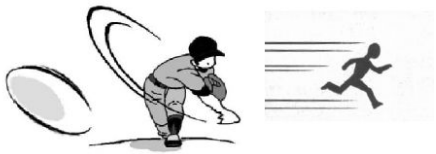
Another look at Daniel Simons' work

A challenging area of research:

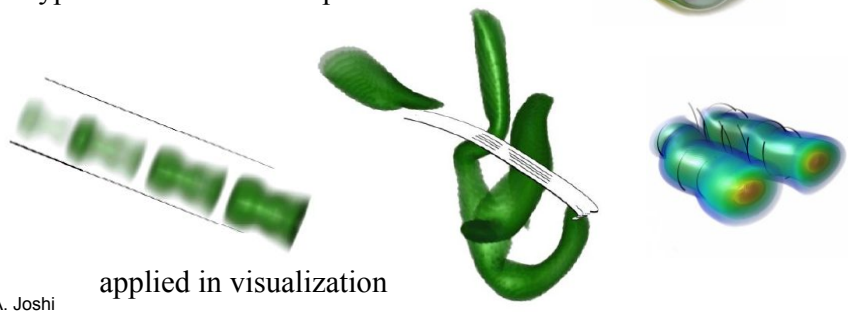
- visualization of time-varying behavior in a single frame
- can use illustration techniques

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

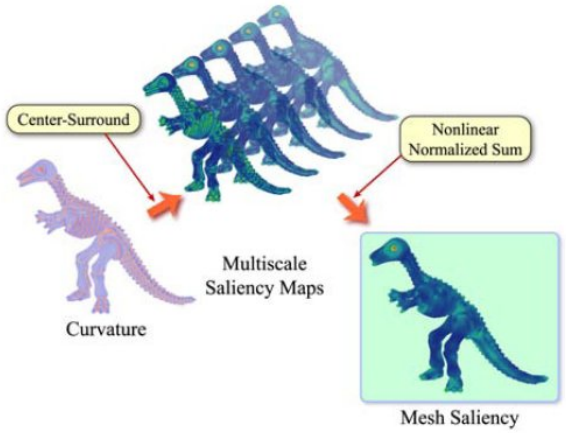
A. Joshi

Saliency-Guided Enhancement for Visualization

Gaze-directed abstraction of photographs (DeCarlo)

Saliency-Guided Enhancement for Visualization

Using saliency to guide geometric mesh simplification (Lee & Varshney)



Saliency-Guided Enhancement for Visualization