

12

Hot Topics in Visualization

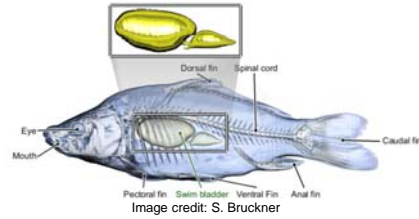
Ronald Peikert

SciVis 2007 - Hot Topics

12-1

Hot Topic 1: Illustrative visualization

Illustrative visualization: computer supported interactive and expressive visualizations through abstractions as in traditional illustrations.



Ronald Peikert

SciVis 2007 - Hot Topics

12-2

Illustrative visualization

Illustrative visualization uses several **non-photorealistic rendering (NPR)** techniques:

- smart visibility
- silhouettes
- hatching
- tone shading
- focus+context techniques
 - context-preserving volume rendering

Ronald Peikert

SciVis 2007 - Hot Topics

12-3

Smart visibility

Abstraction techniques:

- cut-aways (a)
- ghosted views (b)
- section views (c)
- exploded views (d)



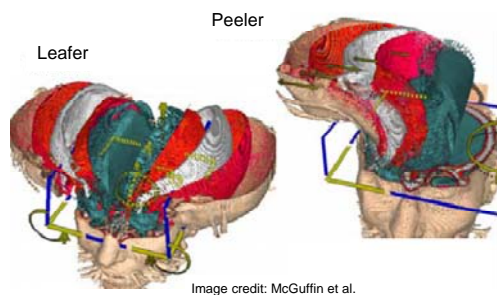
Ronald Peikert

SciVis 2007 - Hot Topics

12-4

Smart visibility

Browsing deformations:



Ronald Peikert

SciVis 2007 - Hot Topics

12-5

Silhouette algorithms

The **silhouette** of a surface consists of those points where view vector V and surface normal N are orthogonal.

Silhouettes can be either **outlines** or **internal silhouettes**.

In contrast to other important feature lines such as curvature ridges/valleys and texture boundaries, silhouettes are view-dependent.

Ronald Peikert

SciVis 2007 - Hot Topics

12-6

Silhouette algorithms

Object space algorithms exist for:

- polygonal surfaces. Principle:
 - for each polygon
 - set front-facing flag to all edges if $\mathbf{N} \cdot \mathbf{V} \geq 0$
 - set back-facing flag to all edges if $\mathbf{N} \cdot \mathbf{V} < 0$
 - for each edge
 - draw if both flags are set
 (assumes triangles or planar quads)
- implicit surfaces
- NURBS surfaces

Ronald Peikert

SciVis 2007 - Hot Topics

12-7

Silhouette algorithms

Image space algorithms:

- for polygonal surfaces
 - render polygons with depth buffer enabled
 - look for discontinuities in depth buffer:
 - compute depth difference between two adjacent pixels, or the Laplacian on a 3x3 stencil
 - if larger than threshold, draw a silhouette pixel
- for volume data (Ebert and Rheingans).
 - idea: "silhouette points" are where the gradient is orthogonal to the view vector
 - use opacity transfer function depending on $|\nabla s \cdot \mathbf{V}|$

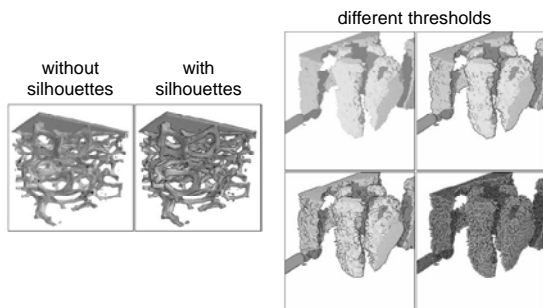
Ronald Peikert

SciVis 2007 - Hot Topics

12-8

Silhouette algorithms

Example: case study (Bigler)



Ronald Peikert

SciVis 2007 - Hot Topics

12-9

Silhouette algorithms

Example: Silhouettes in volumes (DVR without lighting!)

- Skin is transparent in non-silhouette regions to avoid visual obstruction
- Bones are darkened along silhouettes to emphasize structure



Focus on ankle joints



Image credit: N. Svakhine and D. Ebert

Ronald Peikert

SciVis 2007 - Hot Topics

12-10

Hatching

Surface rendering with hatching techniques:

- shading and shadows (Winkenbach/Salesin)
- smooth surfaces (Hertzmann/Zorin)

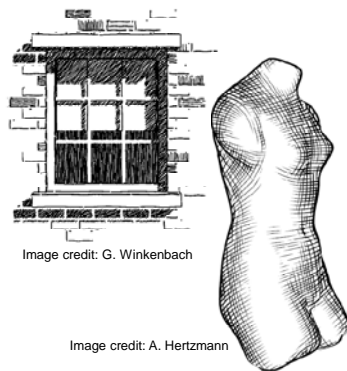


Image credit: G. Winkenbach

Image credit: A. Hertzmann

Ronald Peikert

SciVis 2007 - Hot Topics

12-11

Hatching

Volume illustration with hatching (Nagy):

- compute an isosurface
- compute **curvature fields** (1st and 2nd principal curvature directions on the isosurface), fast algorithm by Monga et al.
- compute hatching as streamlines of both curvature fields, using **streamline placement** techniques



Image credit: Z. Nagy

Ronald Peikert

SciVis 2007 - Hot Topics

12-12

Hatching

- render streamlines as **illuminated lines**
- overlay with volume rendering

Image credit: Z. Nagy

Ronald Peikert SciVis 2007 - Hot Topics 12-13

Tone shading

Tone shading or "toon shading" (cartoons) uses **tones** instead of **luminance** for shading.

Examples: Warm to cool hue shift

Gray model, tone shaded

Depth cue: warm colors advance while cool colors recede.

Image credit: A. Gooch

Ronald Peikert SciVis 2007 - Hot Topics 12-14

Tone shading

Phong shading

vs.

tone shading

Image credit: A. Gooch

Ronald Peikert SciVis 2007 - Hot Topics 12-15

Context-preserving volume rendering

Ghosted view: surface transparency depends on the **grazing angle** (angle between view ray and surface).

More transparent for large, more opaque for small grazing angle.

Example:

Image credit: K. Hulsey Illustration Inc.

Context-preserving volume rendering (Bruckner):

Use of ghosted views in volume rendering:

Ronald Peikert SciVis 2007 - Hot Topics 12-16

Context-preserving volume rendering

Overview of context-preserving volume rendering model:

$$\alpha_i = \alpha(\mathbf{s}(\mathbf{x})) \|\nabla \mathbf{s}(\mathbf{x})\|_{[0,1]}^{\left(\kappa_r \sigma(\mathbf{x}) \left(1 - \|\mathbf{x} - \mathbf{x}_{eye}\|_{[0,1]} \right)^{\kappa_s} \right)^{\kappa_s}}$$

gradient magnitude, normalized $\|\nabla \mathbf{s}(\mathbf{x})\|_{[0,1]}$

shading intensity $\sigma(\mathbf{x})$

eye distance, normalized $\|\mathbf{x} - \mathbf{x}_{eye}\|_{[0,1]}$

previously accumulated opacity α_{i-1}

Image credit: S. Bruckner

Ronald Peikert SciVis 2007 - Hot Topics 12-17

Context-preserving volume rendering

$$\alpha_i = \alpha(\mathbf{s}(\mathbf{x})) \|\nabla \mathbf{s}(\mathbf{x})\|_{[0,1]}^{\left(\kappa_r \sigma(\mathbf{x}) \left(1 - \|\mathbf{x} - \mathbf{x}_{eye}\|_{[0,1]} \right)^{\kappa_s} \right)^{\kappa_s}}$$

High shading intensity (of local Phong lighting model with light source at eye point) means: large grazing angle. It results in higher transparency.

Parameters

- κ_r corresponds roughly to the depth of a clipping plane
- κ_s controls the sharpness of the transition between visible and clipped

Ronald Peikert SciVis 2007 - Hot Topics 12-18

Context-preserving volume rendering

context-preserving VR




Image credit: S. Bruckner




Image credit: Nucleus Medical Art, Inc.

vs.

medical illustration




Image credit: Nucleus Medical Art, Inc.




Image credit: S. Bruckner

Ronald Peikert SciVis 2007 - Hot Topics 12-19

Hot Topic 2: Lagrangian Coherent Structures

Motivation: Vector field topology does not well describe the topology of a "strongly" time-dependent vector field.

- Separatrices are defined in terms of streamlines, not pathlines, i.e. by integrating the instantaneous vector field.
- Critical points of saddle type are not the places where flow separation happens.

Example: "Double gyre" [S. Shadden]

$$u(x, y, t) = -\pi A \sin(\pi f(x, t)) \cos(\pi y)$$

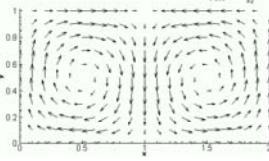
$$v(x, y, t) = \pi A \cos(\pi f(x, t)) \sin(\pi y) \frac{df(x, t)}{dx}$$

$$f(x, t) = \varepsilon \sin(\omega t) x^2 + (1 - 2\varepsilon \sin(\omega t)) x$$

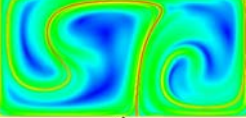
Ronald Peikert SciVis 2007 - Hot Topics 12-20

Lagrangian Coherent Structures

The vector field (with parameters $A = 0.1$, $\omega = 2\pi/10$, $\varepsilon = 0.25$)



Lagrangian coherent structures (the red pixels approximate a material line).




topological saddle point

Ronald Peikert SciVis 2007 - Hot Topics 12-21

Lagrangian Coherent Structures

An LCS in nature.




How to find the separating line (or surface)?
Idea: Integrate backward and detect large amount of separation.

Ronald Peikert SciVis 2007 - Hot Topics 12-22

The finite-time Lyapunov exponent

The FTLE describes the amount of separation (stretching) after a finite advection time T .

Principle:



Definition:

$$FTLE(x, t_0, T) = \lim_{\delta \rightarrow 0} \max_{\text{direction of } \delta} \frac{1}{|T|} \ln \frac{\|\Delta\|}{\|\delta\|}$$

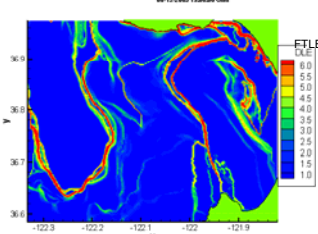
$$= \frac{1}{|T|} \ln \left(\|\nabla \Phi_{t_0}^{t_0+T}(x)\|_2 \right) \quad \left(\|A\|_2 = \sqrt{\lambda_{\max}(A^T A)} \right)$$

Ronald Peikert SciVis 2007 - Hot Topics 12-23

LCS as FTLE ridges

Definition (G. Haller): LCS are (height) ridges of the FTLE field.

Example: Ocean currents in Monterey Bay.



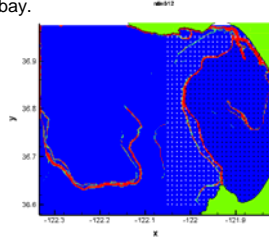
(Video: S. Shadden)

Ronald Peikert SciVis 2007 - Hot Topics 12-24

LCS as FTLE ridges

LCS are material lines (or material surfaces).

Example: The LCS separates recirculating flow from flow which leaves the bay.



(Video: S. Shadden)

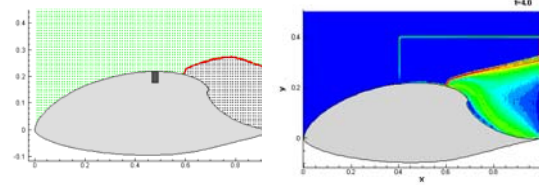
Ronald Peikert

SciVis 2007 - Hot Topics

12-25

LCS as FTLE ridges

Example: Flow over an airfoil with active flow control.



(Videos: S. Shadden)

Ronald Peikert

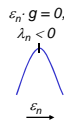
SciVis 2007 - Hot Topics

12-26

Ridge computation

Efficient computation of height ridges (of a scalar field $s(\mathbf{x})$ in n -space):

- compute derived fields $\mathbf{g} = \nabla s$, $\mathbf{H} = \nabla^2 \mathbf{g}$
- for ridges of **dimension 1** use **Parallel Vectors** method:
 - find places where \mathbf{g} and $\mathbf{H}\mathbf{g}$ are parallel vectors
 - test if 2nd directional derivative is negative in directions $\perp \mathbf{g}$
- for ridges of **co-dimension 1** (i.e. of dimension $n-1$) use **Marching Ridges** method (Furst et al. 2001):
 - compute eigenvalues of \mathbf{H} : $\lambda_1 \geq \dots \geq \lambda_n$
 - ε_n : eigenvector for λ_n ($\varepsilon_n \perp$ ridge)
 - solve for $\varepsilon_n \cdot \mathbf{g} = 0$ (single scalar equation!)



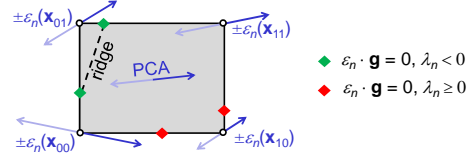
Ronald Peikert

SciVis 2007 - Hot Topics

12-27

Ridge computation

- Problem: ε_n is not a vector field (ambiguous directions). **Marching Ridges** does the following per cell:
 - orient ε_n at nodes of cell by PCA
 - evaluate $\varepsilon_n \cdot \mathbf{g}$ at nodes
 - interpolate zero crossings on edges
 - use zero crossings with $\lambda_n < 0$
 - generate triangles for **Marching Cubes** case



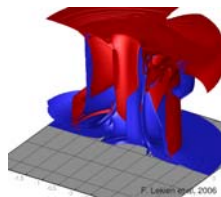
Ronald Peikert

SciVis 2007 - Hot Topics

12-28

LCS as separation surfaces in 3D

Example: 3D simulation data (Rayleigh-Bénard convection), LCS for positive and negative time.



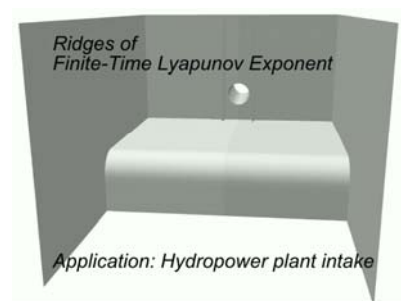
(Image: F. Lekien)

Ronald Peikert

SciVis 2007 - Hot Topics

12-29

LCS as separation surfaces in 3D



(Video: F. Sadlo)

Ronald Peikert

SciVis 2007 - Hot Topics

12-30

LCS as separation surfaces in 3D

*Ridges of
Finite-Time Lyapunov Exponent*



Application: Francis Draft Tube

(Video: F. Sadlo)

Ronald Paikert

SciVis 2007 - Hot Topics

12-31