Visualization
– Illustrative Visualization

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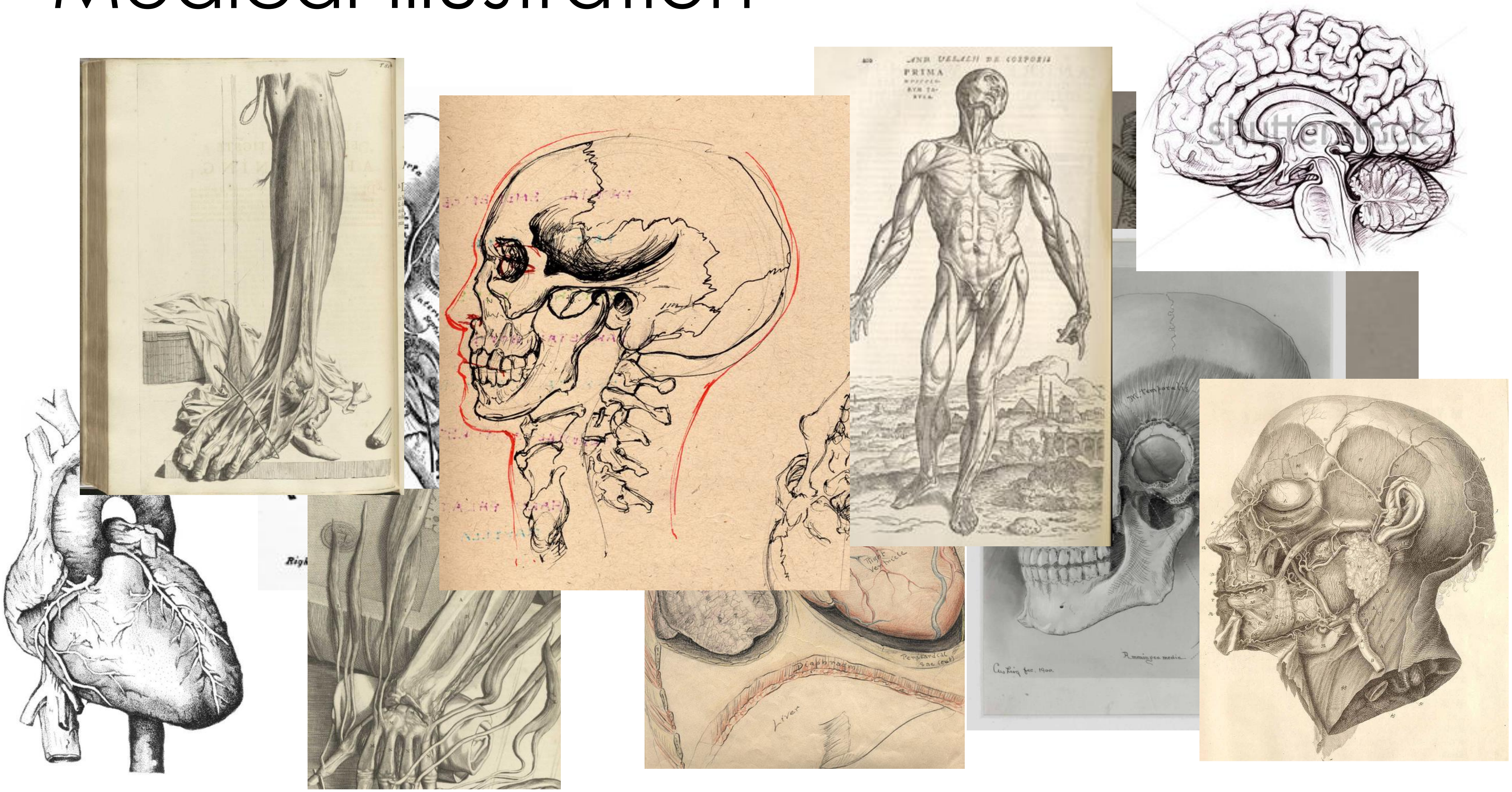
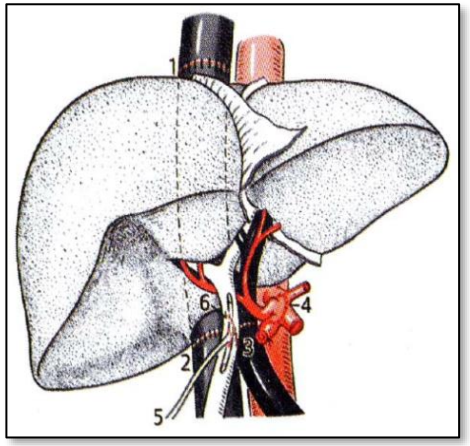
- Illustrative Visualization
  - Illustrative Volume Rendering
  - Features Lines
- Summary

Medical Illustration

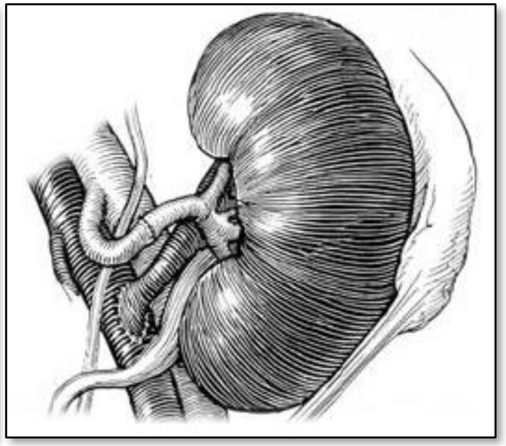


Motivation and Goals

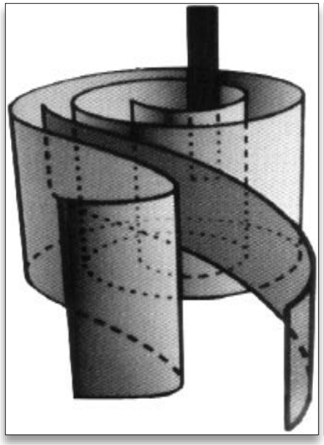
- Role Model: Illustrations in medical textbooks, atlases, technical drawings
- Application and adaptation of illustration techniques



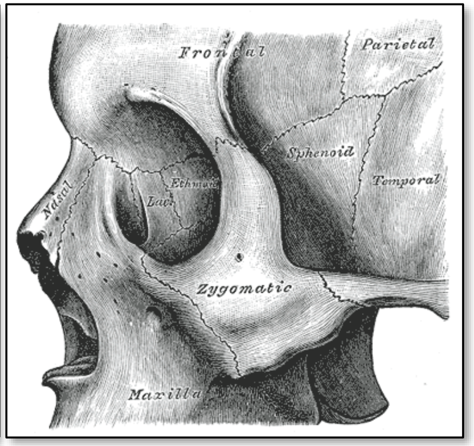
Stippling



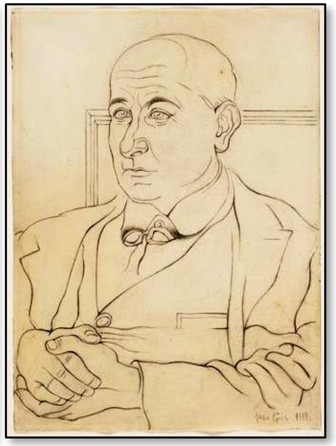
Hatching (Andrews 2006)



Line Rendering (Dooley/Cohen 1990)



Shading (Gray 1918)



Feature Lines (Matisse und Juan Gris 2007)

Smart Visibility (Hulsey 2005)

Motivation and Goals

- Goals:
  - *„Illustrative visualization has the main purpose to communicate information and not necessarily to look real.“* (Hodges 2003)
  - Information reduction to the essence ➔ Better understanding of complex relations
  - Accentuation (focus) and attenuation (context) of information
  - Visualization of spatial relations
  - Increase of the surface perception
  - Adaptation to the visibility of objects

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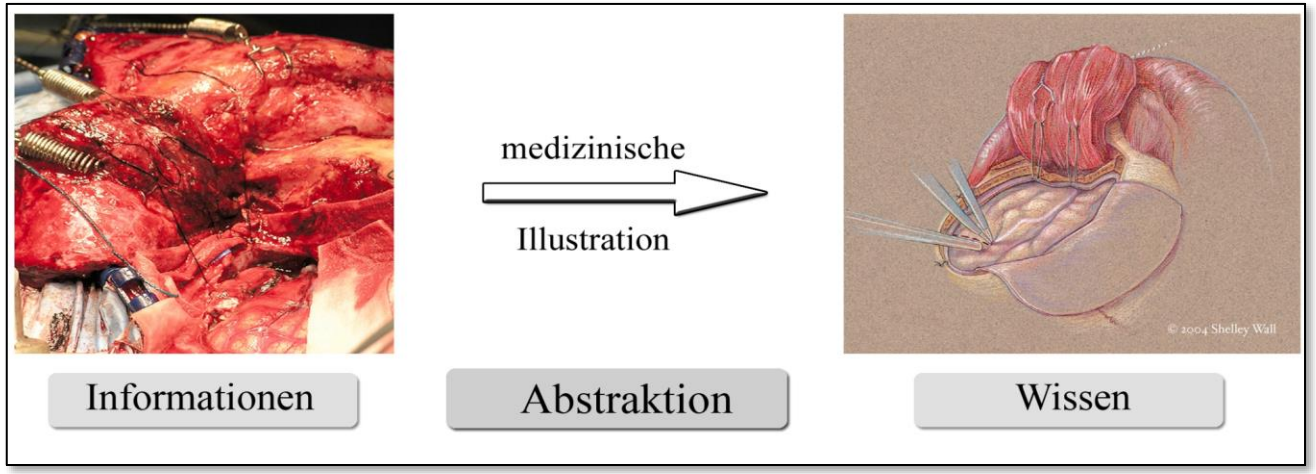
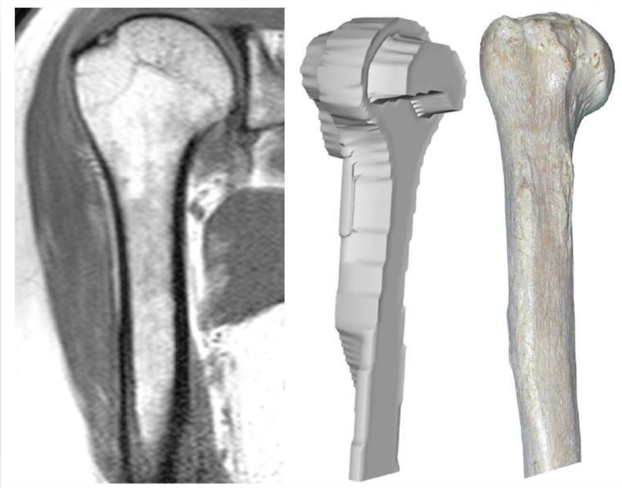


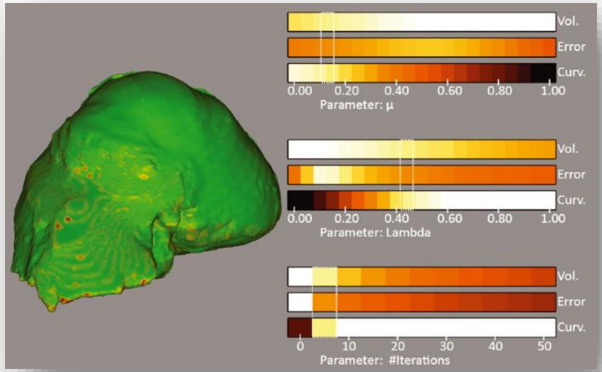
Viola et al. 2005 and Sousa et al. 2006

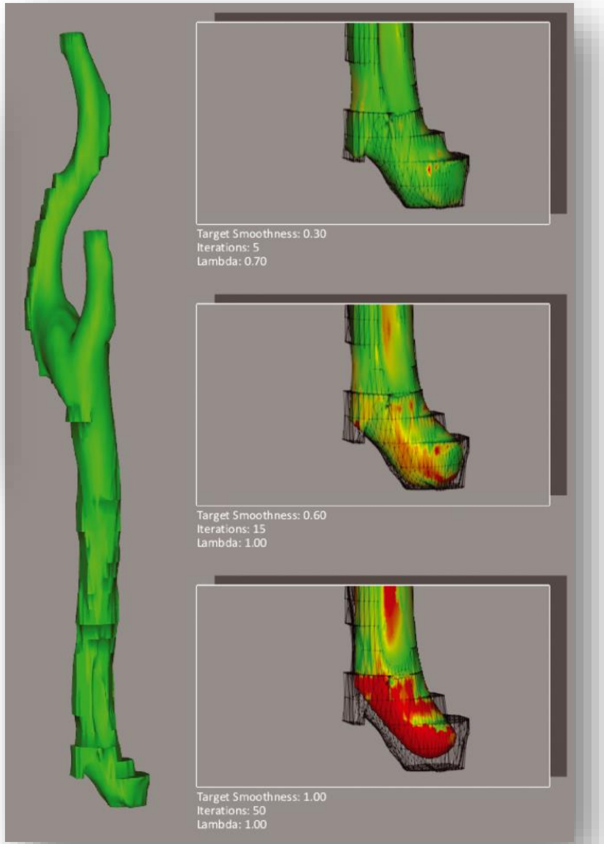
Requirements

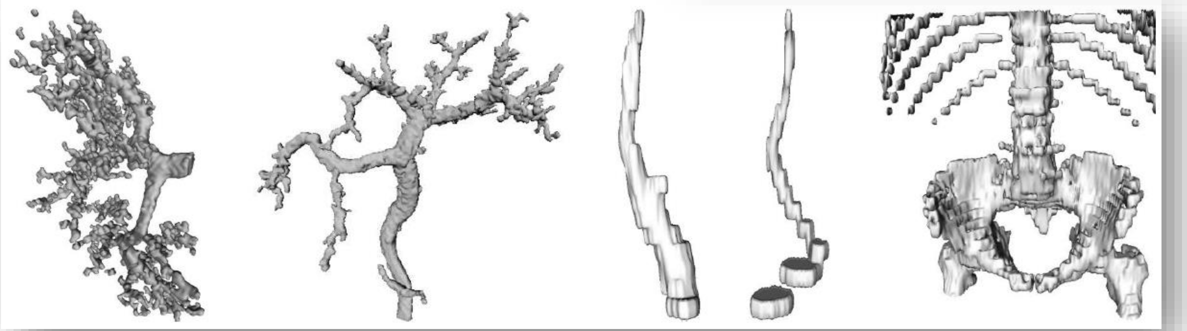
- Smoothing: Features should be retained



[Mönch et al. 2013]





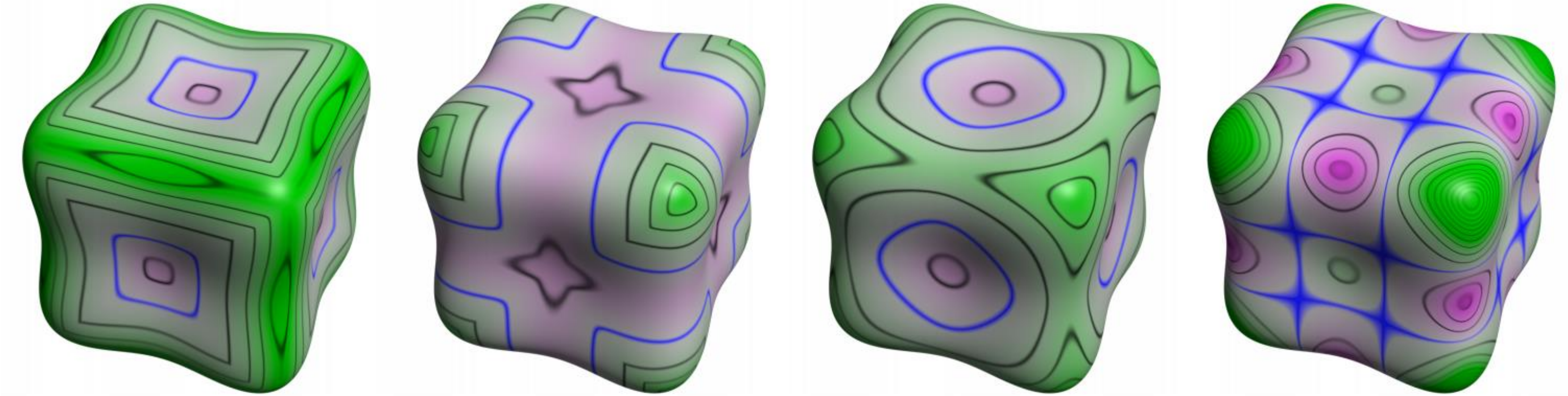


[Bade et al. 2006]

Curvature–Based Transfer Functions

Curvature–Based Transfer Functions

- Direct volume rendering maps data measures to opacities and colors
- Incorporating curvature measures into the illustration
- Curvature-based transfer functions extend the expressivity and utility of volume rendering



(From: Kindlmann et al. 2003)

Curvature Measurement

- Curvature depends on small positional changes on the surface, and the resulting changes in the surface normal
- Volume data, surfaces are implicitly represented as isosurfaces of reconstructed continuous data values f(x)

$$f : \mathbb{R}^n \to \mathbb{R}$$

$$\nabla f = \left(\frac{\partial f}{\partial x_1}, \frac{\partial f}{\partial x_2}, \frac{\partial f}{\partial x_3}, \ldots, \frac{\partial f}{\partial x_n} \right)^T$$

(From: Kindlmann et al. 2003)

Curvature Measurement

- Assume the values f increase as we move further inside objects of interest (e.g., a standard CT scan), the surface normal is defined as:

$$n = -\frac{\nabla f}{|\nabla f|}$$

(From: Kindlmann et al. 2003)

Curvature Measurement

- Assume the values f increase as we move further inside objects of interest (e.g., a standard CT scan), the surface normal is defined as:

$$n = -\frac{\nabla f}{|\nabla f|}$$

- Curvature information is encoded in the 3x3 matrix:

$$\nabla n^T$$

(From: Kindlmann et al. 2003)

Curvature Measurement

- Curvature information is encoded in the 3x3 matrix: ∇n^T
- Do not want to calculate the gradient of a pre-computed normal

(From: Kindlmann et al. 2003)

Curvature Measurement

- Curvature information is encoded in the 3x3 matrix: ∇n^T
- Do not want to calculate the gradient of a pre-computed normal, but:

$$\begin{aligned}\nabla n^T &= -\nabla \left(\frac{\nabla f^T}{|\nabla f^T|} \right) \\ &= -\frac{1}{|\nabla f^T|}(I - nn^T)H\end{aligned}$$

$$\begin{aligned} I &\ \ldots\ \ \text{identity matrix} \\ H &\ \ldots\ \ \text{Hessian matrix}\end{aligned}$$

Curvature Measurement

$$\begin{aligned}\nabla n^T &= -\nabla\left(\frac{\nabla f^T}{|\nabla f^T|}\right)\\ &= -\frac{1}{|\nabla f^T|}(I - nn^T)H\end{aligned}$$

$$H = \left(\frac{\partial^2 f}{\partial x_i \partial x_j}\right)_{i,j=1,\ldots,n} = \begin{pmatrix} \partial^2 f/\partial x_1^2 & \ldots & \partial^2 f/\partial x_1 \partial x_n \\ \vdots & \ddots & \vdots \\ \partial^2 f/\partial x_n \partial x_1 & \ldots & \partial^2 f/\partial x_n^2 \end{pmatrix}$$

Curvature Measurement

$$\nabla n^T = -\nabla\left(\frac{\nabla f^T}{|\nabla f^T|}\right)$$
$$= -\frac{1}{|\nabla f^T|}\underbrace{\left(I - nn^T\right)}_{P} H$$

Curvature Measurement

$$\begin{aligned}\nabla n^T &= -\nabla\left(\frac{\nabla f^T}{|\nabla f^T|}\right)\\ &= -\frac{1}{|\nabla f^T|}\underbrace{\left(I - nn^T\right)}_{P} H\\ &= -\frac{1}{|\nabla f^T|} P H\end{aligned}$$

Curvature Measurement

- What is P?

$$P = I - nn^T$$

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$$2x + 2y + z = 0$$

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$$2x + 2y + z = 0 \qquad n = \frac{1}{3}\begin{pmatrix} 2 \\ 2 \\ 1 \end{pmatrix}$$

Curvature Measurement

- What is P?

$$P = I - nn^T$$

$$= \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} - \begin{pmatrix} 2/3 \\ 2/3 \\ 1/3 \end{pmatrix} \begin{pmatrix} 2/3 & 2/3 & 1/3 \end{pmatrix}$$

$$= \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} - \begin{pmatrix} 4/9 & 4/9 & 2/9 \\ 4/9 & 4/9 & 2/9 \\ 2/9 & 2/9 & 1/9 \end{pmatrix}$$

$$= \begin{pmatrix} 5/9 & -4/9 & -2/9 \\ -4/9 & 5/9 & -2/9 \\ -2/9 & -2/9 & 8/9 \end{pmatrix}$$

- Simple example:

$$2x + 2y + z = 0$$

$$n = \frac{1}{3} \begin{pmatrix} 2 \\ 2 \\ 1 \end{pmatrix}$$

Curvature Measurement

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Curvature Measurement

- What is P?

$$P \cdot \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 5/9 & -4/9 & -2/9 \\ -4/9 & 5/9 & -2/9 \\ -2/9 & -2/9 & 8/9 \end{pmatrix} \cdot \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$$

$$= \begin{pmatrix} -1/9 \\ -1/9 \\ 4/9 \end{pmatrix}$$

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Curvature Measurement

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$$P \cdot \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} -1/9 \\ -1/9 \\ 4/9 \end{pmatrix}$$

- Simple example:

$$2x + 2y + z = 0$$

$$n = \frac{1}{3} \begin{pmatrix} 2 \\ 2 \\ 1 \end{pmatrix}$$

$$\begin{aligned} 2x + 2y + z &= 0 \\ 2 \cdot (-1/9) + 2 \cdot (-1/9) + (4/9) &= 0 \\ -4/9 + 4/9 &= 0 \\ 0 &= 0 \end{aligned}$$

Curvature Measurement

- What is P?
- P is an operator that projects every point on the tangent plane defined by the normal n

Curvature Measurement

- Rewrite:

$$\nabla n^T = -\frac{1}{|\nabla f^T|} PH$$

Curvature Measurement

- Rewrite:

$$\nabla n^T = -\frac{1}{|\nabla f^T|} PH$$

- P & H are symmetric and P projects vector on the tangent space
  - Restricting ∇n^T to the tangent space is symmetric -> exist othonormal basis (p1,p2) such that ∇n^T is diagonal

Curvature Measurement

- Rewrite:

$$\nabla n^T = -\frac{1}{|\nabla f^T|} PH$$

- Given a basis (p1,p2,n):

$$\nabla n^T = \begin{pmatrix} \kappa_1 & 0 & \sigma_1 \\ 0 & \kappa_2 & \sigma_2 \\ 0 & 0 & 0 \end{pmatrix}$$

Curvature Measurement

- Given a basis (p1,p2,n):

$$G = \nabla n^T P = \begin{pmatrix} \kappa_1 & 0 & 0 \\ 0 & \kappa_2 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

- In general G has not the easily transparent form:

$$G = -\frac{PHP}{|\nabla f|}$$

Curvature Measurement

$$G = -\frac{PHP}{|\nabla f|}$$

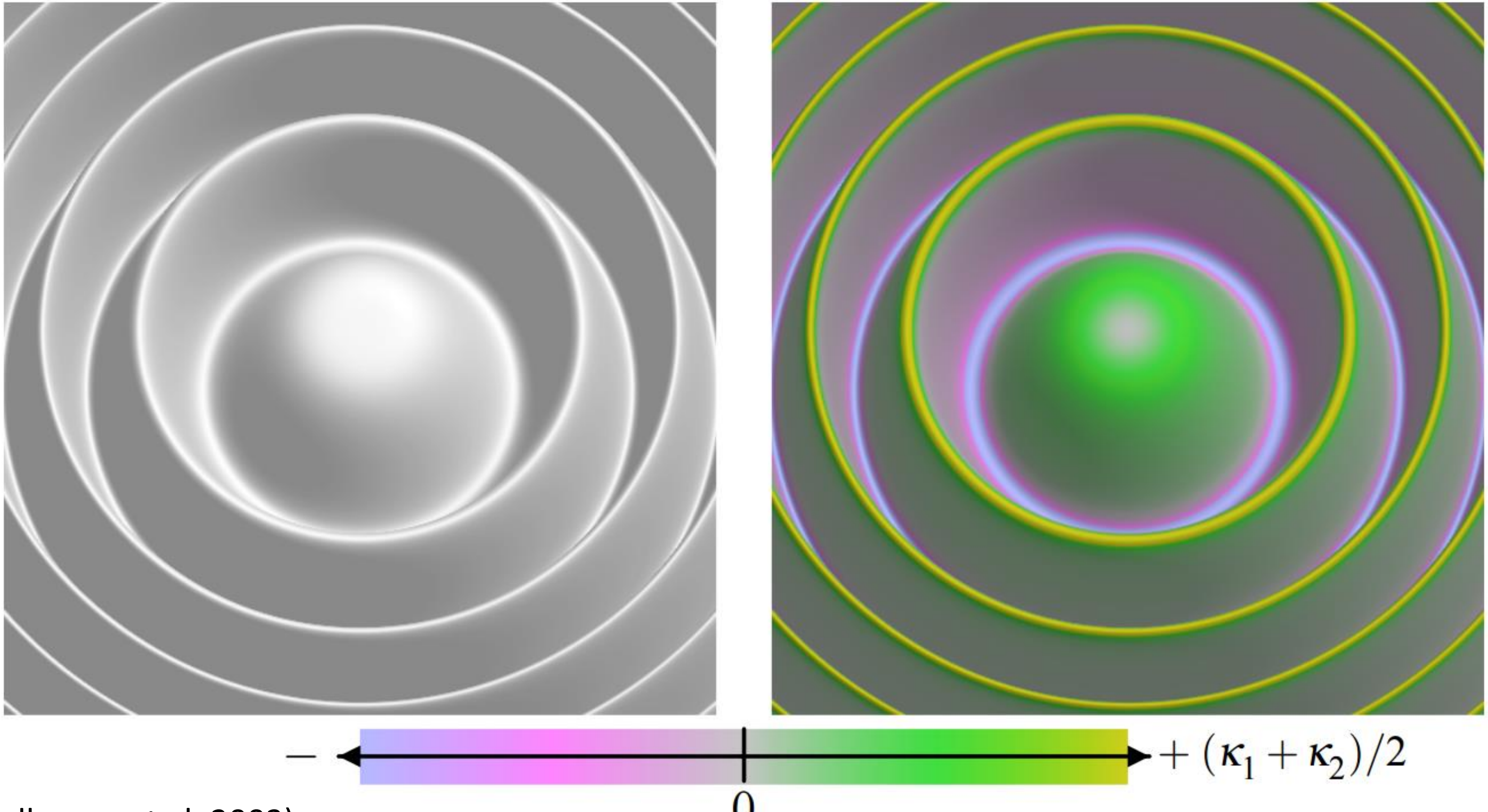
$$T = trace(G) = \kappa_1 + \kappa_2$$

$$F = |G|_F = \sqrt{\kappa_1^2 + \kappa_2^2}$$

Curvature Measurement

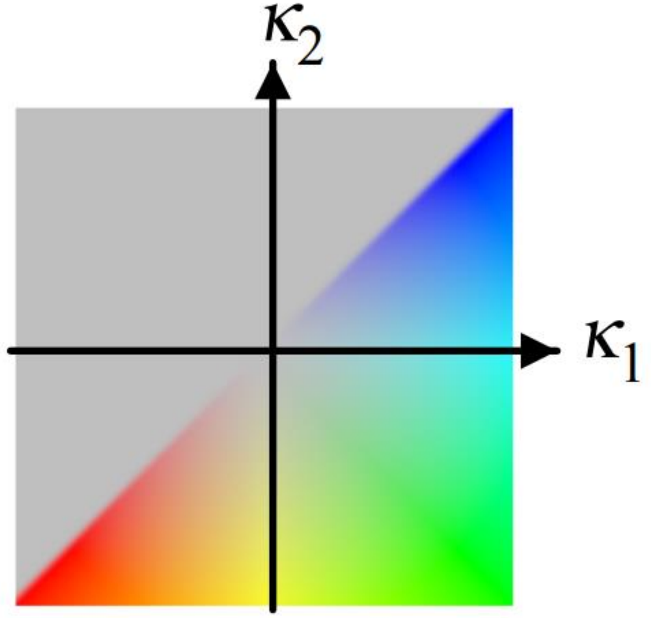
$$\kappa_{1/2} = \frac{T \pm \sqrt{2F^2 - T^2}}{2}$$

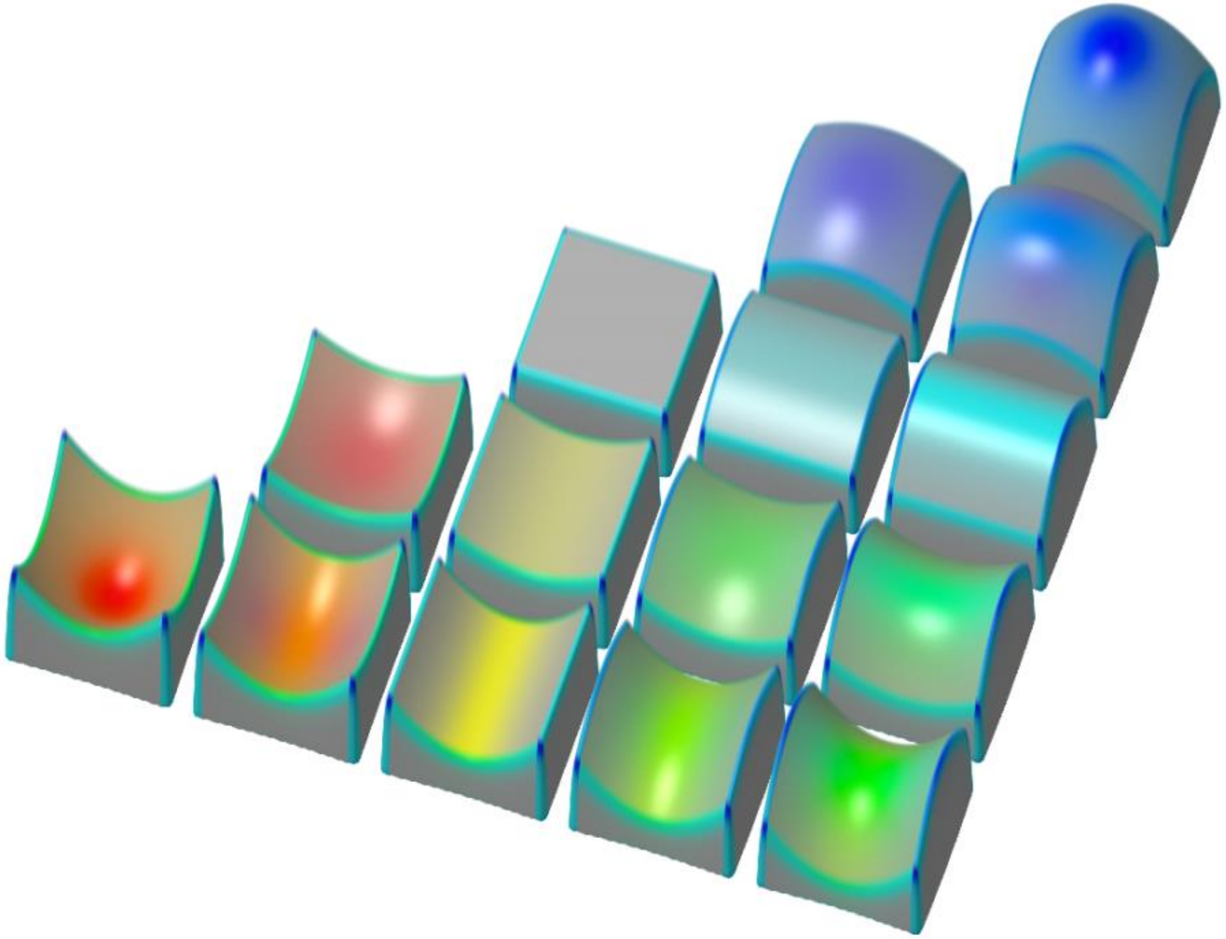
Curvature-Based Transfer Function



(From: Kindlmann et al. 2003)

Emphasizing Valleys and Ridges





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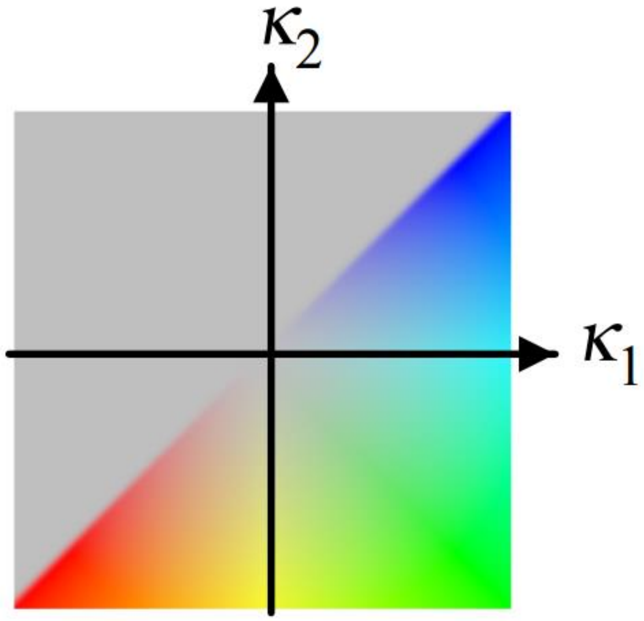

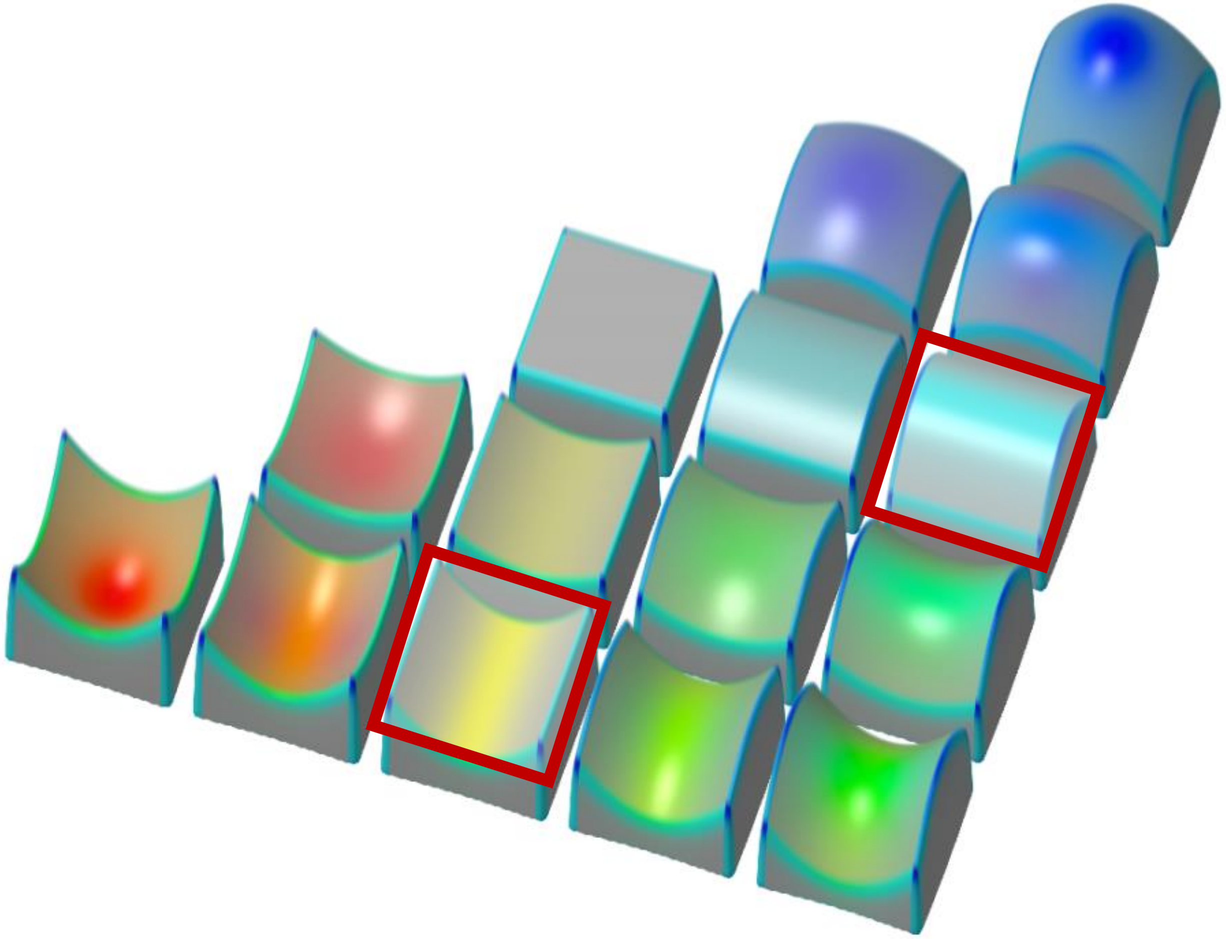

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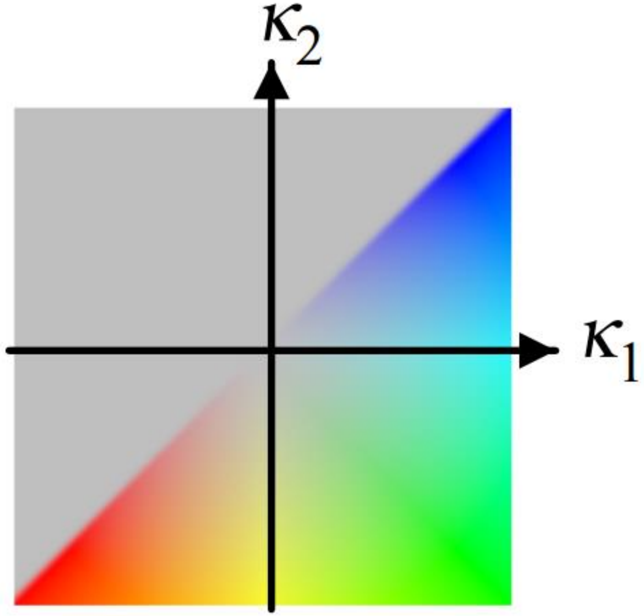
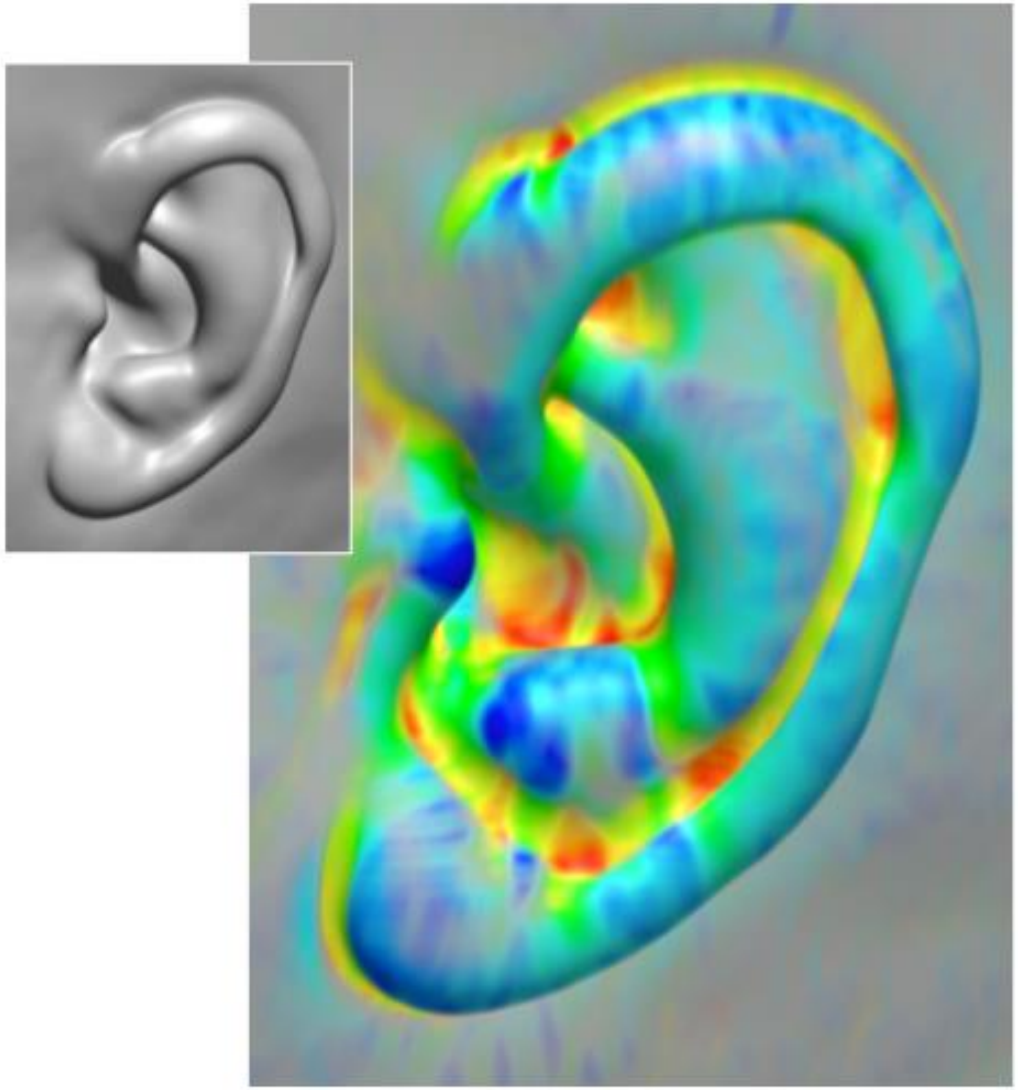
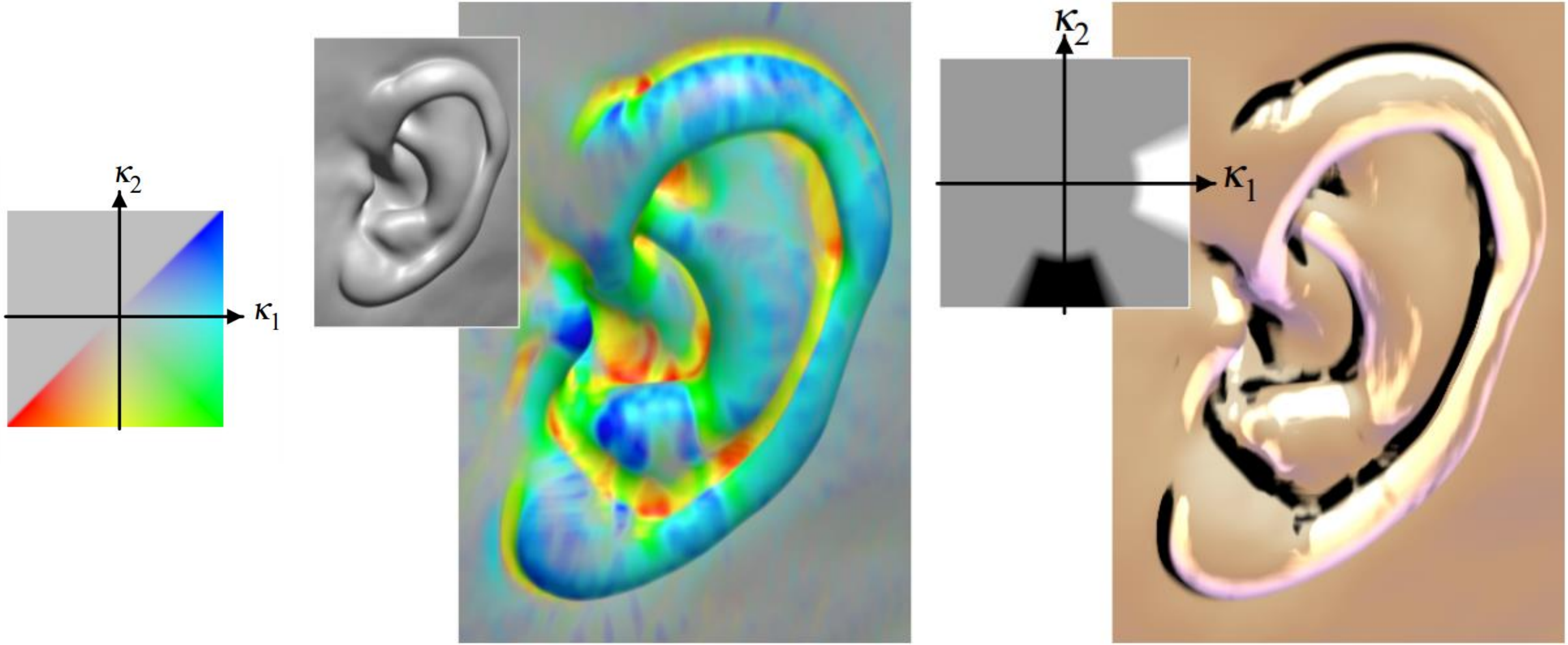




(From: Kindlmann et al. 2003)

Emphasizing Valleys and Ridges



(From: Kindlmann et al. 2003)

Non-Photorealistic Volume Rendering

- Contours based solely on:

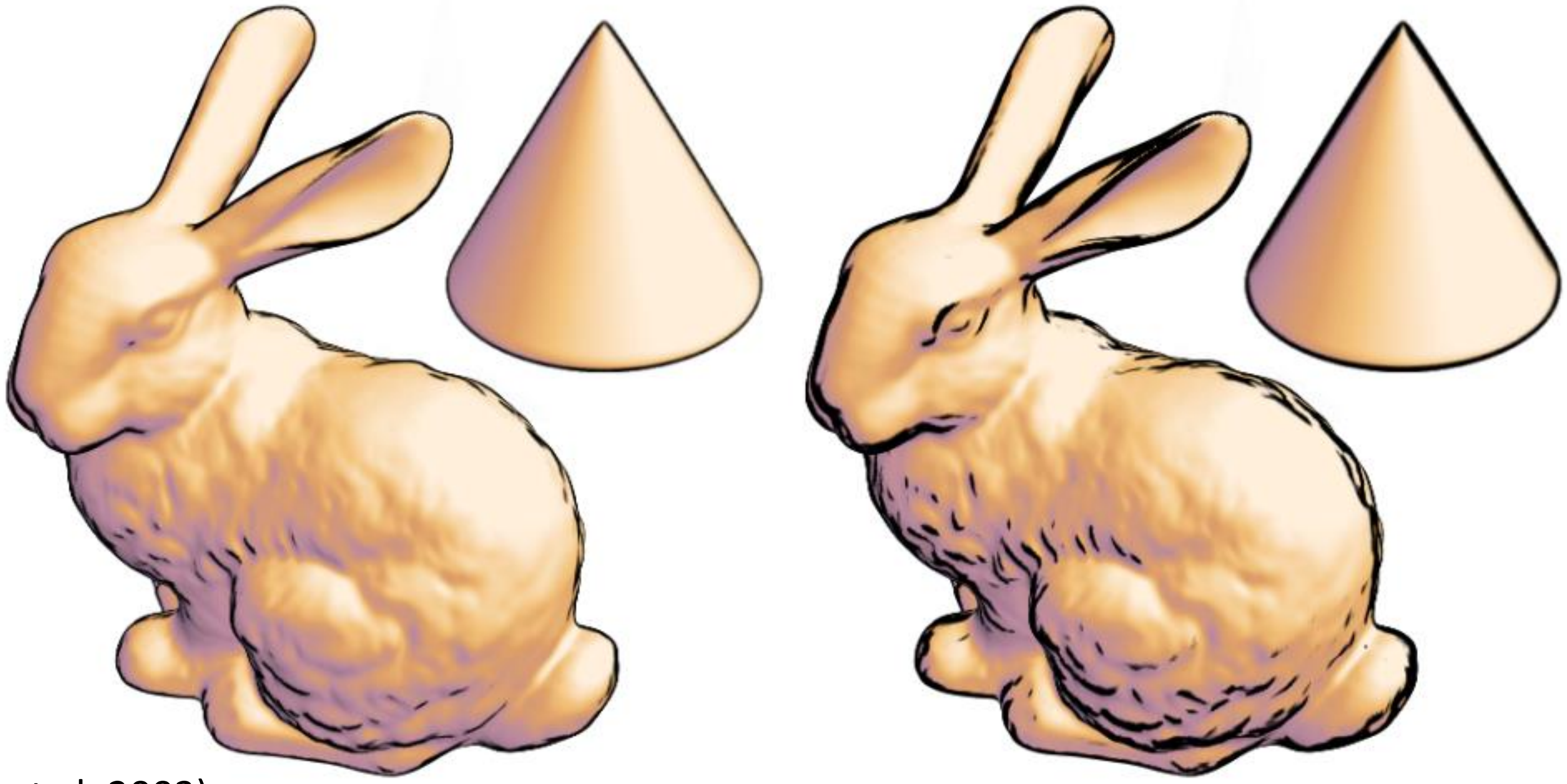
$$n \cdot v < \epsilon$$

- Uncontrolled variation in the apparent contour thickness

(From: Kindlmann et al. 2003)

Non-Photorealistic Volume Rendering

- How to fix this?



(From: Kindlmann et al. 2003)

Non–Photorealistic Volume Rendering

- Use the curvature in view direction κ_v

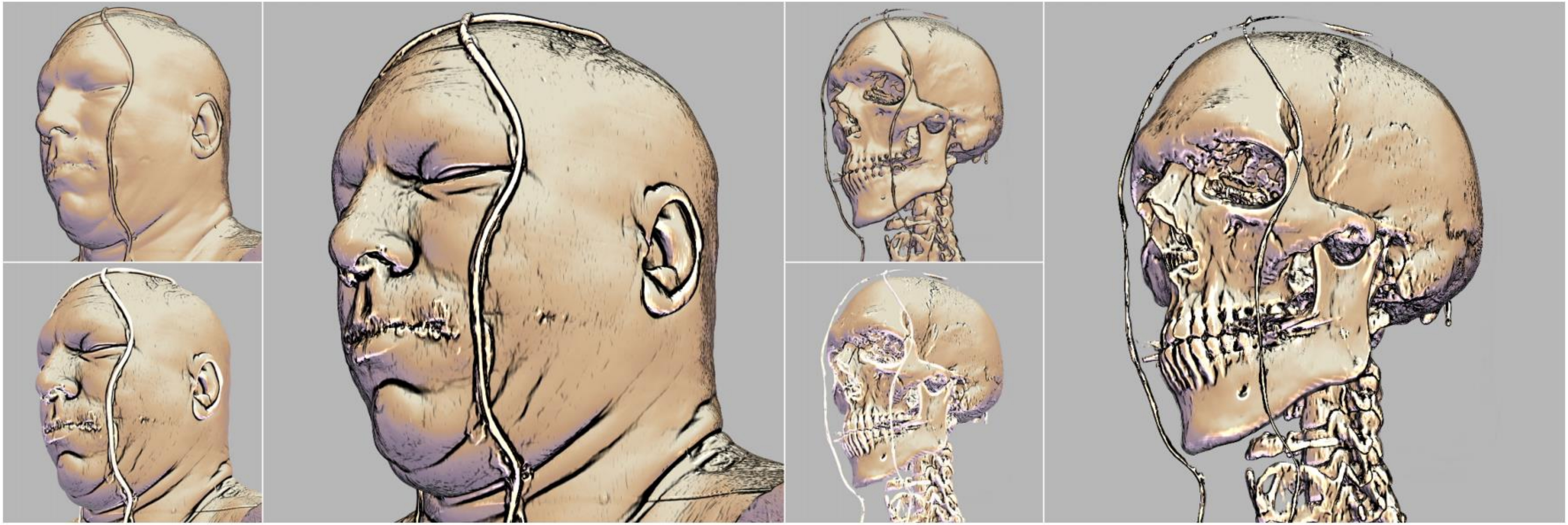
- Then, we get

$$n \cdot v \leq \sqrt{T\kappa_v(2 - T\kappa_v)}$$

$T \ldots$ image space thickness

(From: Kindlmann et al. 2003)

Emphasizing Valleys and Ridges

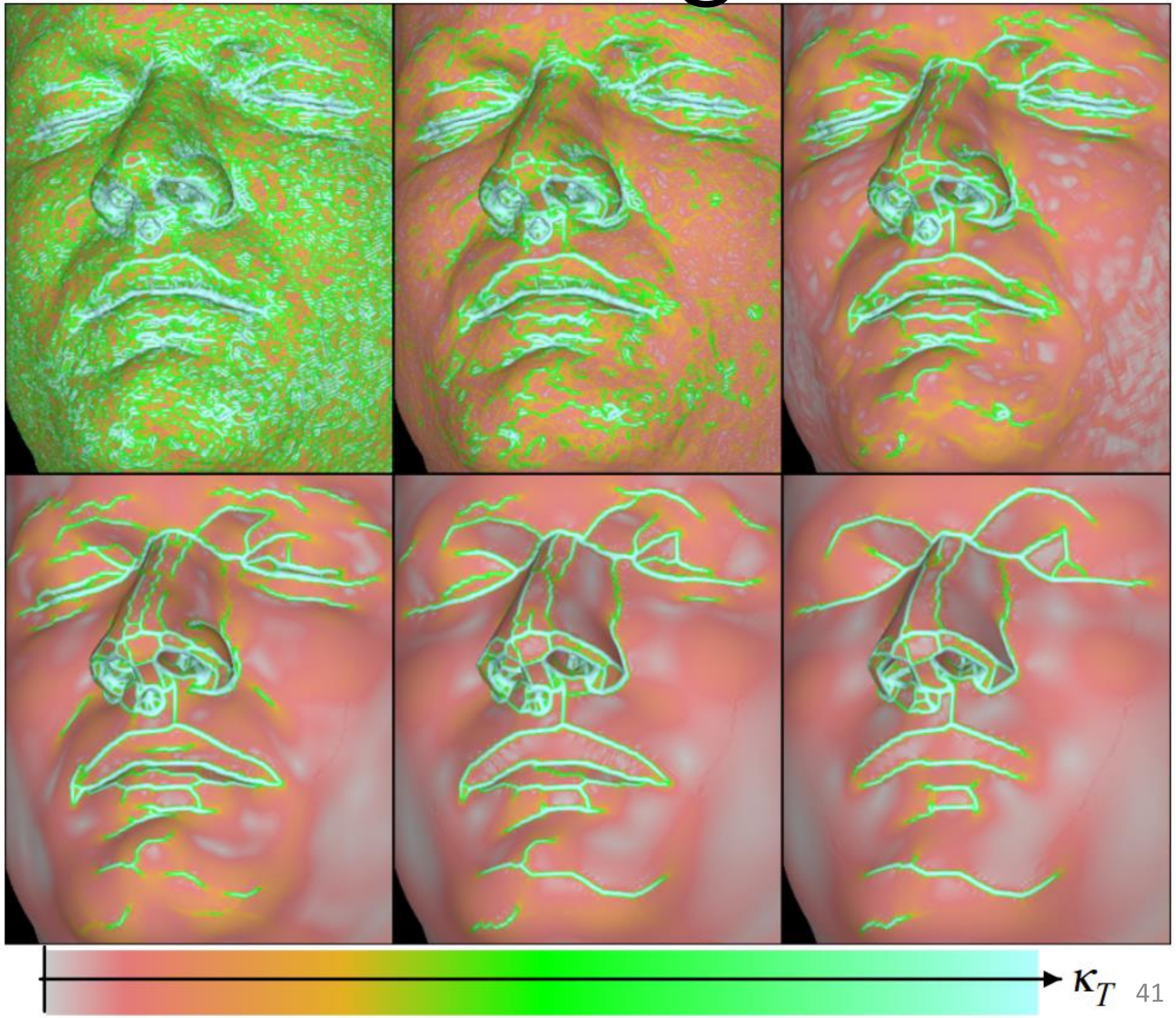


(From: Kindlmann et al. 2003)

Visualizing Surface Smoothing

- Visualizing of anisotropic surface smoothing

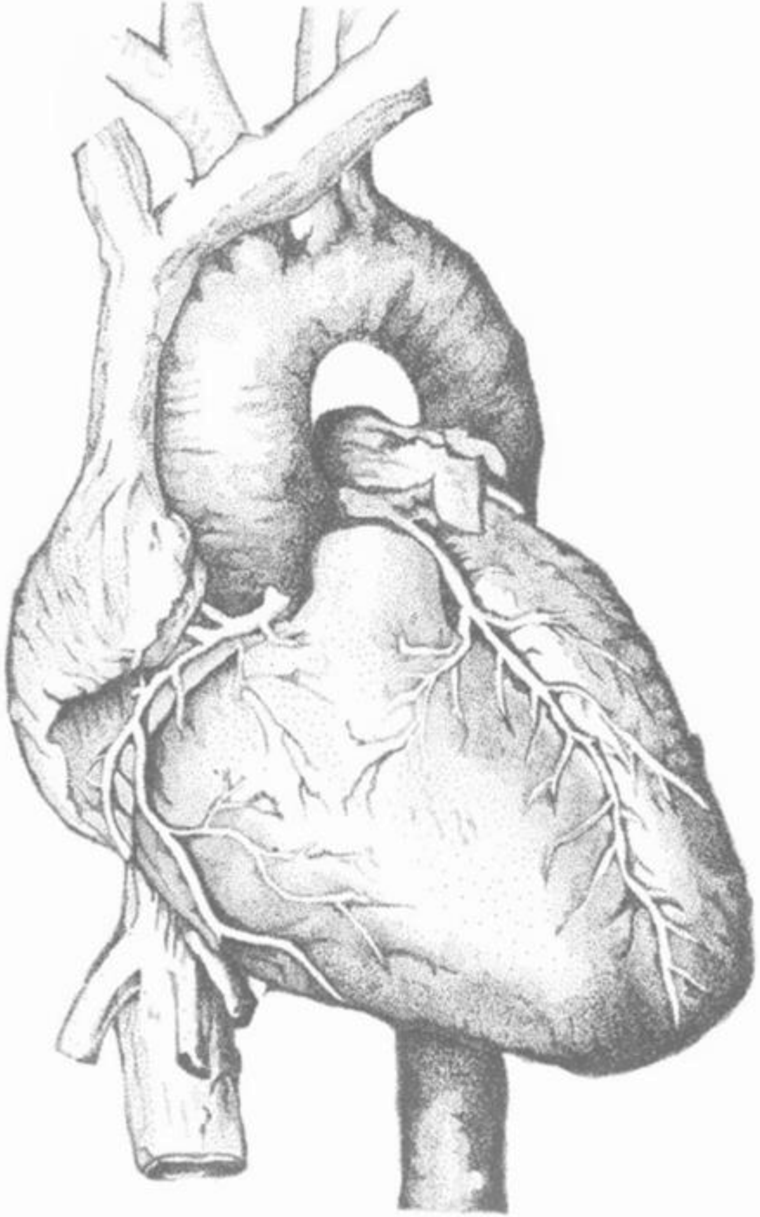
$$\kappa_T = \sqrt{\kappa_1^2 + \kappa_2^2}$$

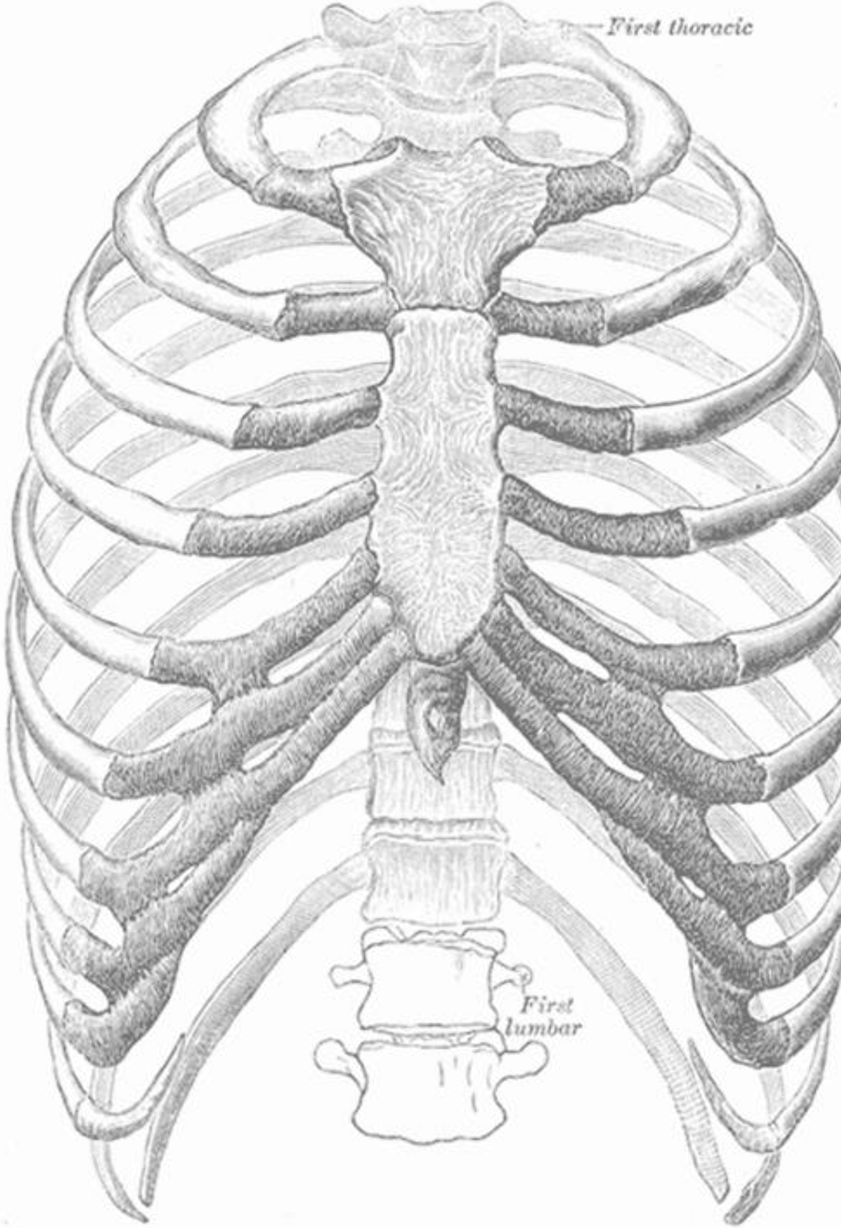


(From: Kindlmann et al. 2003)

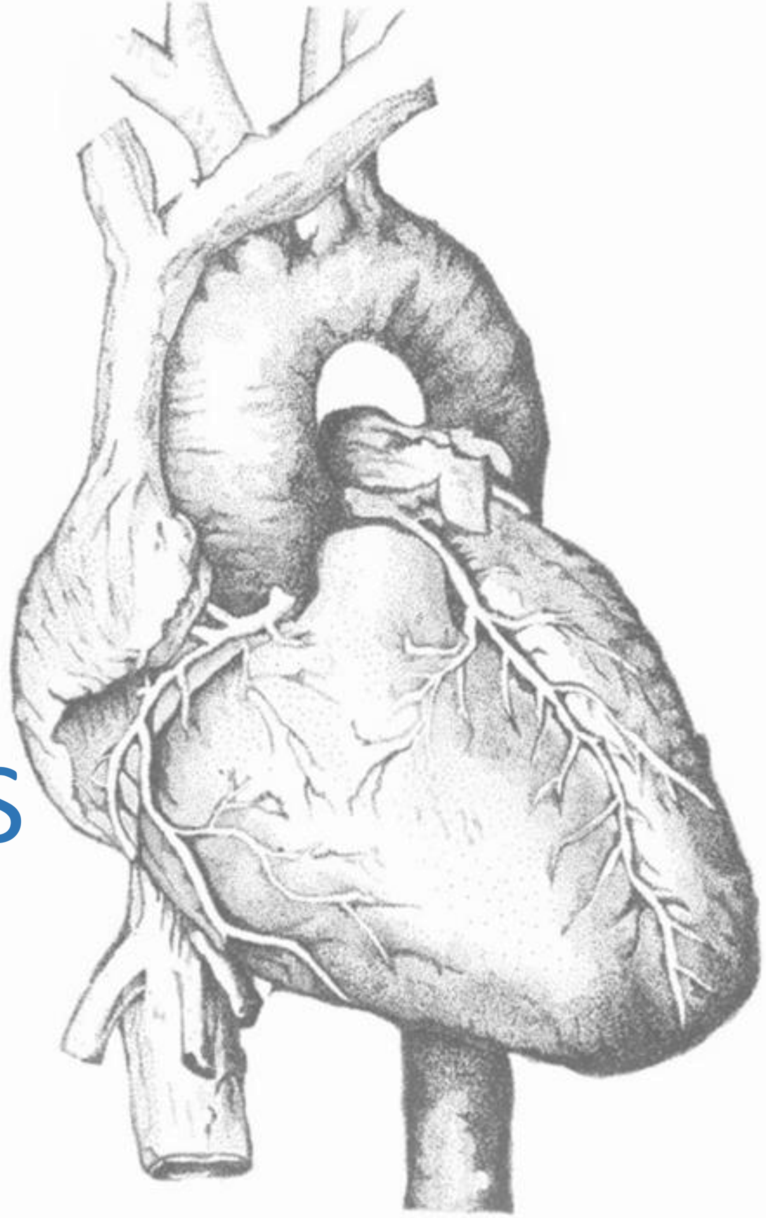
Feature Lines

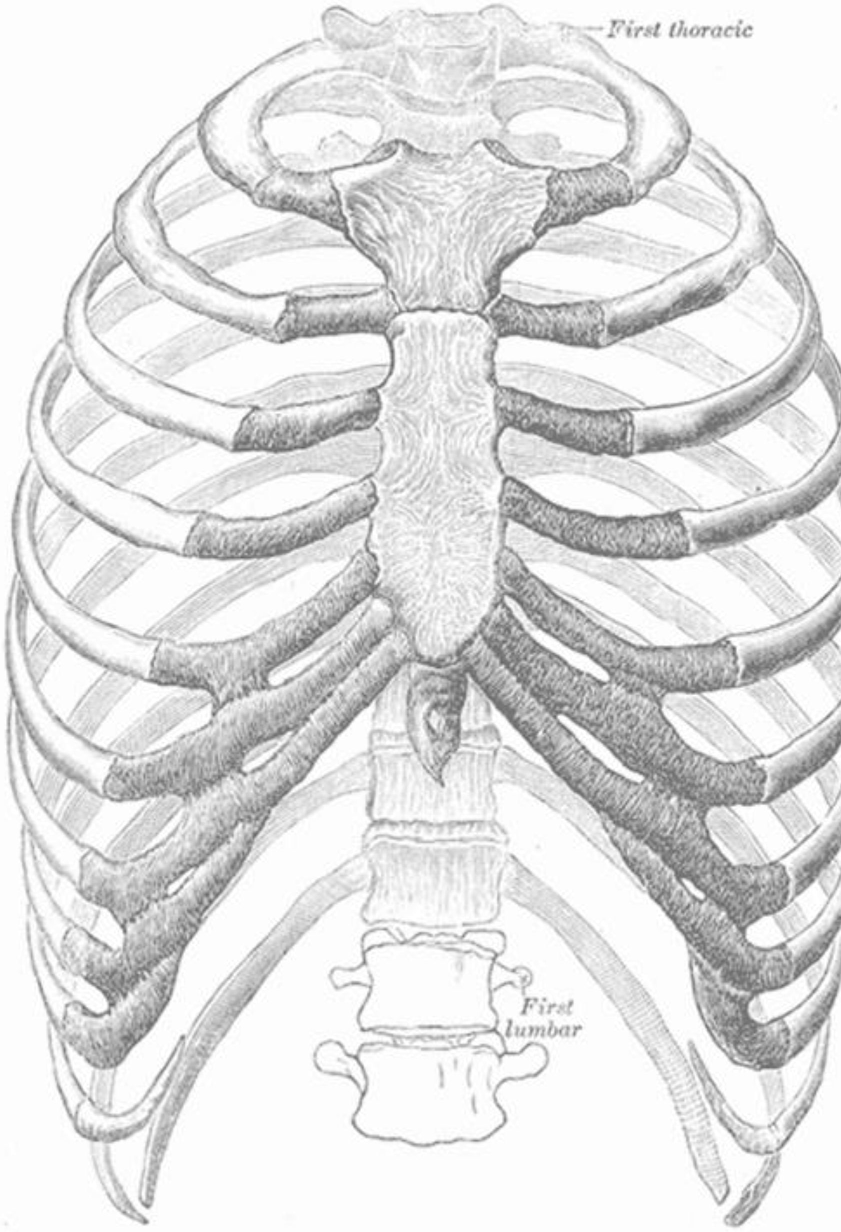
MEDICAL ILLUSTRATIONS BASED ON



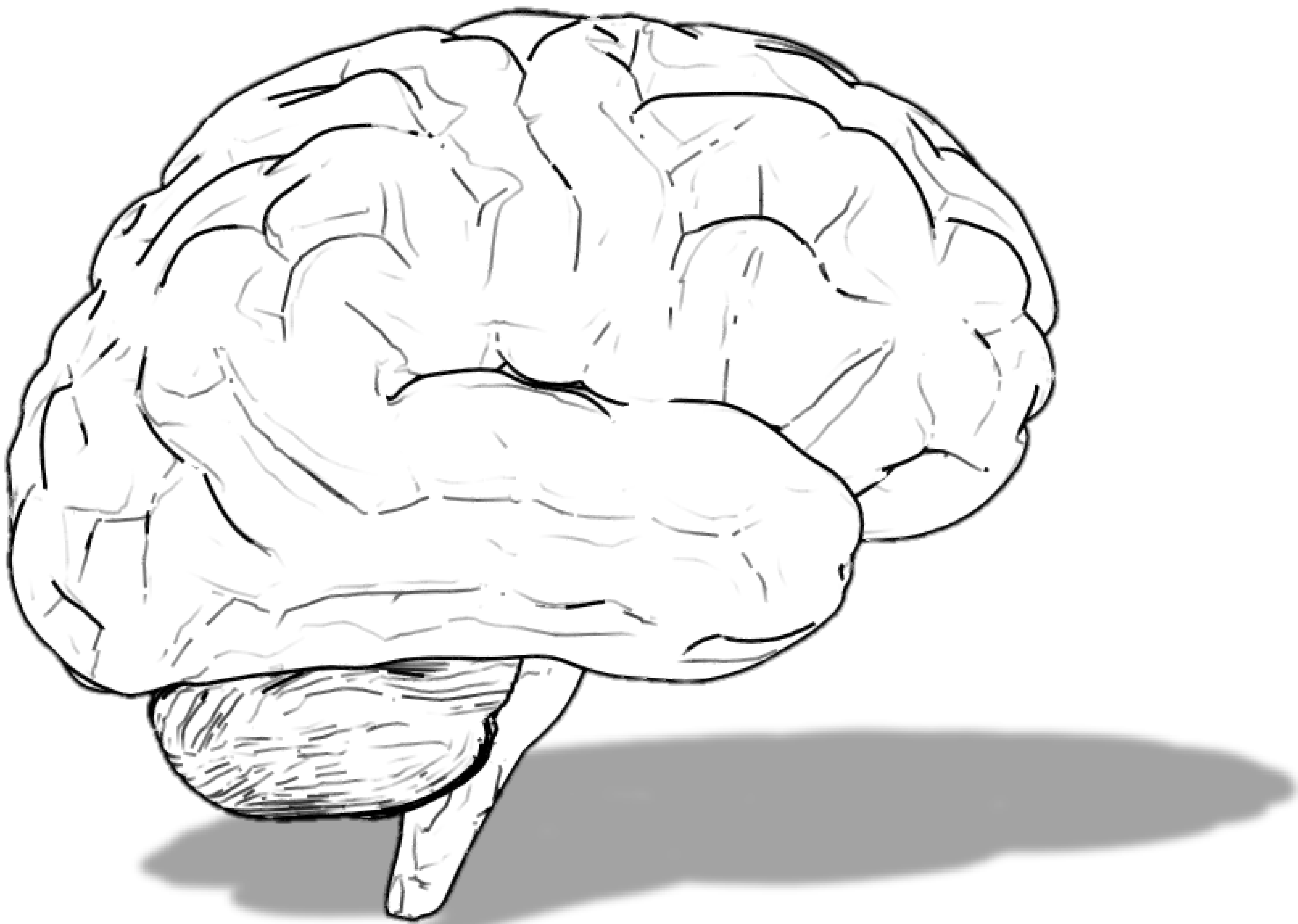


MEDICAL ILLUSTRATIONS BASED ON LINE DRAWINGS

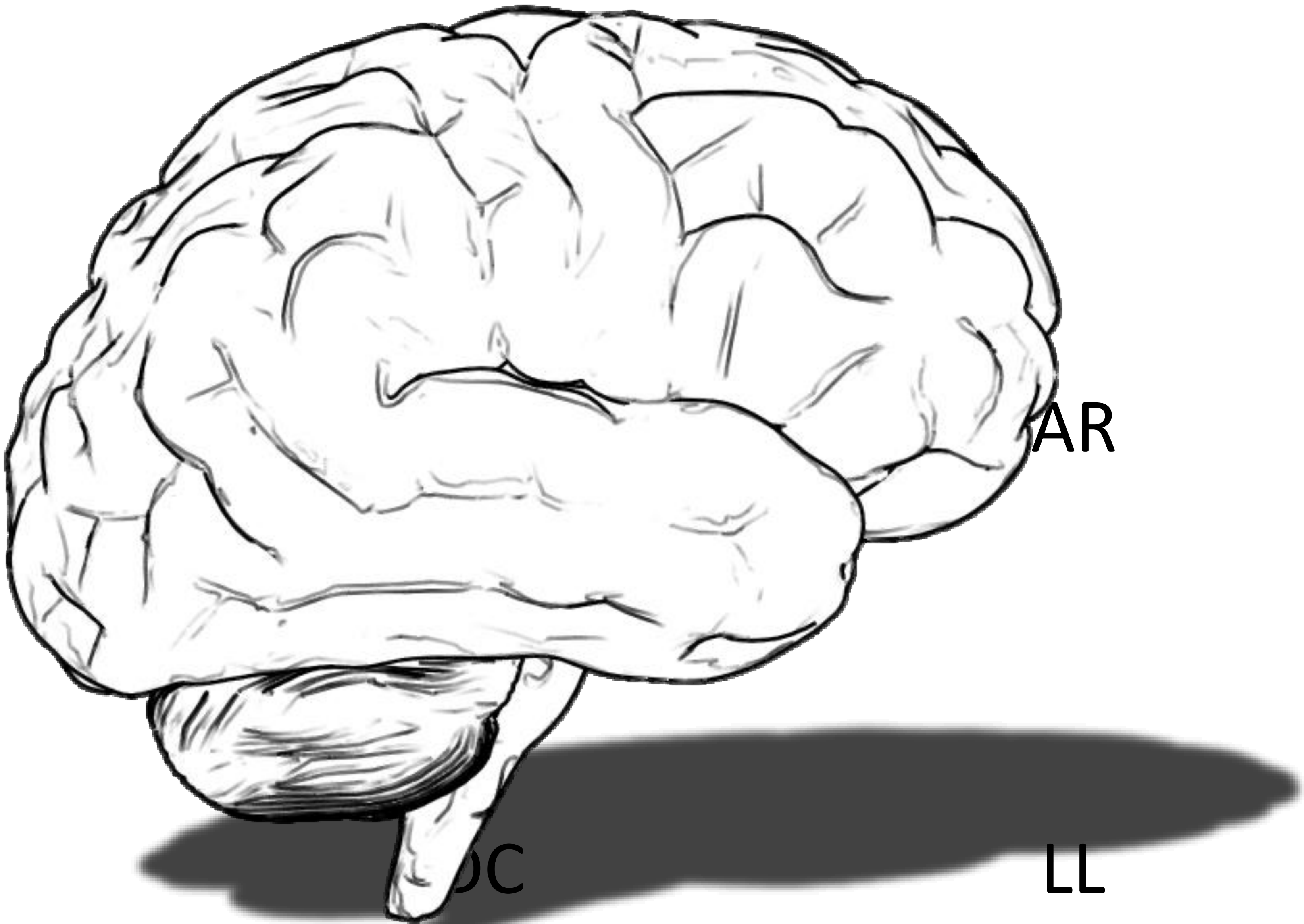




Feature Lines



Feature Lines



RV

AR

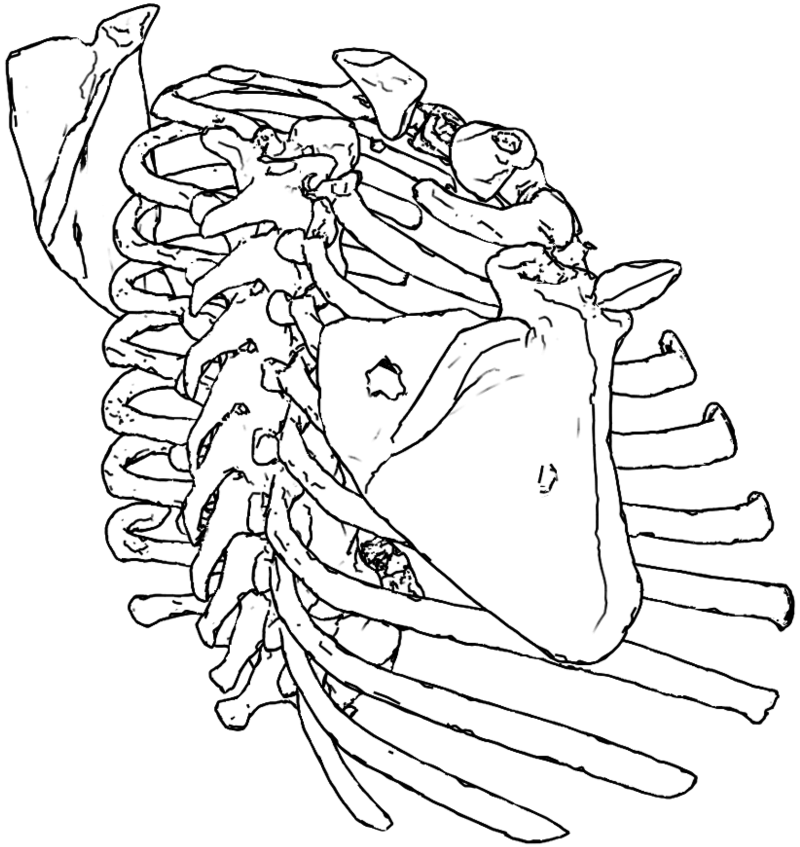
PEL

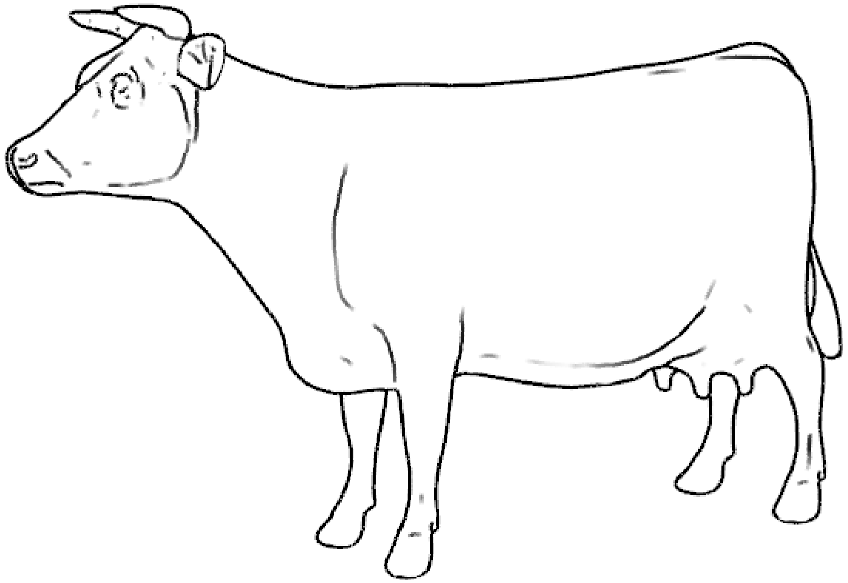
C

LL

Feature Lines

- Illustrate features on surfaces
- Separate lines





General Requirements of Feature Lines

- Smoothing:
  - Most of the feature line methods use higher order derivatives
  - The methods assume sufficiently smooth input data

- Frame coherence:
  - During the interaction the user should not be distracted by features that pop out or disappear suddenly

- Filtering:
  - Filtering of feature lines to set apart relevant lines from distracting ones

Feature Lines

- Comparison of image-based and object-based silhouette generation:
    - Both use graphics hardware, are real-time capable
    - Image-based: Easier to implement, result depends on the resolution of the buffers, stylization not possible
    - Object-based: Stylization through analytic description of the edges possible, more accurate, hard to implement and dependent on the quality of the 3D surfaces

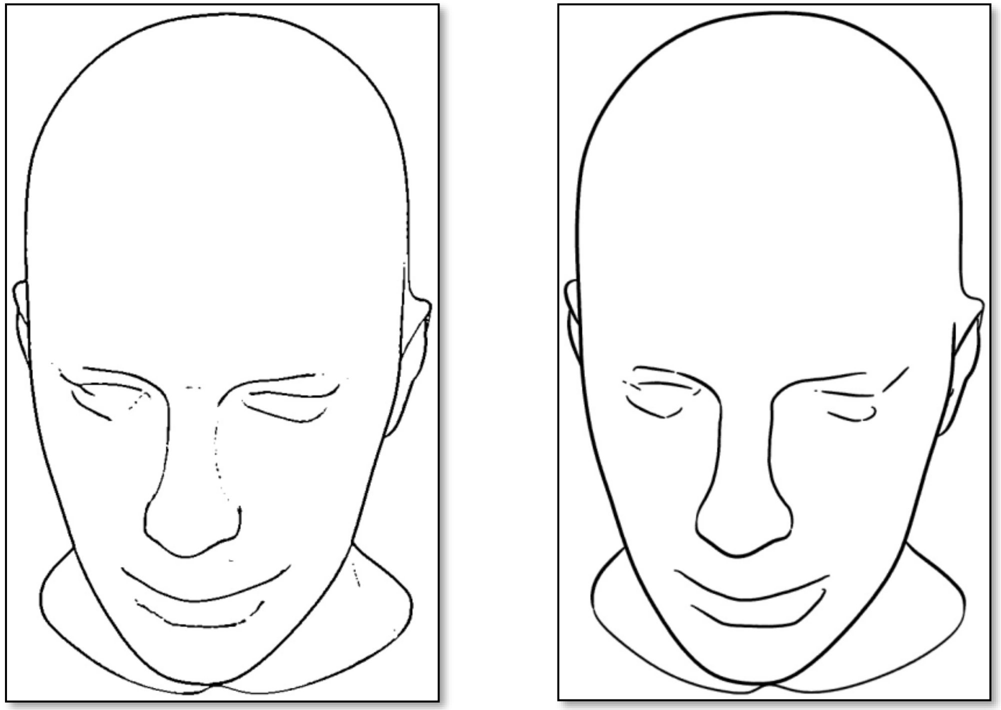
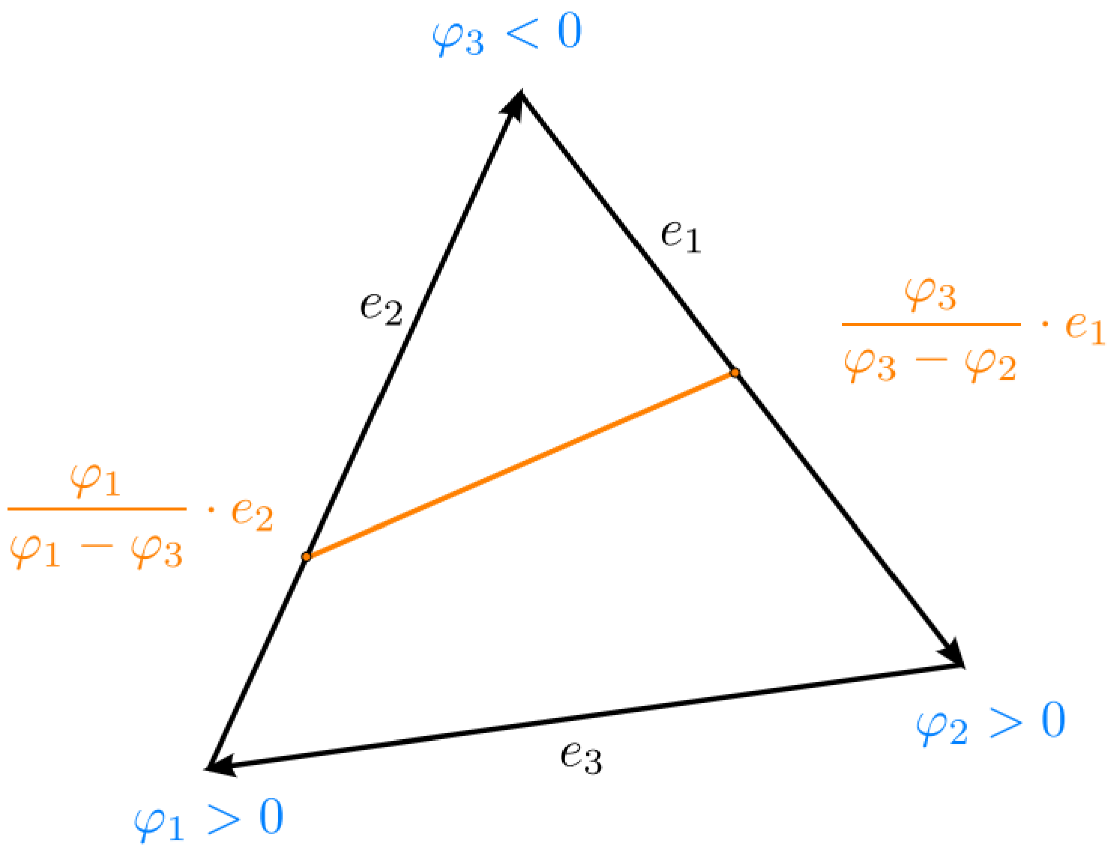


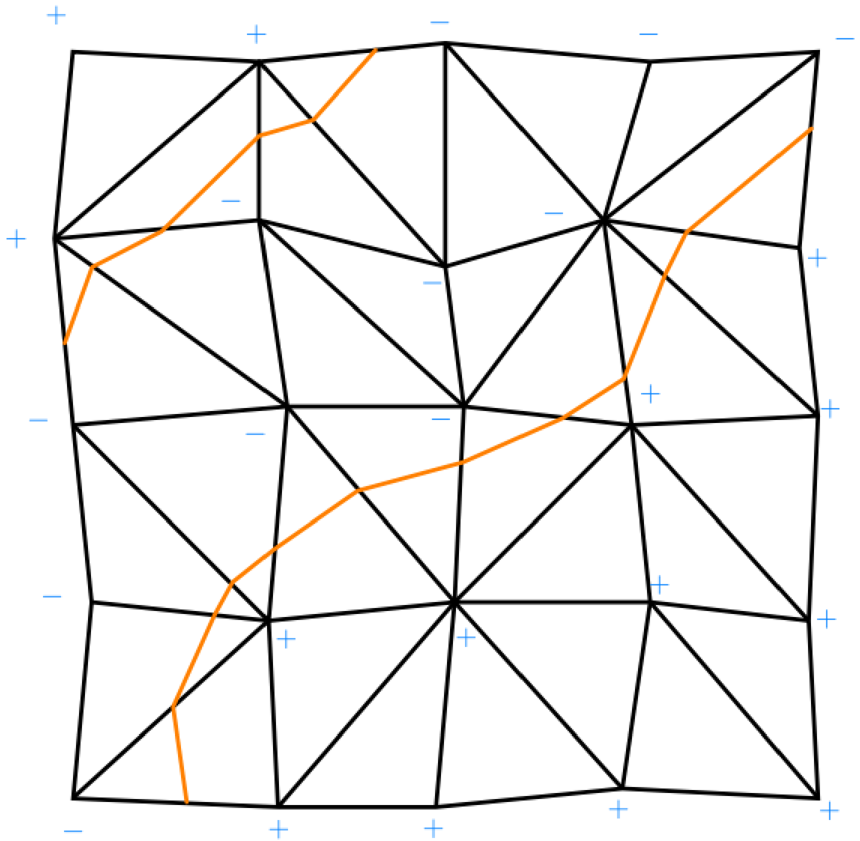
Image-based (left) and object-based (right)

Isolines on Triangulated Surfaces

- Given is a scalar field on the surface
- How to determine the zero-crossings?

Isolines on Triangulated Surfaces





(From: Lawonn and Preim, 2015)

Covariant Derivative

- Covariant derivative (derivative of a scalar field along a vector)

$$D_v \varphi(x)$$

Covariant Derivative

- Covariant derivative (derivative of a scalar field along a vector)

$$D_v\varphi(x) = \lim_{h \to 0} \frac{\varphi(x + hv) - \varphi(x)}{h}$$

Covariant Derivative

- Covariant derivative (derivative of a scalar field along a vector)
- If the scalar field is differentiable:

$$D_v\varphi(x) = \langle \nabla\varphi(x), v \rangle$$

Covariant Derivative

$$f(x,y) = 5 - x^2 - y^2$$

$$v(x,y) = \begin{pmatrix} -y \\ x \end{pmatrix}$$

$$D_{v(x,y)} f(x,y)$$

Covariant Derivative

$$f(x,y) = 5 - x^2 - y^2$$

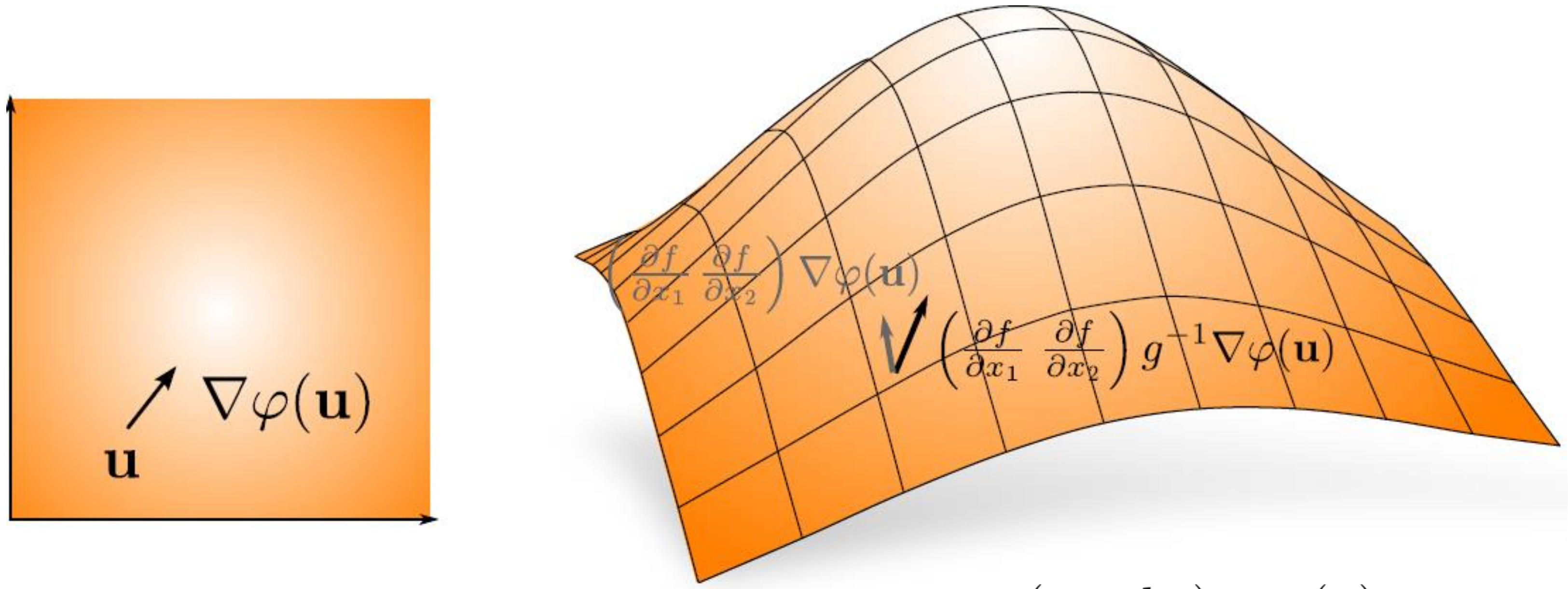
$$v(x,y) = \begin{pmatrix} -y \\ x \end{pmatrix}$$

$$\begin{aligned} D_{v(x,y)} f(x,y) &= \langle \nabla f(x,y), v(x,y) \rangle \\ &= \left\langle \begin{pmatrix} -2x \\ -2y \end{pmatrix}, \begin{pmatrix} -y \\ x \end{pmatrix} \right\rangle \\ &= 0 \end{aligned}$$

Covariant Derivative

- Covariant derivative of a scalar field along isolines = 0

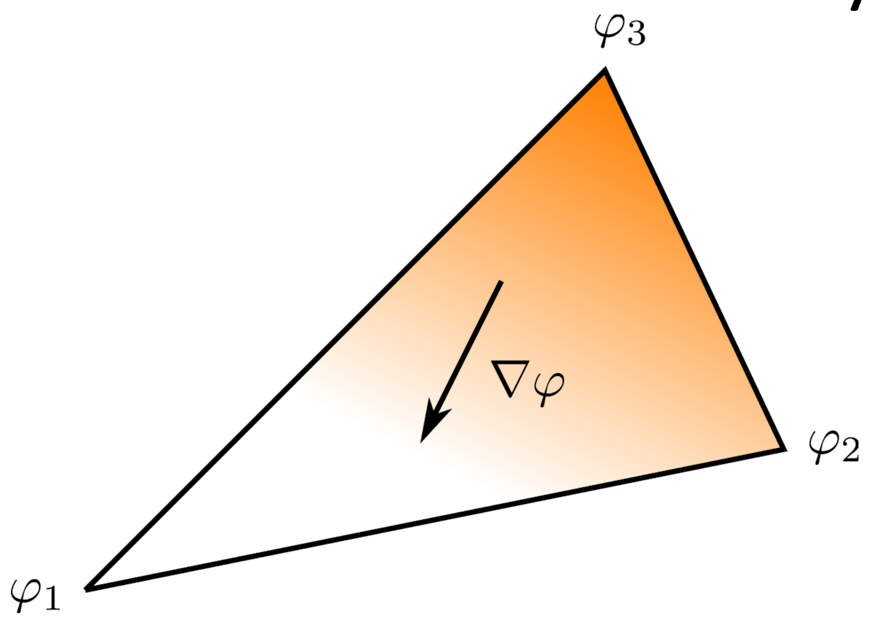
Requirements: Differential Geometry



- Covariant derivative: $D_v\varphi(x) = \lim_{h\to 0} \frac{\varphi(x+hv)-\varphi(x)}{h}.$

- Simplified: $D_v\varphi(x) = \langle \nabla\varphi(x), v\rangle,$

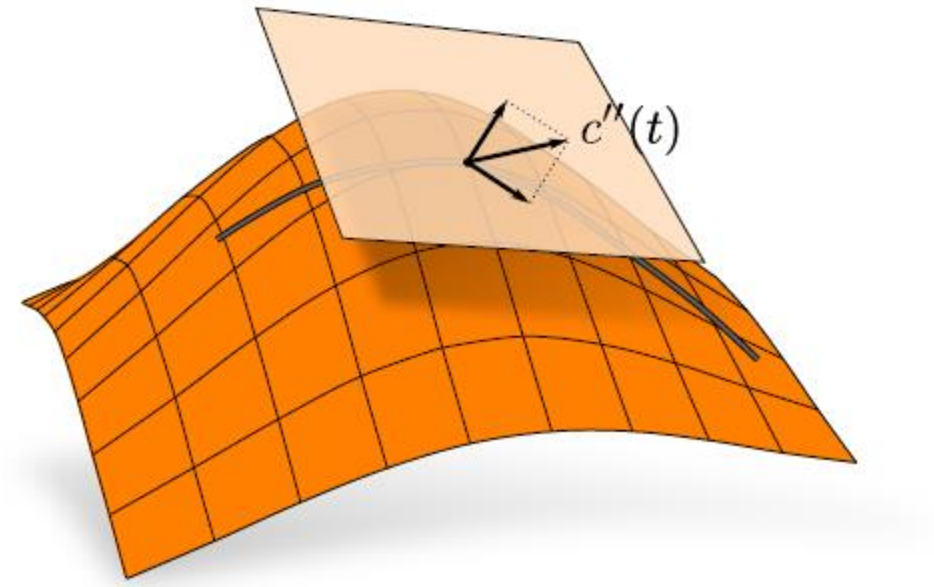
Discrete Differential Geometry



- Discrete covariant derivative: $D_v\varphi(x) = \langle \nabla\varphi(x), v \rangle.$

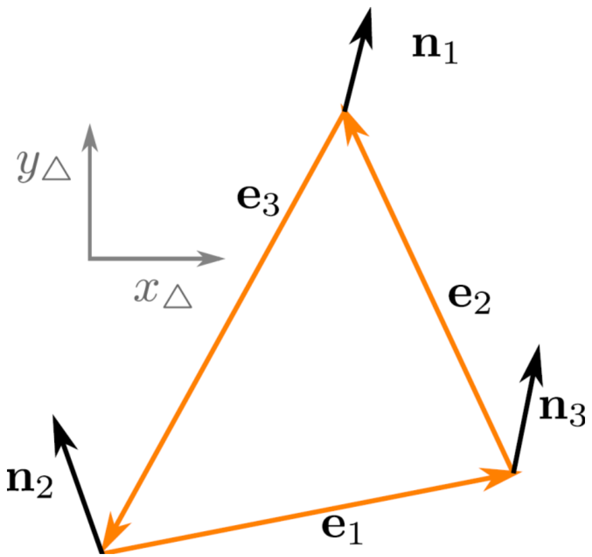
$$\nabla\varphi_\triangle = (\varphi_2 - \varphi_1)\frac{(p_1 - p_3)^\perp}{2A_\triangle} + (\varphi_3 - \varphi_1)\frac{(p_2 - p_1)^\perp}{2A_\triangle}$$

Requirements: Differential Geometry



- Curvature with curves: $c''(t) = \underbrace{proj_{\mathcal{T}_p f} c''(t)}_{\text{tangential part}} + \underbrace{\langle c''(t), n \rangle n}_{\text{normal part}}.$
- Curvature: $\kappa_{c'(t)}(p) = -\langle c'(t), \frac{\partial n}{\partial t} \rangle.$

Discrete Differential Geometry



$$S\begin{pmatrix}\langle e_1, x_\triangle\rangle \\ \langle e_1, y_\triangle\rangle\end{pmatrix} = \begin{pmatrix}\langle n_i - n_j, x_\triangle\rangle \\ \langle n_i - n_j, y_\triangle\rangle\end{pmatrix}$$

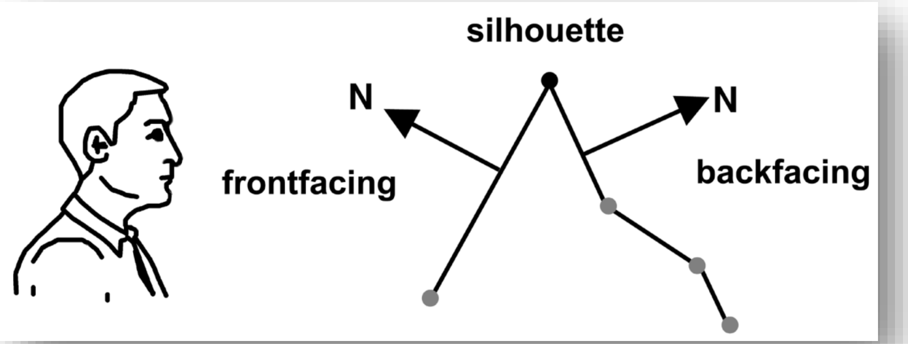
$$S\begin{pmatrix}\langle e_2, x_\triangle\rangle \\ \langle e_2, y_\triangle\rangle\end{pmatrix} = \begin{pmatrix}\langle n_j - n_k, x_\triangle\rangle \\ \langle n_j - n_k, y_\triangle\rangle\end{pmatrix}$$

$$S\begin{pmatrix}\langle e_3, x_\triangle\rangle \\ \langle e_3, y_\triangle\rangle\end{pmatrix} = \begin{pmatrix}\langle n_k - n_i, x_\triangle\rangle \\ \langle n_k - n_i, y_\triangle\rangle\end{pmatrix}$$

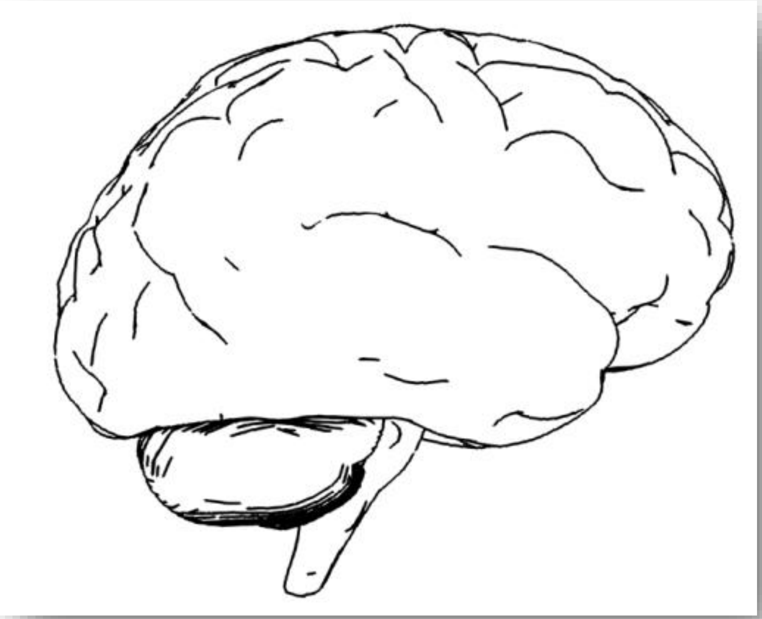
- Curvature approximation with shape operator
- Least square method
- Determine eigenvalues and eigenvectors

Contours

- Definition:
  - Continuous case: $\boxed{\langle c - p, n \rangle = 0}$
- For polygonal surfaces:
  - Not directly adaptable
  - Silhouette connects all edges sharing a visible and a occluded polygon



Gooch 2003



Contours

[Isenberg et al. 2003]

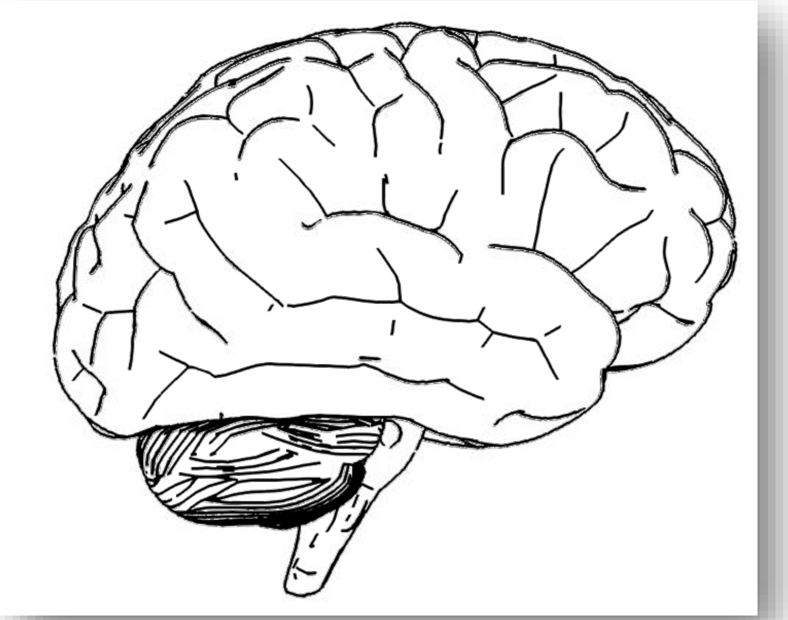
(From: Lawonn and Preim, 2015)

Crease Lines

- Definition:

$$\boxed{\kappa_r \geq \tau \quad \text{or} \quad \langle n_i, n_j \rangle \leq \tau'.}$$

- View-dependent
- 1. order



(From: Lawonn and Preim, 2015)

Ridges & Valleys

- Curvature based:

$$\boxed{D_{k_1}\kappa_1 = 0.}$$

$$D_{k_1}D_{k_1}\kappa_1 \begin{cases} < 0, & \text{and} \quad \kappa_1 > 0\text{: ridges} \\ > 0, & \text{and} \quad \kappa_1 < 0\text{: valleys.} \end{cases}$$

- View-independent
- 3. order

Ridges & Valleys

[Interrante et al. 1995]

(From: Lawonn and Preim, 2015)

Suggestive Contours

- View-dependent:

$$\boxed{D_w \langle n, v \rangle = 0 \quad \text{and} \quad D_w D_w \langle n, v \rangle > 0.}$$

or

$$\boxed{\kappa_r = 0 \quad \text{and} \quad D_w \kappa_r > 0.}$$

- 2. Order
- No convex objects

Suggestive Contours

[DeCarlo et al. 2003]

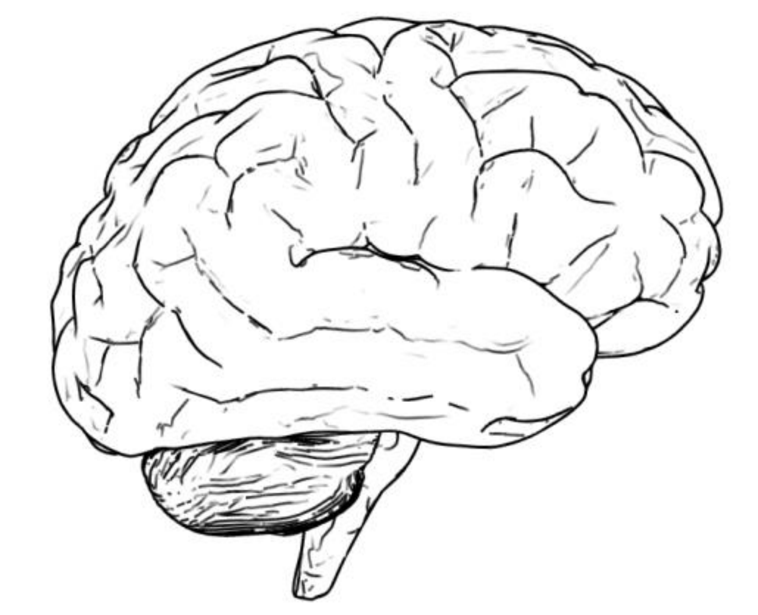
(From: Lawonn and Preim, 2015)

Apparent Ridges

- View-dependent:

$$\boxed{D_{t'}\kappa_1' = 0 \quad \text{and} \quad D_{t'}D_{t'}\kappa_1' < 0.}$$

- 3. Order
- Combines advantages of RV and SC



Apparent Ridges

[Judd et al. 2007]

(From: Lawonn and Preim, 2015)

Photic Extremum Lines

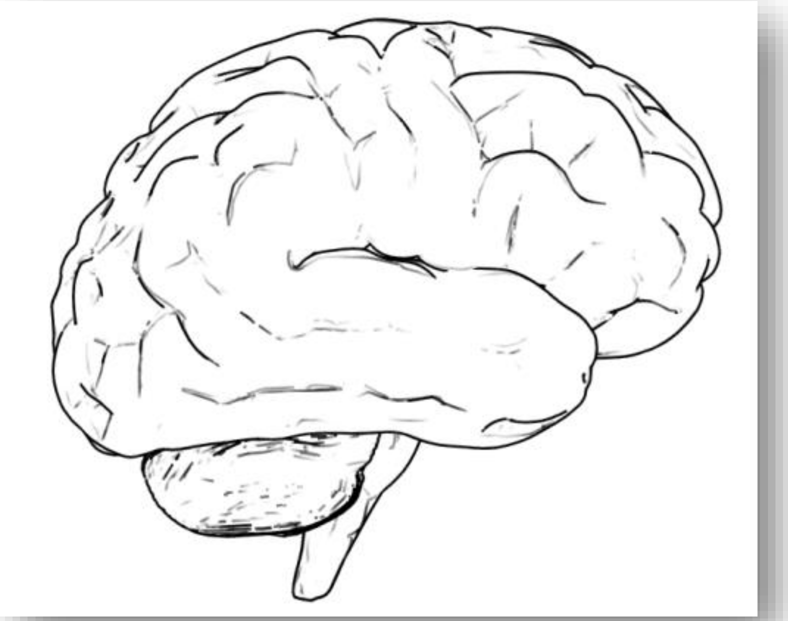
- View-dependent:

$$\boxed{D_w\|\nabla f\| = 0 \quad \text{and} \quad D_w D_w\|\nabla f\| < 0.}$$

$$w = \frac{\nabla f}{\|\nabla f\|} \quad \text{and} \quad f = \langle v, n \rangle.$$

- 3. order

- More degrees of freedom by adding lights



Photic extremum lines

(PELs) [Xie et al. 2007]

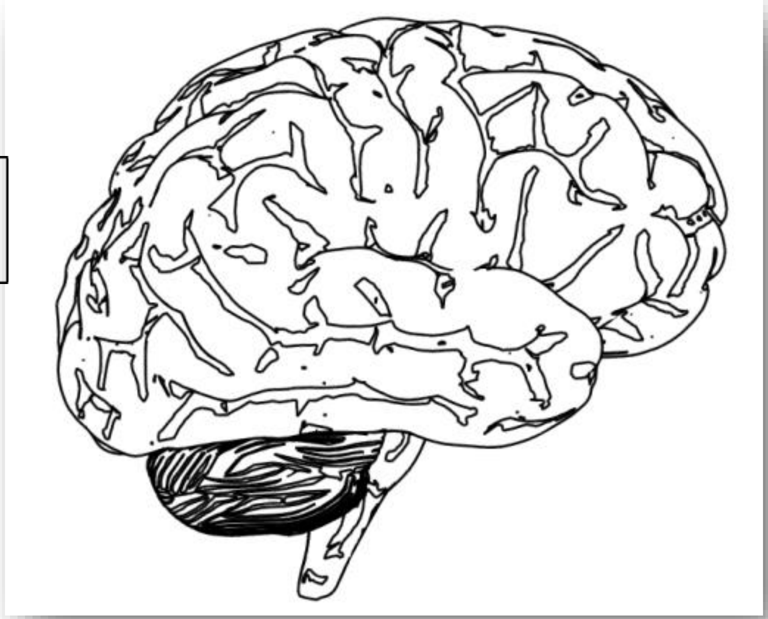
(From: Lawonn and Preim, 2015)

Demarcating Curves

- View-independent:

$$\boxed{\langle w, Sw \rangle = 0 \quad \text{with} \quad w = \arg\max_{\|v\|=1} D_v \kappa.}$$

- 3. order
- Curvature change maximal
- Determine a 2x2x2 rang-3 tensors
- Can be analytical determined



Demarcating Curves

[Kolomenkin et al. 2008]

(From: Lawonn and Preim, 2015)

Laplacian Lines

- View-dependent:

$$\boxed{\Delta f = 0 \quad \text{and} \quad \|\nabla f\| \geq \tau.}$$

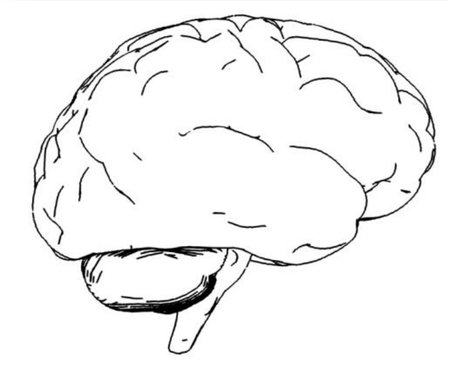
- 3. order
- Laplacian-of-Gaussian
- Preprocessing

Laplacian lines

[Zhang et al. 2011]

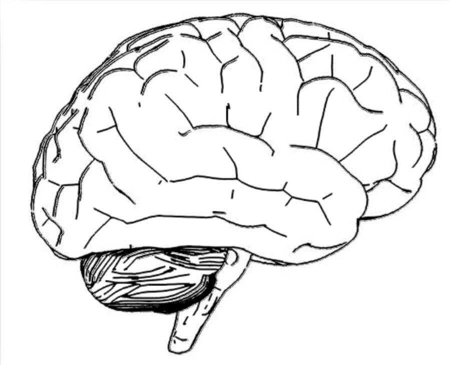
(From: Lawonn and Preim, 2015)

Feature Lines



Contours

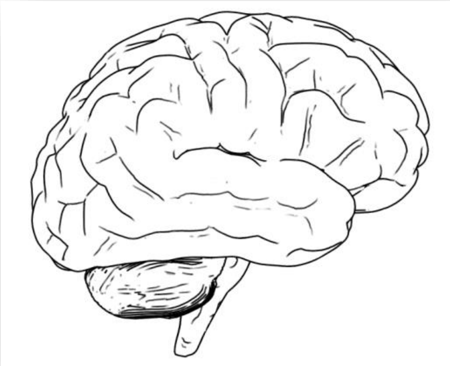
[Isenberg et al. 2003]



Crease lines

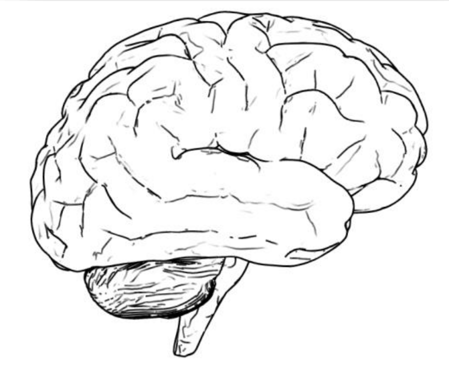
Ridges & Valleys

[Interrante et al. 1995]



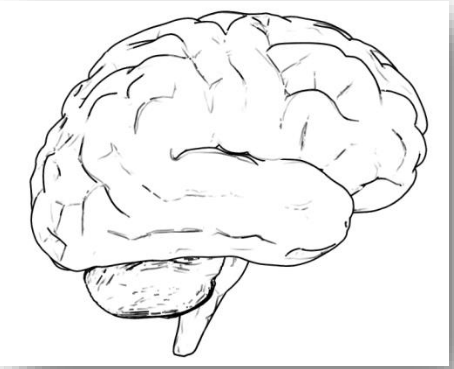
Suggestive Contours

[DeCarlo et al. 2003]



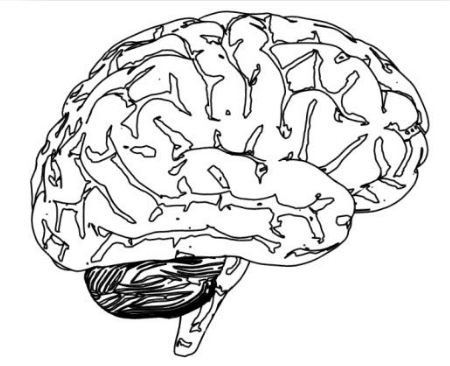
Apparent Ridges

[Judd et al. 2007]



Photic extremum lines

(PELs) [Xie et al. 2007]



Demarcating Curves

[Kolomenkin et al. 2008]

Laplacian lines

[Zhang et al. 2011]

(From: Lawonn and Preim, 2015)

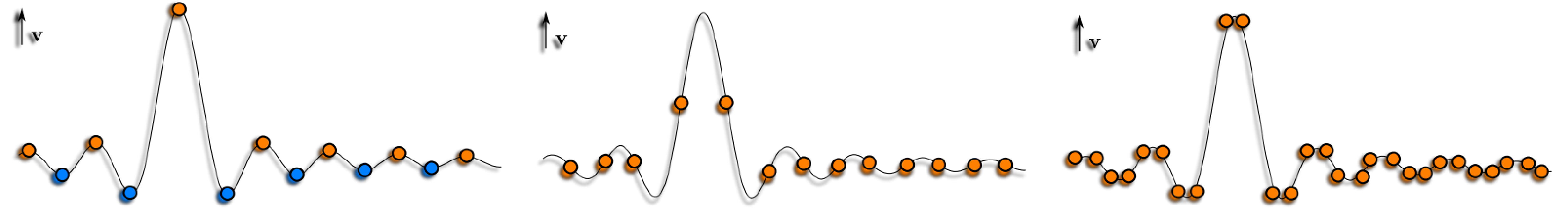
Comparisons

Name	Order	View-dep.
Contours	1	yes
Crease Lines	1	no
Ridges & Valleys	3	no
Suggestive Contours	2	yes
Apparent Ridges	3	yes
Photic Extremum Lines	3	yes
Demarcating Curves	3	no
Laplacian Lines	3	yes

(From: Lawonn and Preim, 2015)

Comparisons

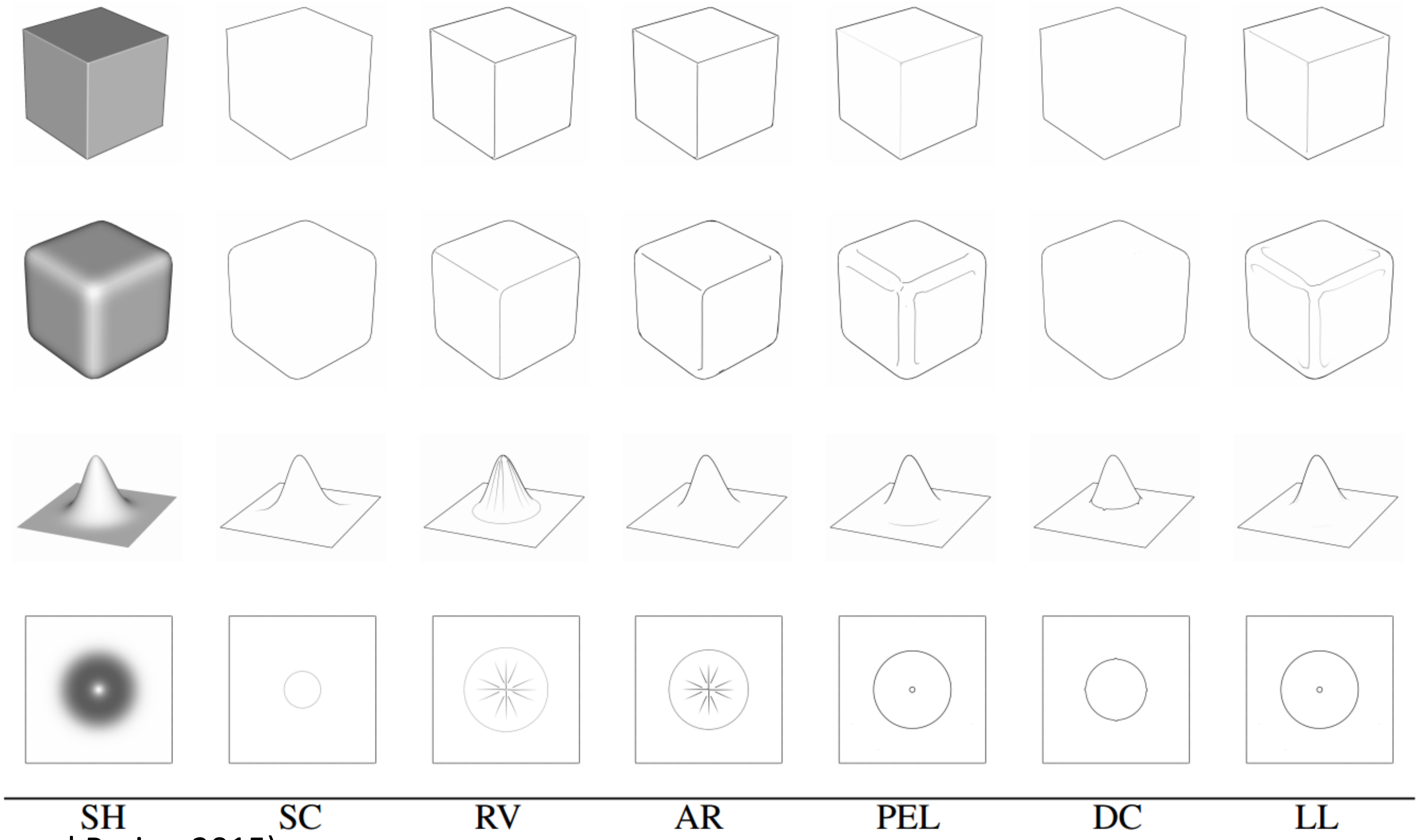
- Comparison of higher order feature line techniques on an analytical surface



(a) Ridges and Valleys, Apparent Ridges (b) Suggestive Contours, Demarcating Curves (c) Photic Extremum Lines, Laplacian Lines

(From: Lawonn and Preim, 2015)

Comparisons



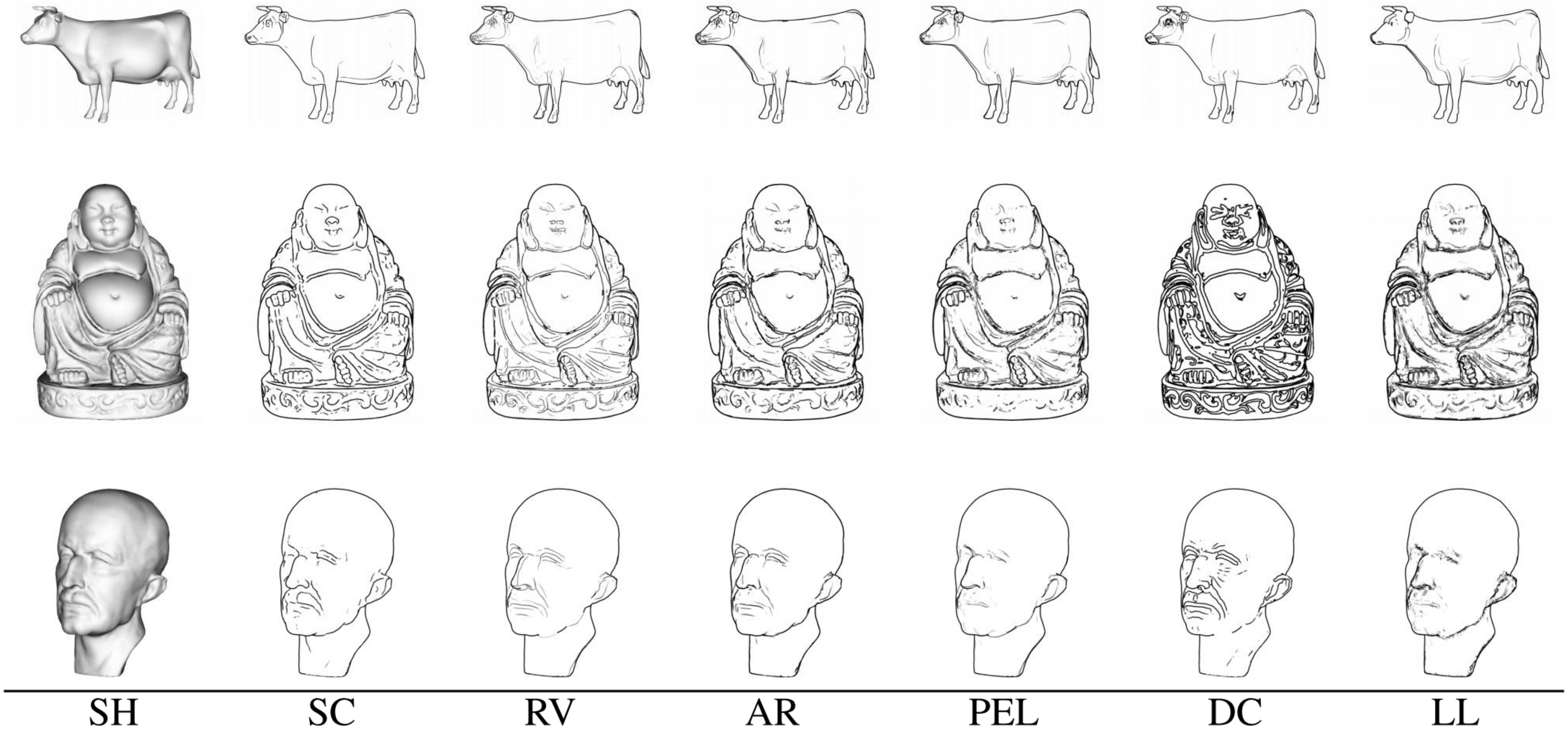
(From: Lawonn and Preim, 2015)

Comparisons

Name	Sharp Edges	Round Edges	Bumps (s.w.)	Bumps (top)	Contour	Deformation
Contour	☒	☒	☒	☒	☑	☑
Crease Lines	☑	☒	☒	☒	☒	☑
Ridges & Valleys	☑	☑	☒	☑	☒	☒
Suggestive Contours	☒	☒	☑	☑	☒	☑
Apparent Ridges	☑	☑	☑	☑	☑	☒
Photic Extremum Lines	☑	☒	☒	☑	☑	☑
Demarcating Curves	☒	☒	☒	☑	☒	☒
Laplacian Lines	☑	☒	☒	☑	☑	☒

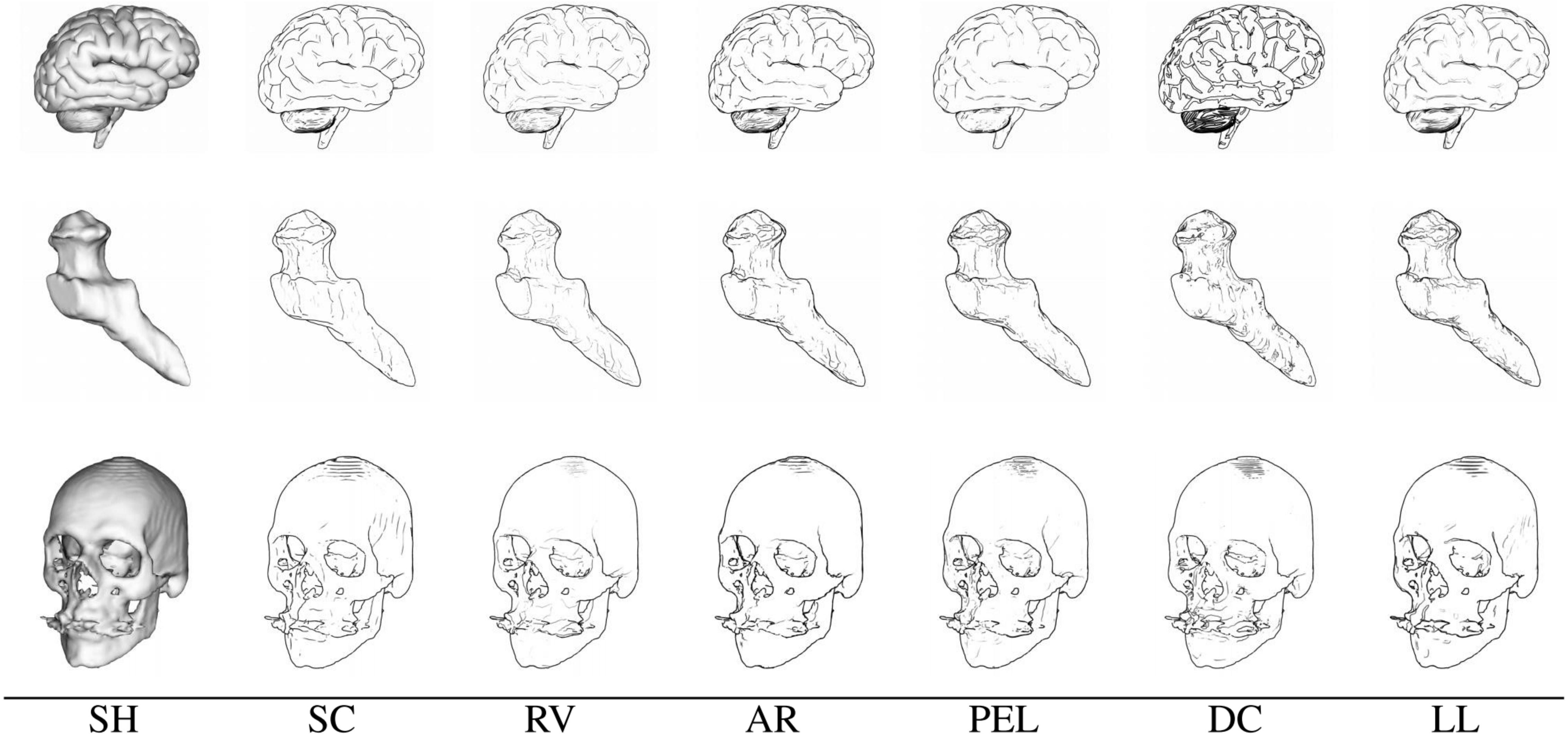
(From: Lawonn and Preim, 2015)

Comparisons



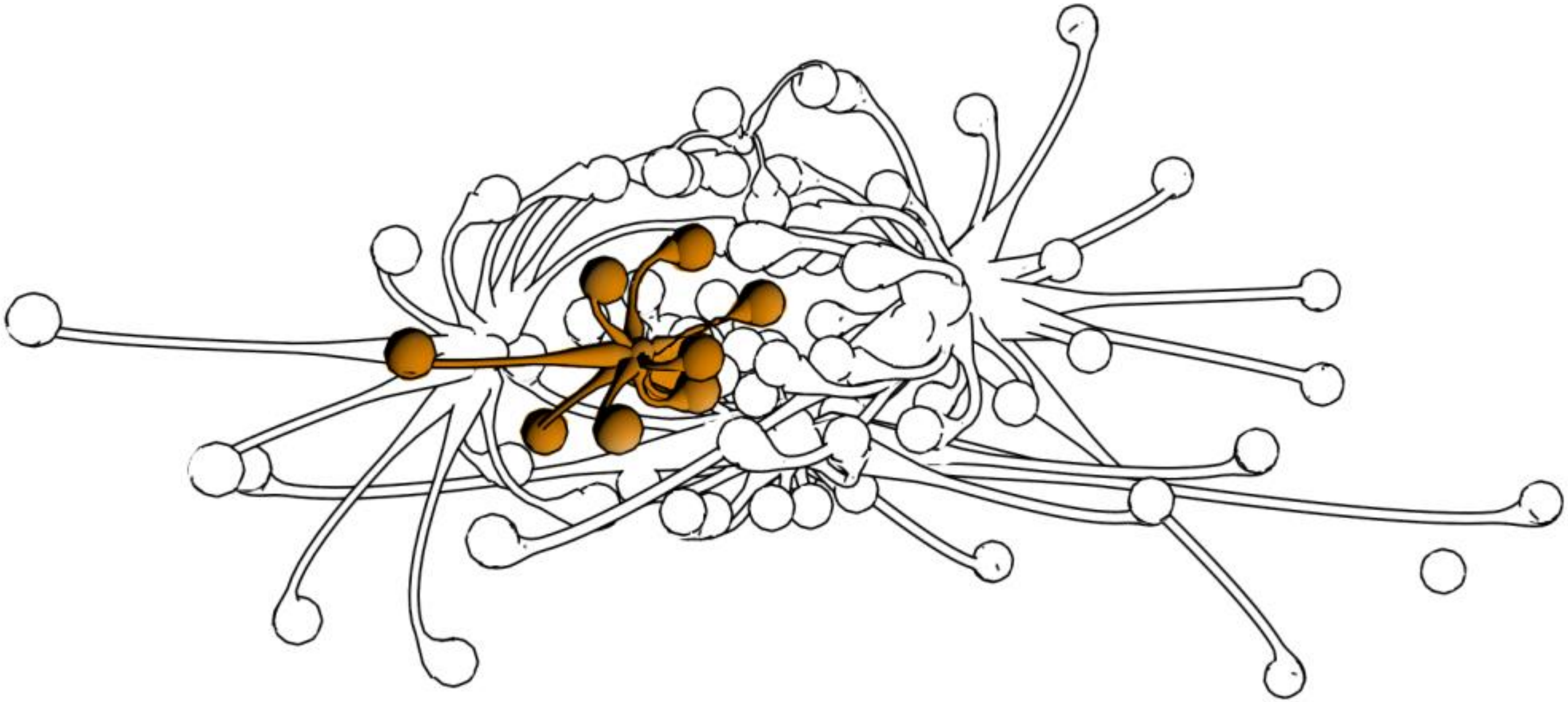
(From: Lawonn and Preim, 2015)

Comparisons



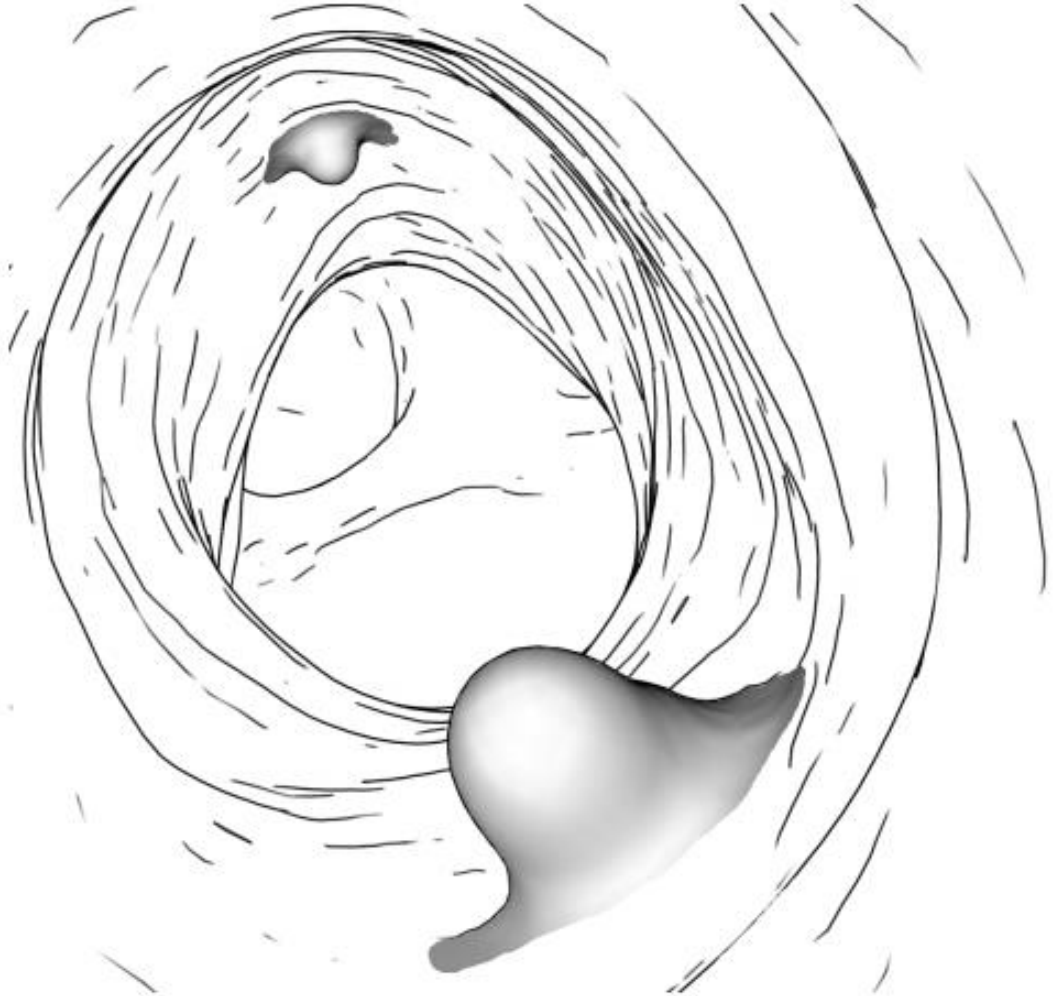
(From: Lawonn and Preim, 2015)

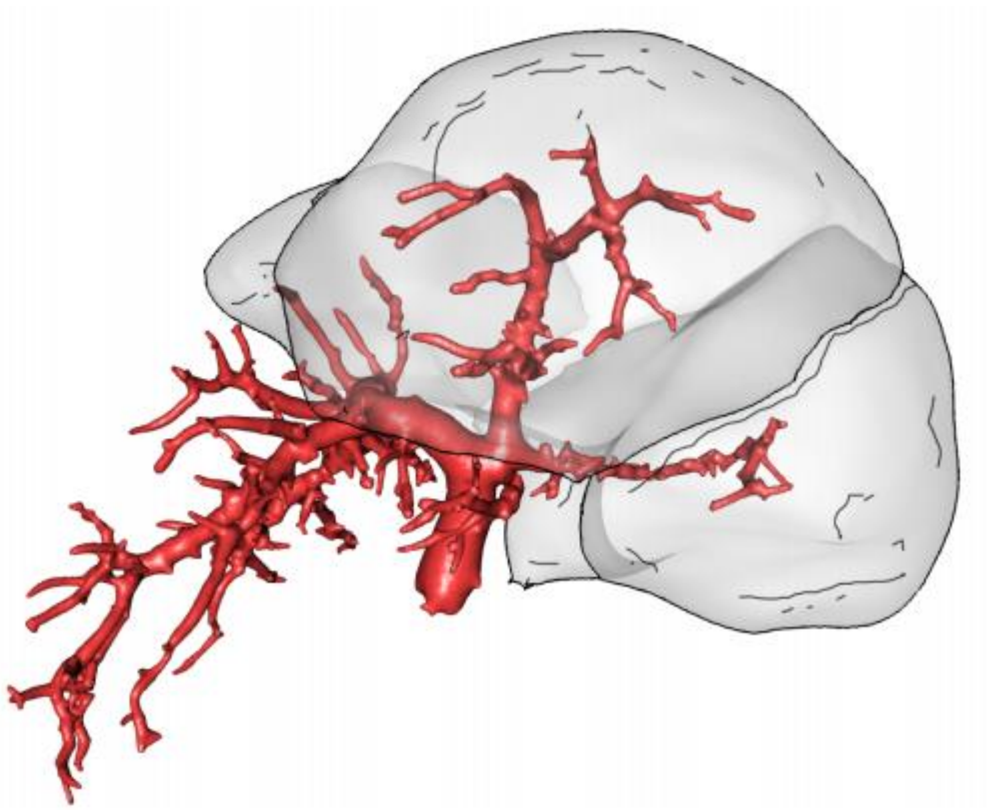
Medical Application



(From: Lawonn and Preim, 2015)

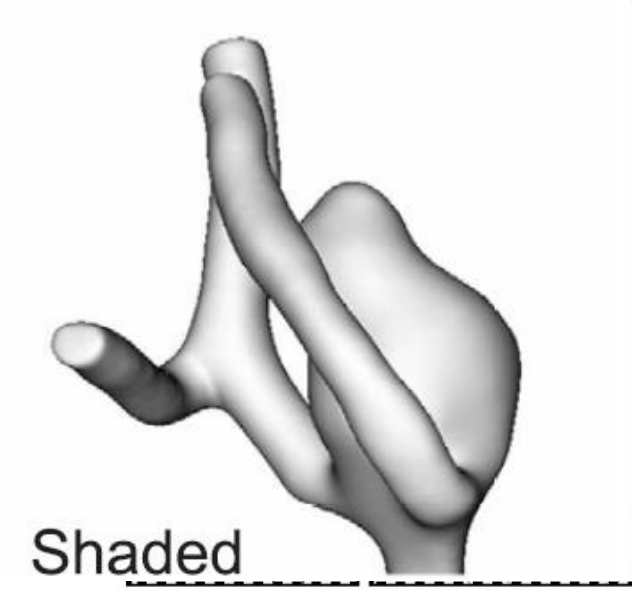
Medical Application

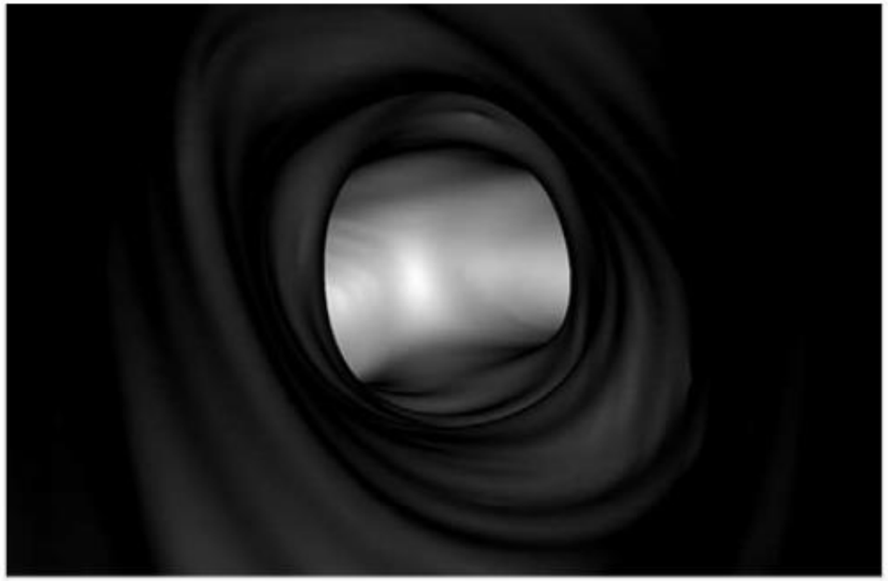


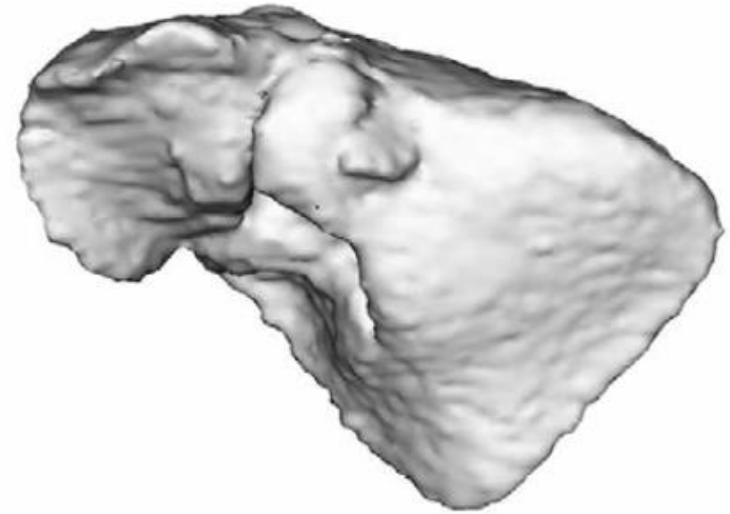


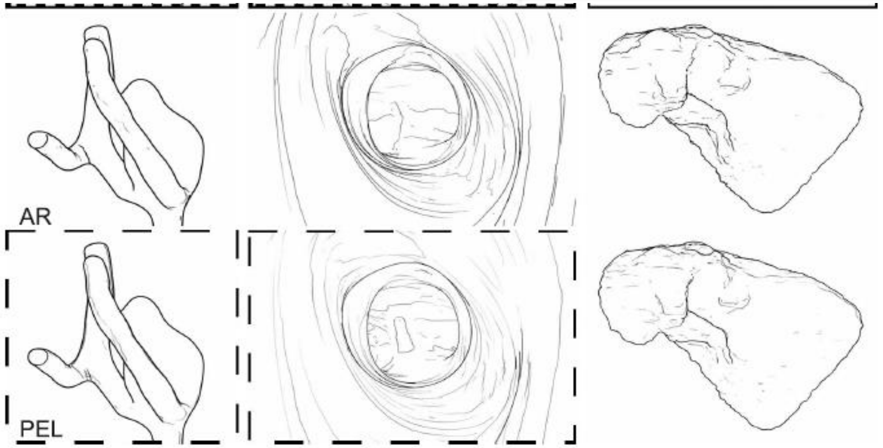
(From: Lawonn and Preim, 2015)

Evaluation of Feature Lines









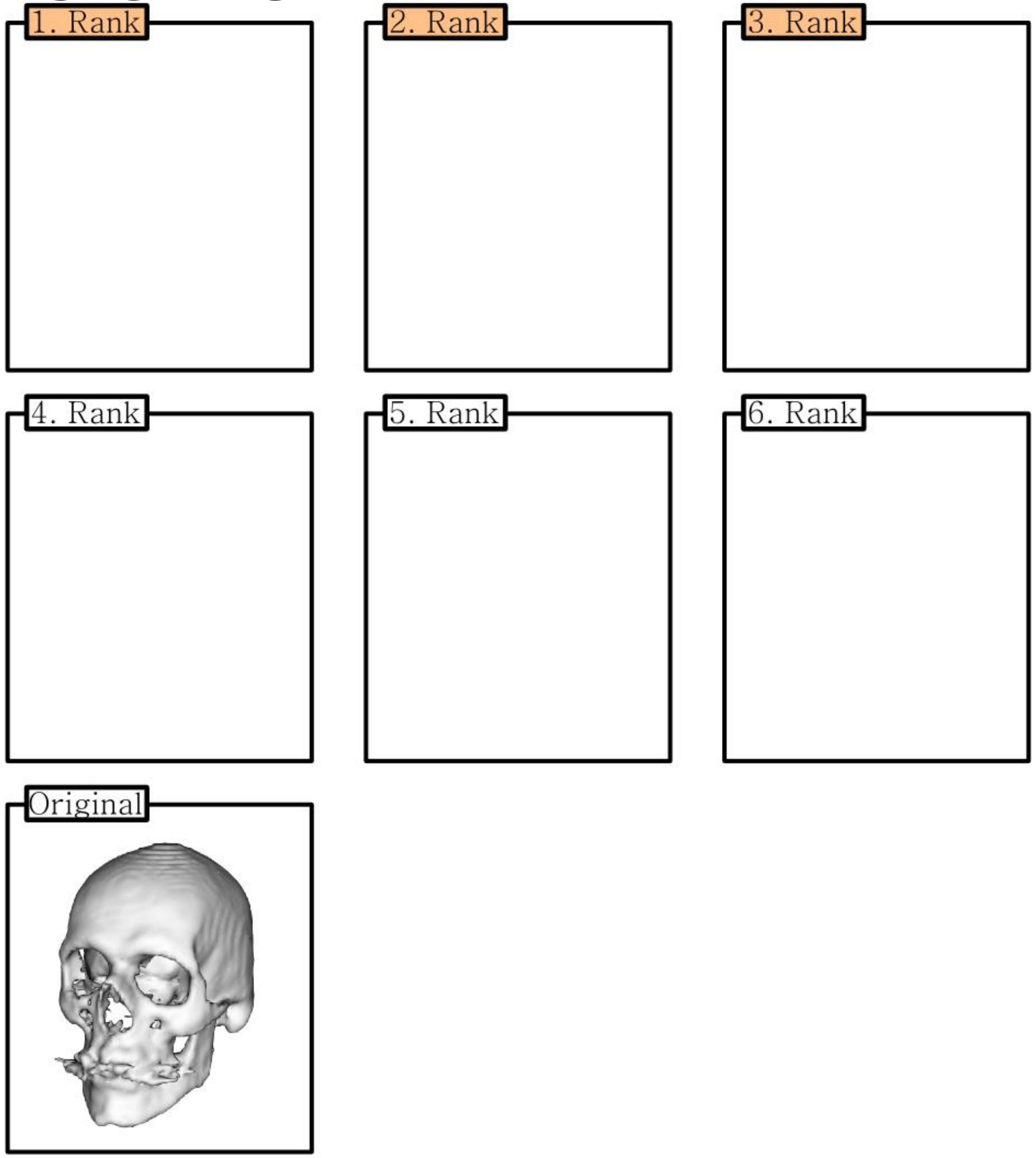
[Lawonn et al.; Qualitative Evaluation of Feature Lines on Anatomical Surfaces, BVM]

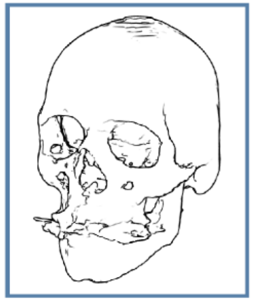
Evaluation

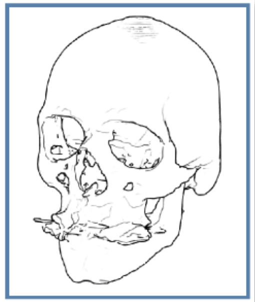
- Realistic assessment
- Aesthetic depiction
- Selection of preferred technique

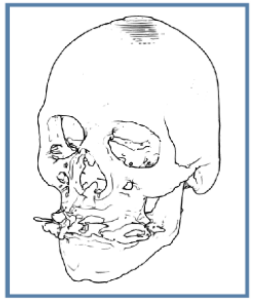
[Lawonn et al.; Comparative Evaluation of Feature Line Techniques for Shape Depiction, VMV]

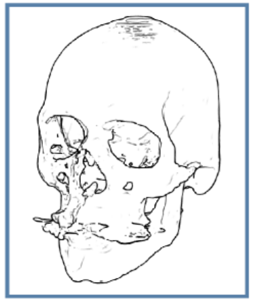
Evaluation

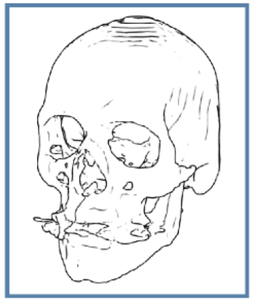


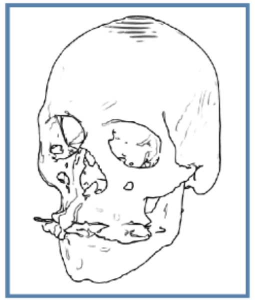






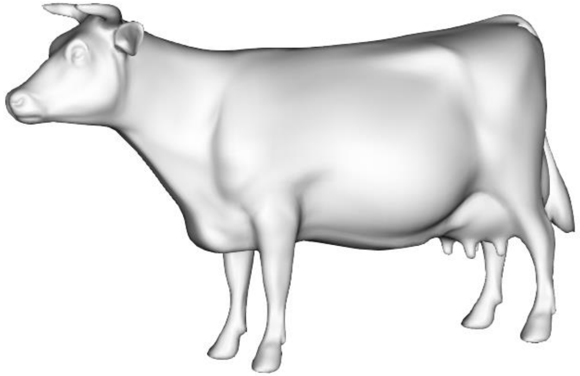


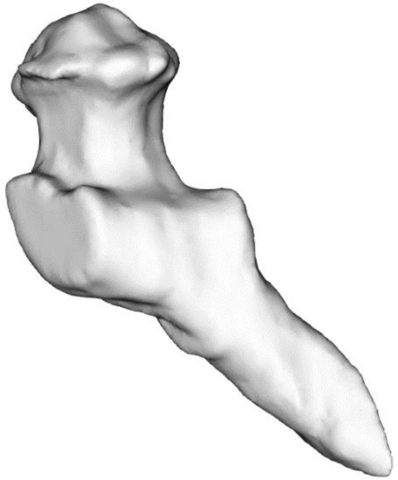




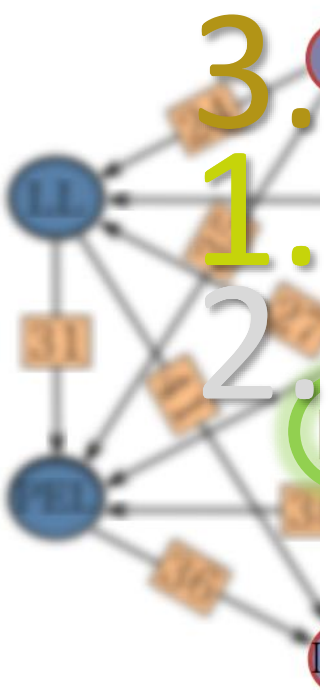
omparative Evaluation of
nniques for Shape Depiction,

Models

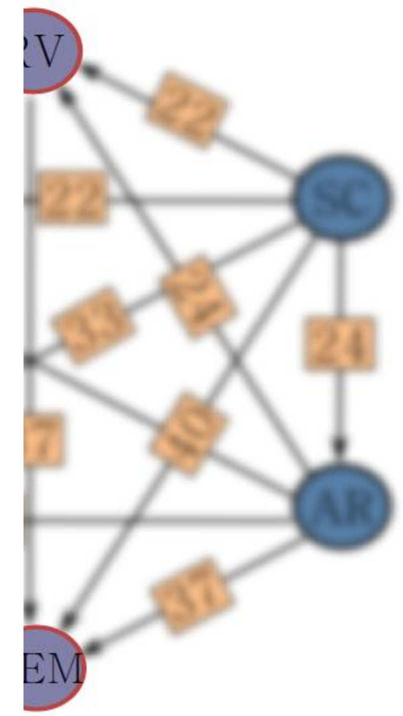




Schulze Method



	RV	SC	AR	DEM	PEL	LL
RV	0	0	0	37	37	24
SC	24	0	24	40	33	24
AR	24	0	0	37	38	27
DEM	0	0	0	0	0	0
PEL	0	0	0	36	0	0
LL	0	0	0	41	31	0



Results

Method	Rank 1-3	Rank 4-6
RV	6	6
SC	7	5
AR	11	1
PEL	5	7
DEM	1	11
LL	8	5

Rank	Aesthetic						Realistic					
	Buddha	Brain	Cow	Femur	Max	Skull	Buddha	Brain	Cow	Femur	Max	Skull
1	AR	LL	PEL	LL	AR	PEL	SC	AR	AR	LL	AR	SC
2	RV	SC	AR	AR	LL	RV	AR	SC	PEL	DEM	LL	LL
3	SC	AR	RV	PEL	RV	SC	RV	LL	RV	AR	SC	PEL
4	LL	RV	DEM	DEM	PEL	AR	LL	RV	DEM	PEL	RV	AR
5	PEL	PEL	SC	SC	SC	LL	PEL	PEL	SC	SC	PEL	DEM
6	DEM	DEM	LL	RV	DEM	DEM	DEM	DEM	LL	RV	DEM	RV

Results

	Buddha	Brain	Cow	Femur	Max	Skull
RV	8	7	3	2	6	1
SC	13	7	4	6	5	14
AR	11	12	14	6	16	6
PEL	2	1	10	9	3	8
DEM	1	3	8	10	1	3
LL	8	13	4	10	12	11

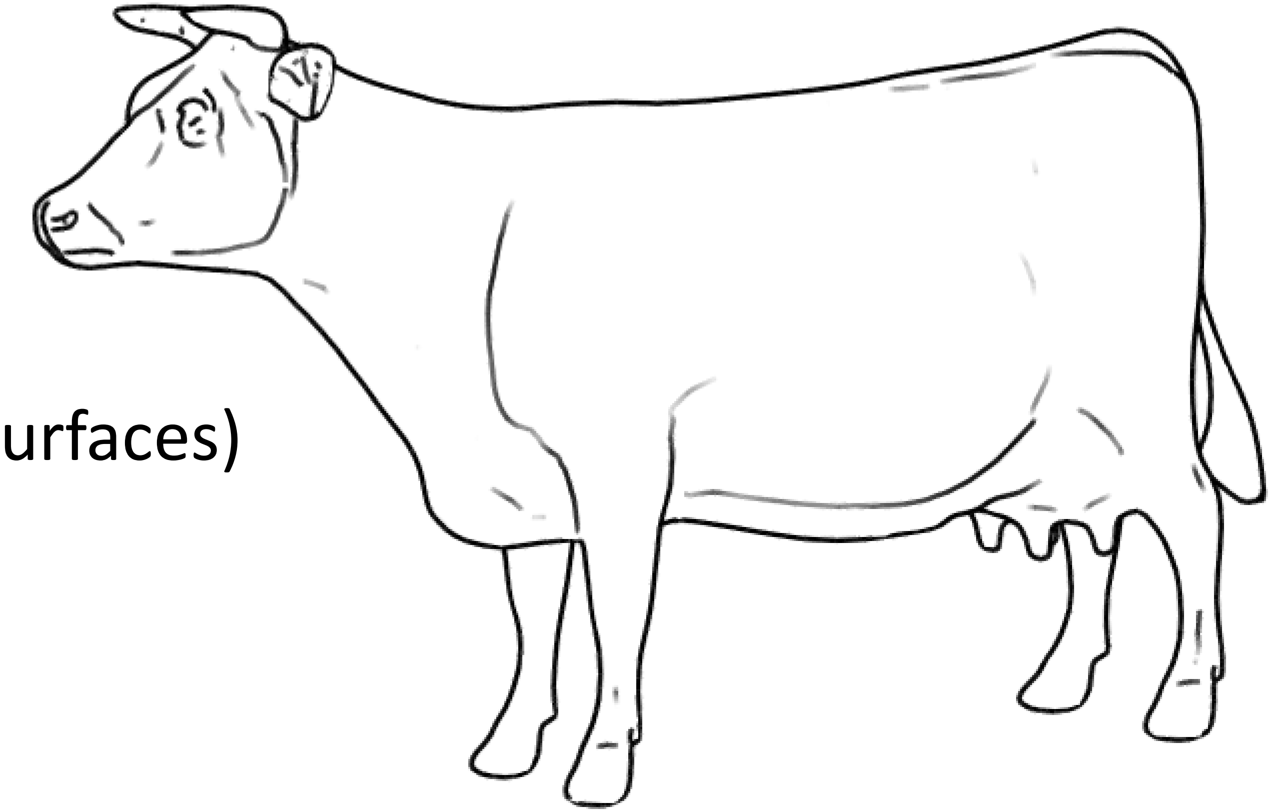
Discussion

- Limitation: pre-generated images
- Realistic depiction of poor perceivable structures

Recommendations

Suggestive Contours:

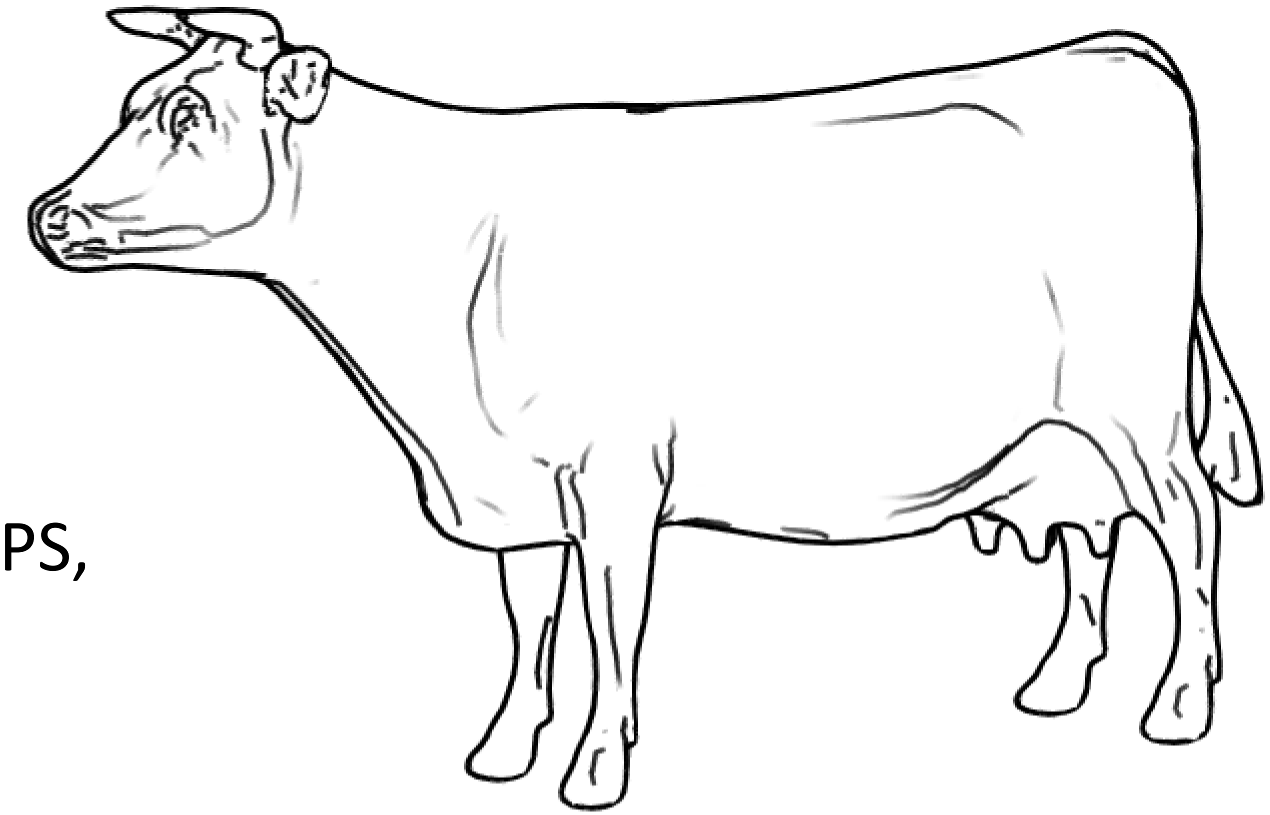
- Noisy surfaces
- 2 representations (animated surfaces)
- No convex structures



Recommendations

Apparent Ridges:

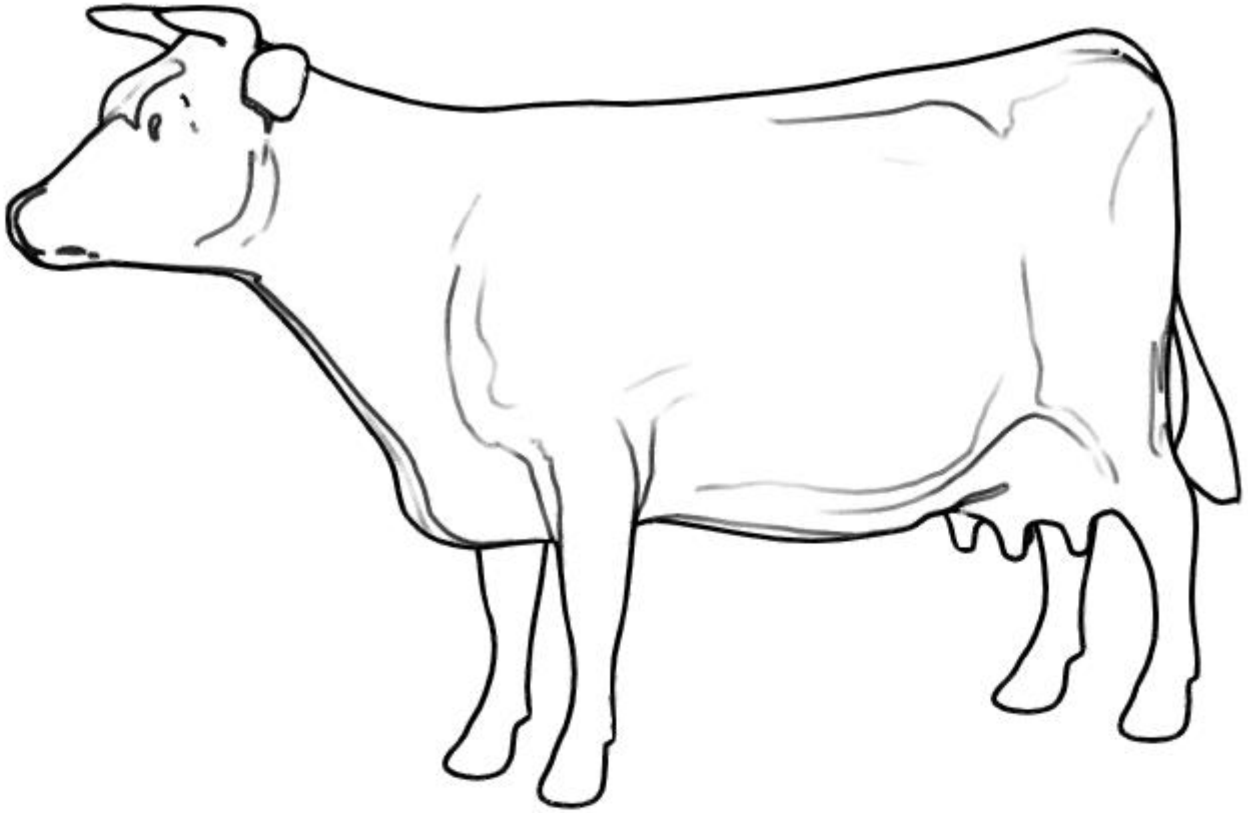
- Convey contour
- Depiction of sharp structures
- Low performance 64k tri. (8 FPS, SC 45 FPS, LL 15 FPS)



Recommendations

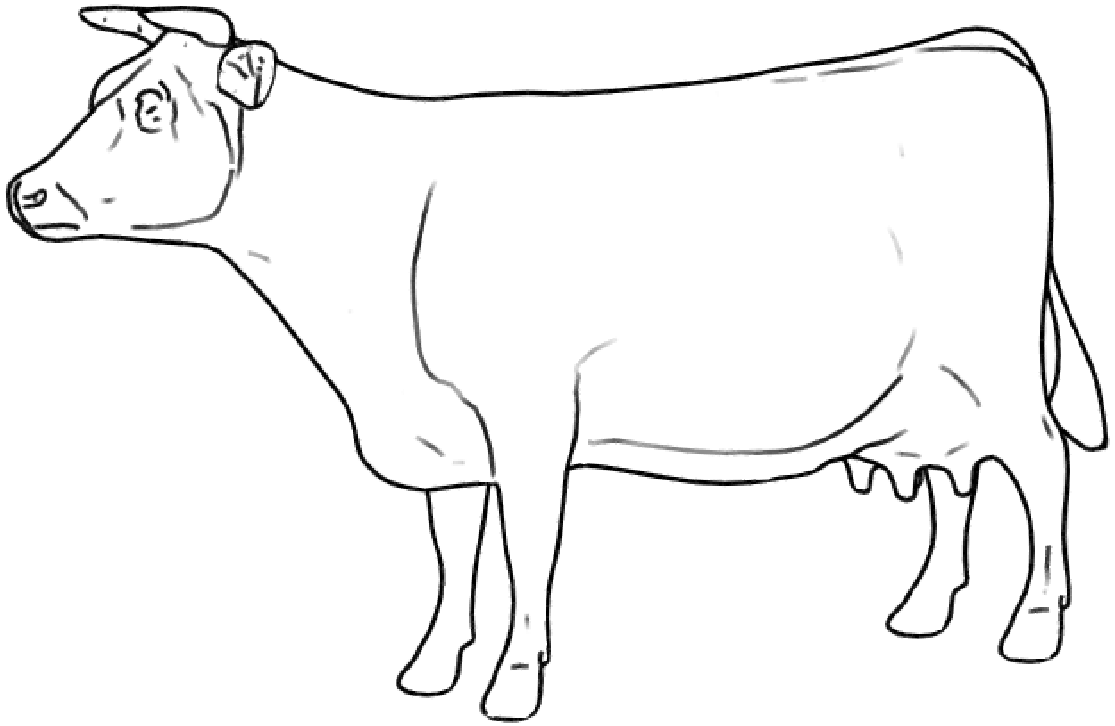
Laplacian Lines:

- Convey contour
- Depiction of sharp structures
- Preprocessing of Laplacian



Recommendations

- Summary: Suggestive Contours
- Very fast
- Satisfying results



Conclusion

- Evaluation with 149 participants
- Aesthetic, realistic, and favored technique
- 6 surfaces
- For analysis: Schulze method
- Apparent ridges, suggestive contours, and Laplacian Lines

- Results are tendency and no definite statement

Questions???