Inverse Toon Shading: Interactive Normal Field Modeling with Isophotes

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Presentation Renderings

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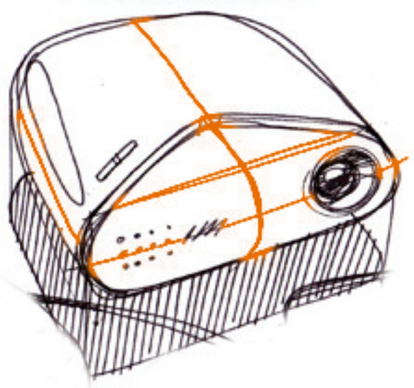
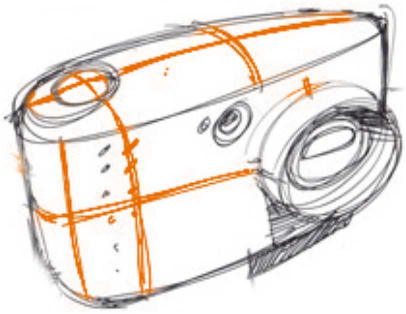
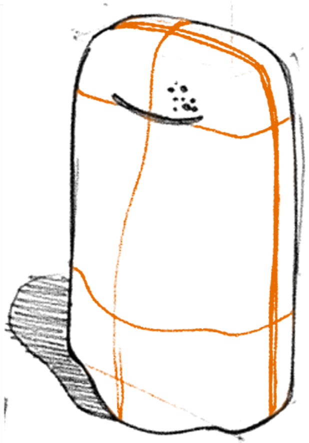
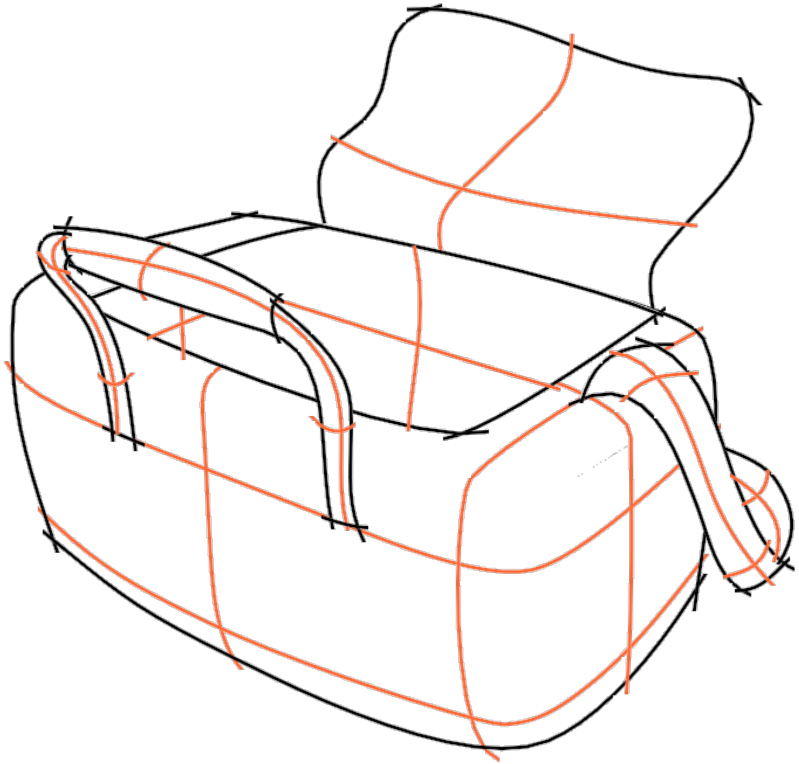
Cross-section sketch >



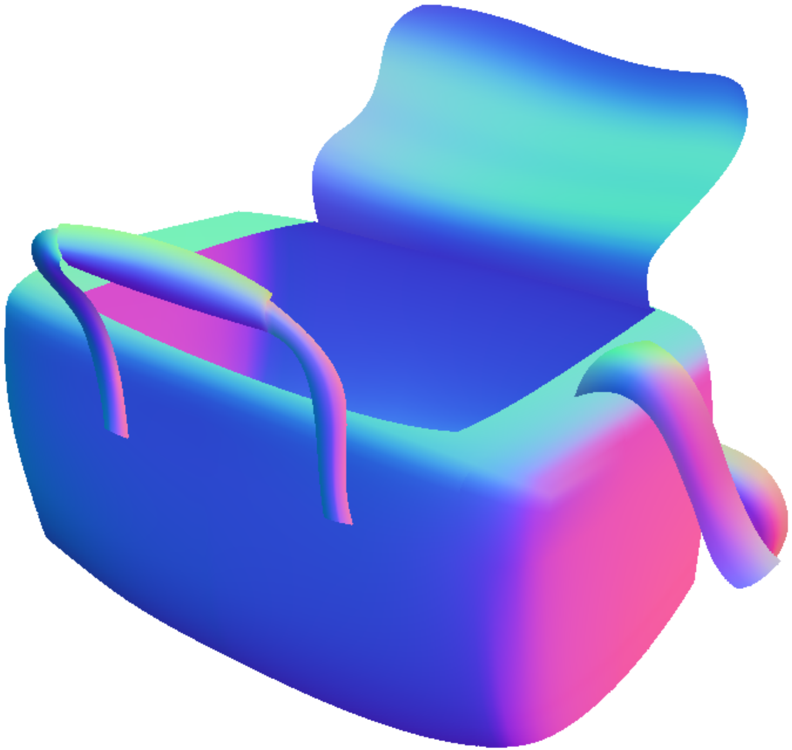




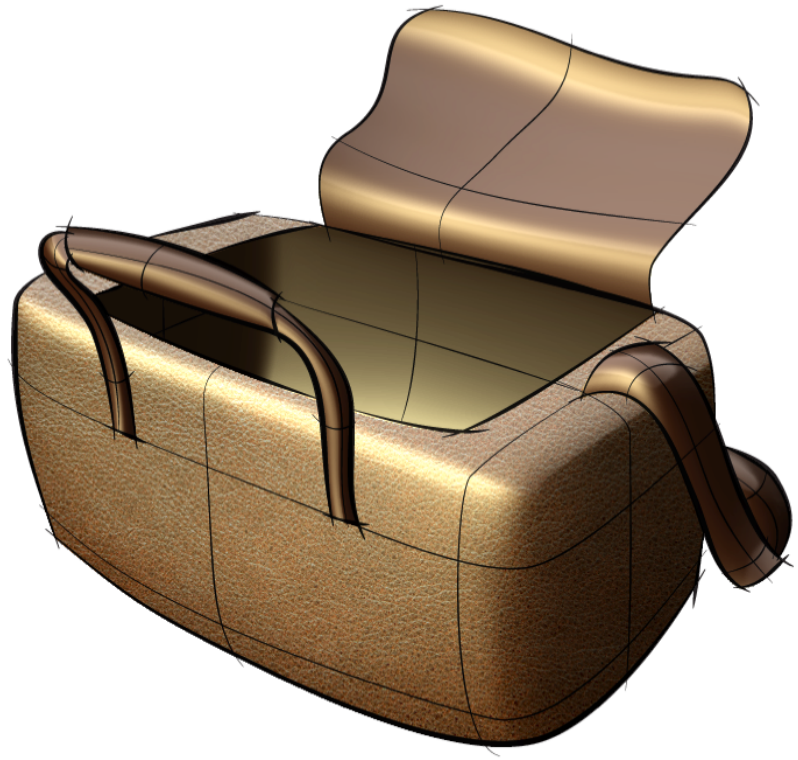
Cross-section sketch >



3D normals >

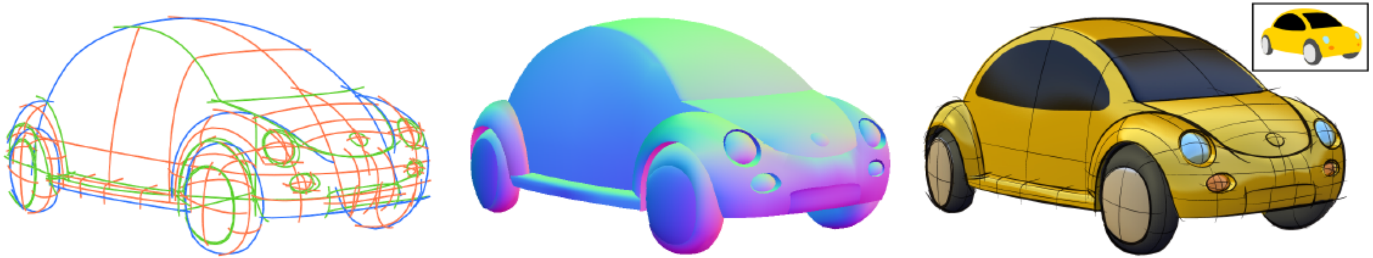


Presentation Renderings!

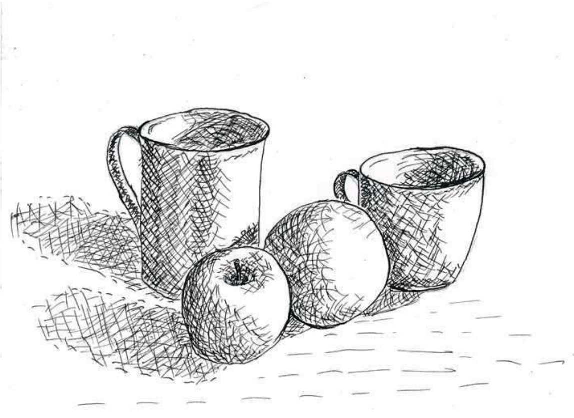
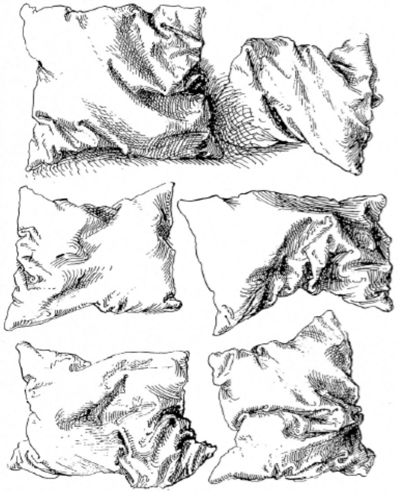


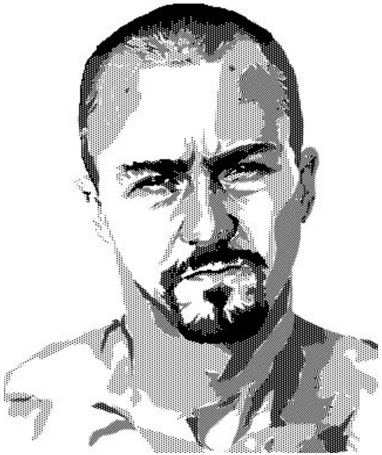
Related Work

Lumo
NPAR 2002.

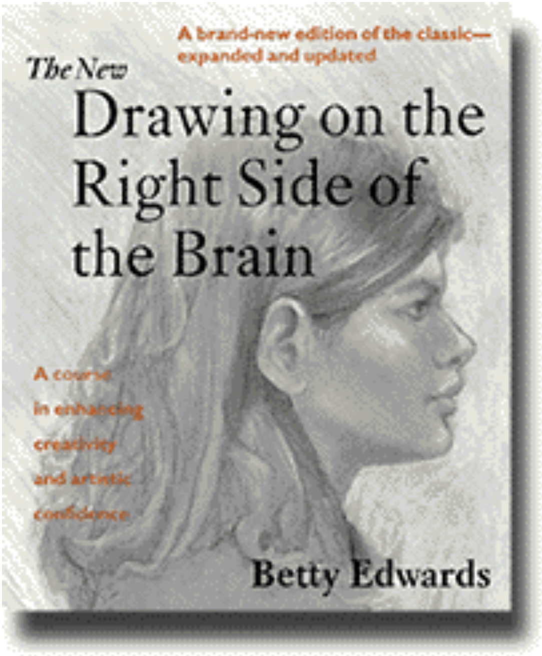


CrossShade
SIGGRAPH 2012.

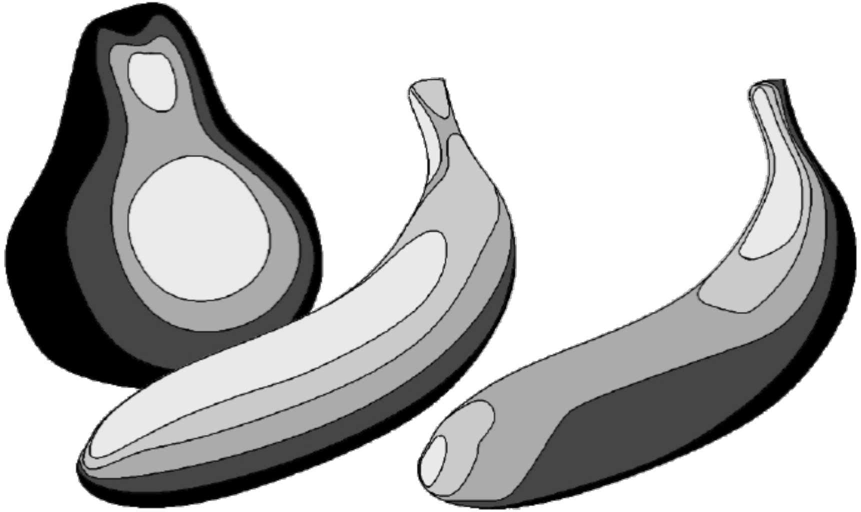

Blocking-in light and shade



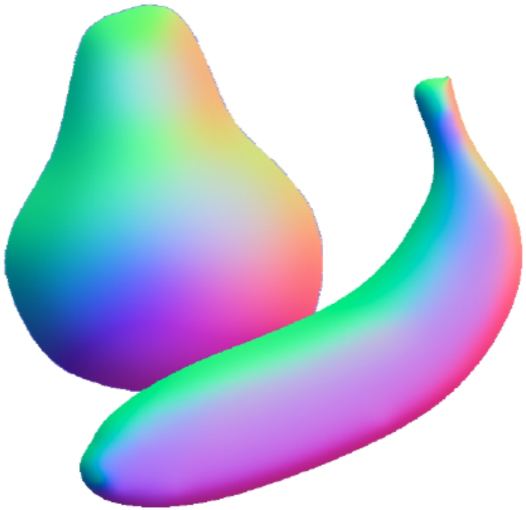
Design Principles

- Sketched curves are descriptive of 3D: 2D shape $\approx$ 3D shape.
- Surface is artistically imagined by massing: local primitives.

Inverse Toon Shading



Inverse Toon Shading

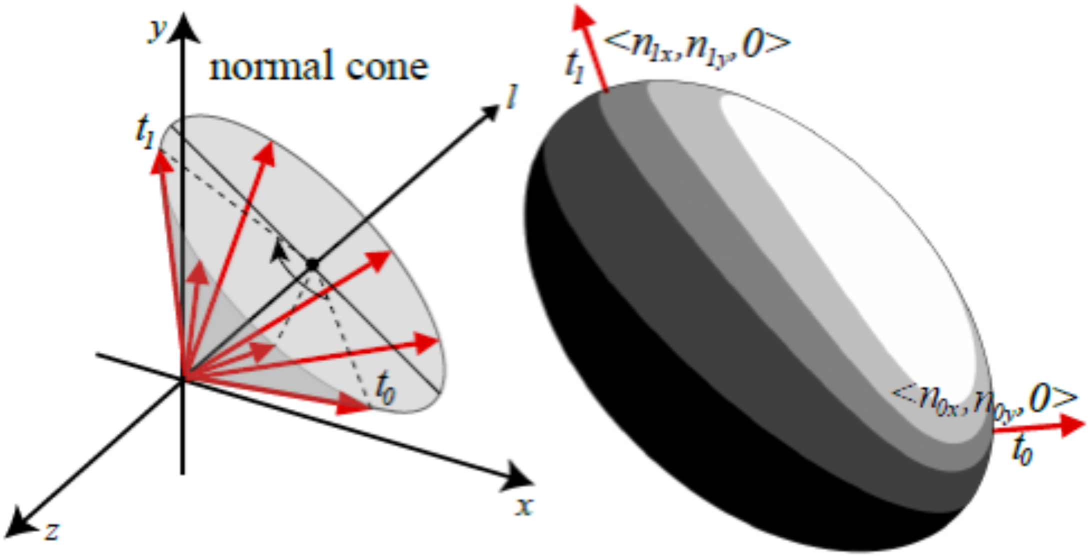


Inverse Toon Shading

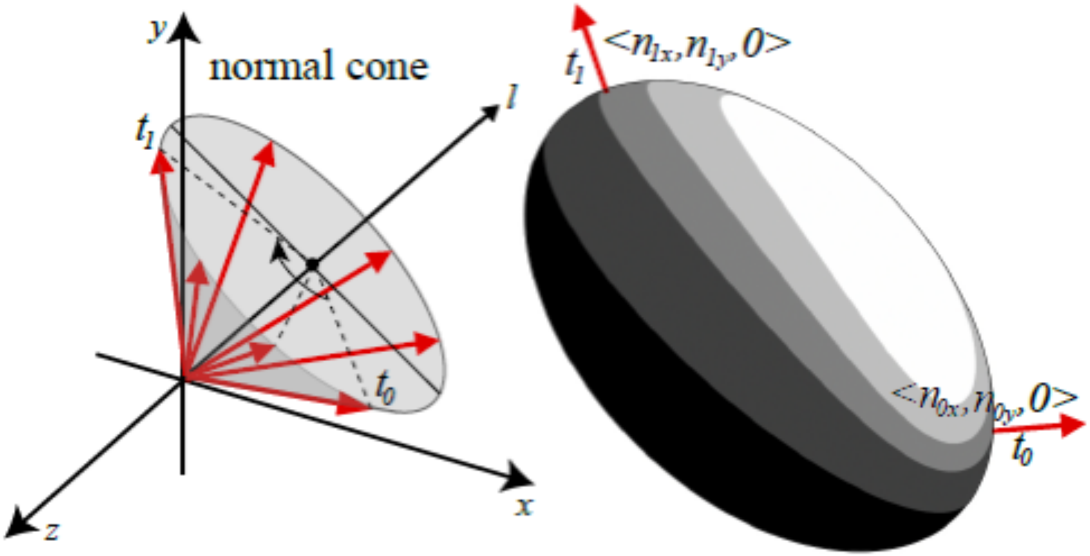
Assumptions

- Smooth 3D shapes (tangent continuity).
- Directional front lighting.
- Diffuse Lambertian Reflection with Specular hot-spots.
- No cast shadows.
- No internal occluding contours.

Light and Value

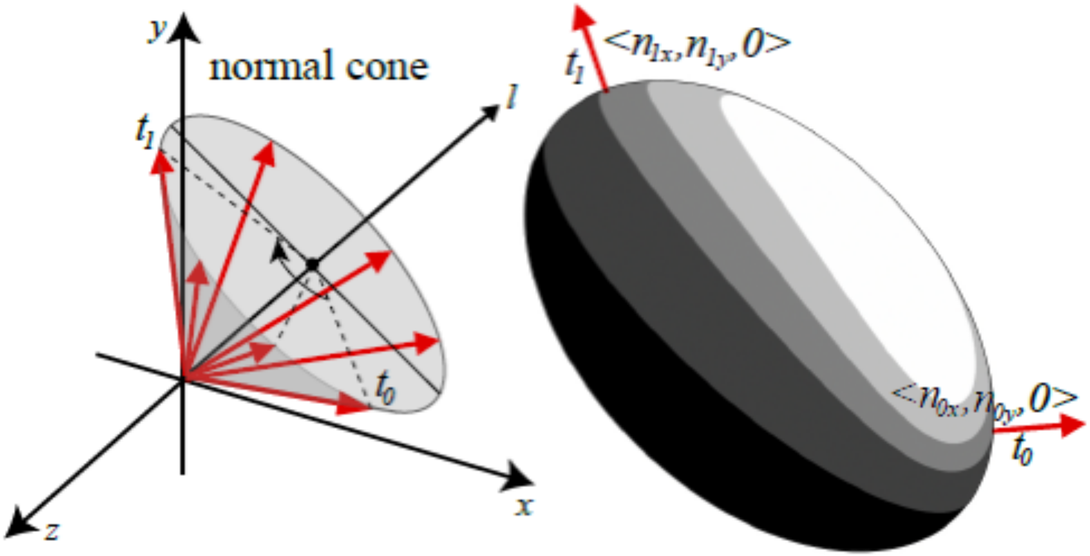


Light and Value



$$l = \langle n_{0_x} + n_{1_x}, n_{0_y} + n_{1_y}, z \rangle$$

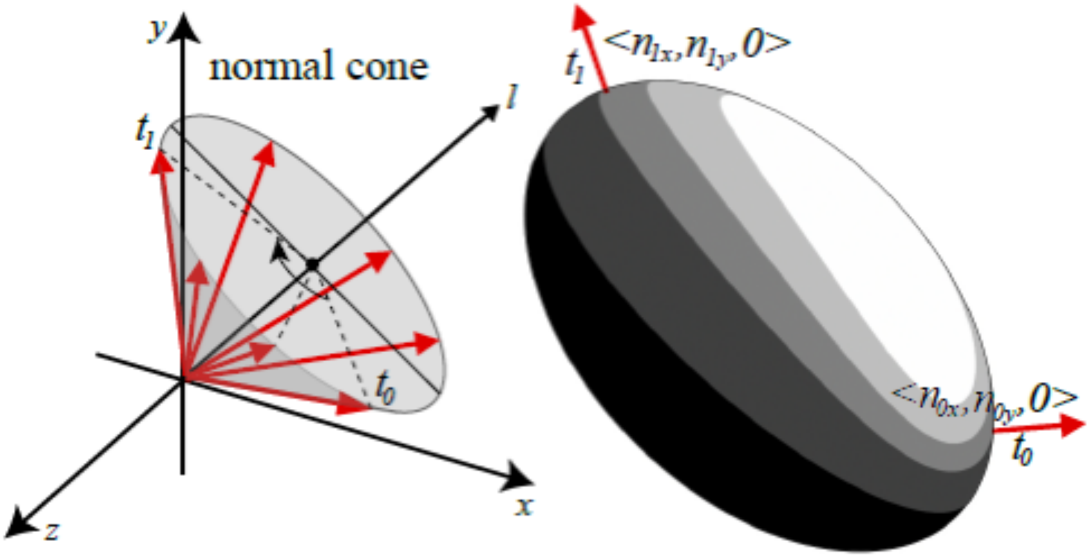
Light and Value



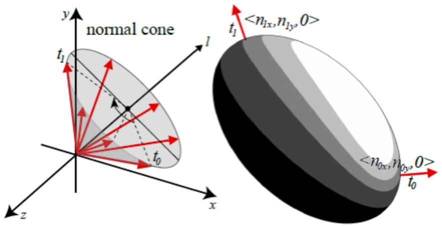
$$l = \langle n_{0_x} + n_{1_x}, n_{0_y} + n_{1_y}, z \rangle$$

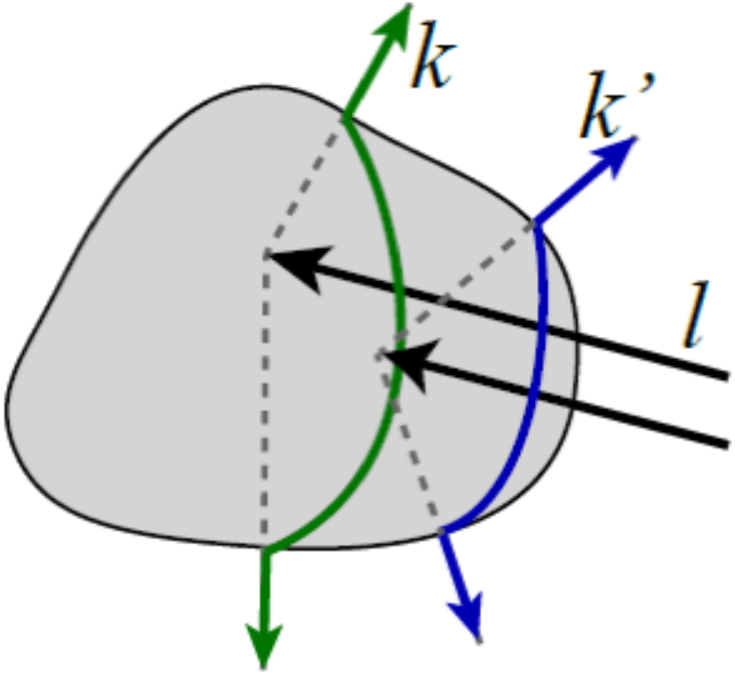
$$z = \pm\sqrt{(1 + n_0 \cdot n_1)^2 / k^2 - 2(1 + n_0 \cdot n_1)}.$$

Light and Value



Light and Value





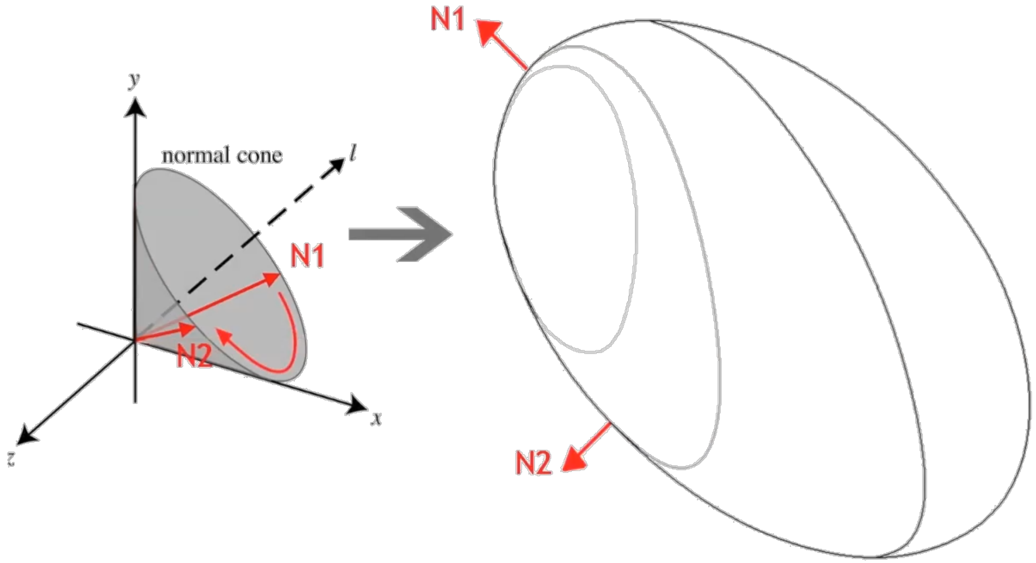
Workflow

Workflow

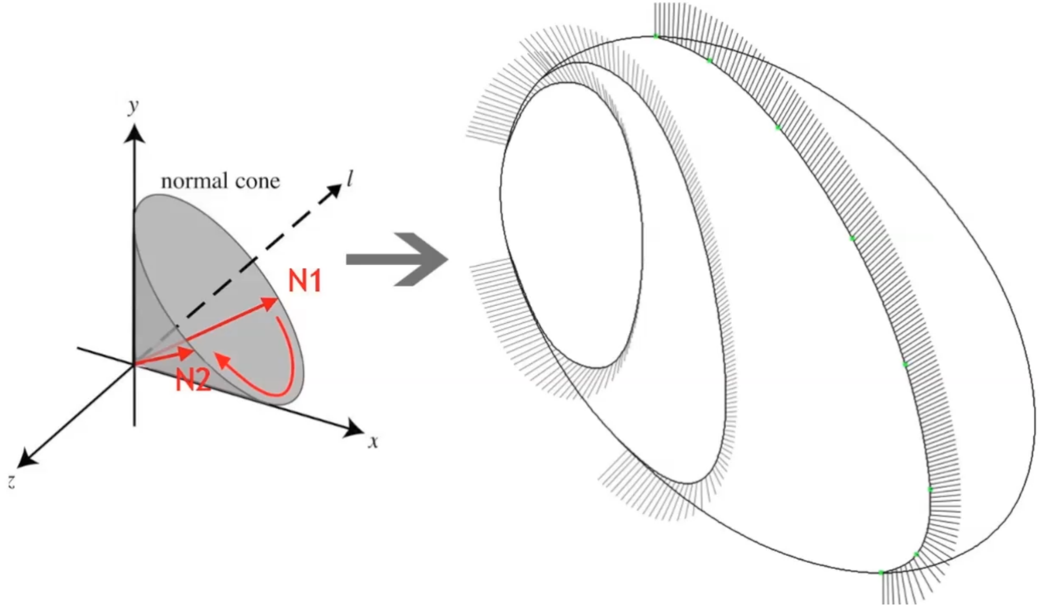
Well defined normals

- Silhouettes and internal contours.
- Intersecting isophotes from different lights.
- Specular hot-spots.

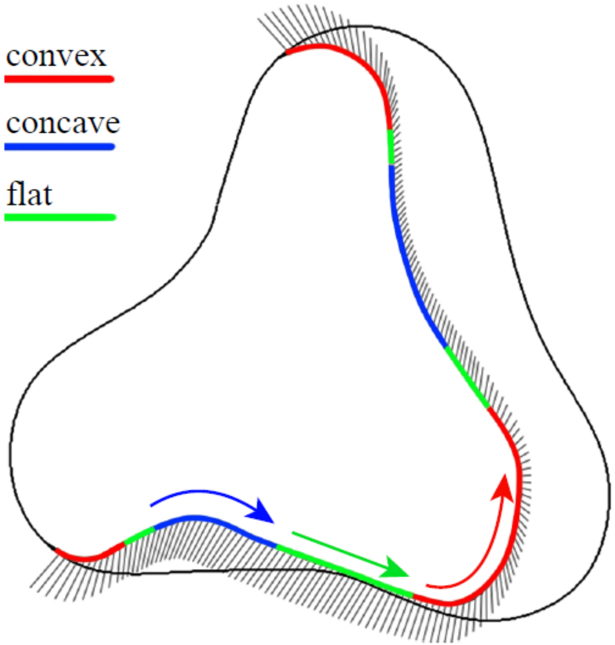
2D arc-length interpolation



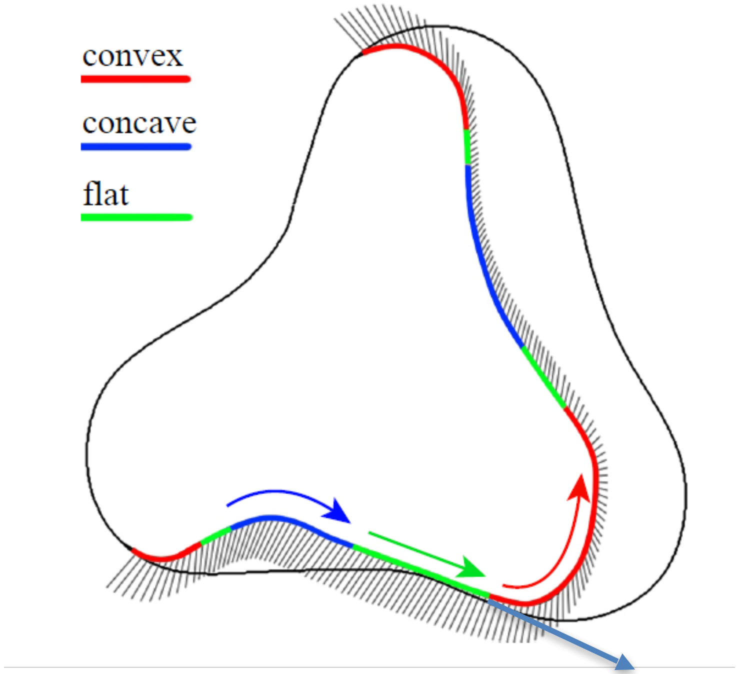
2D arc-length interpolation



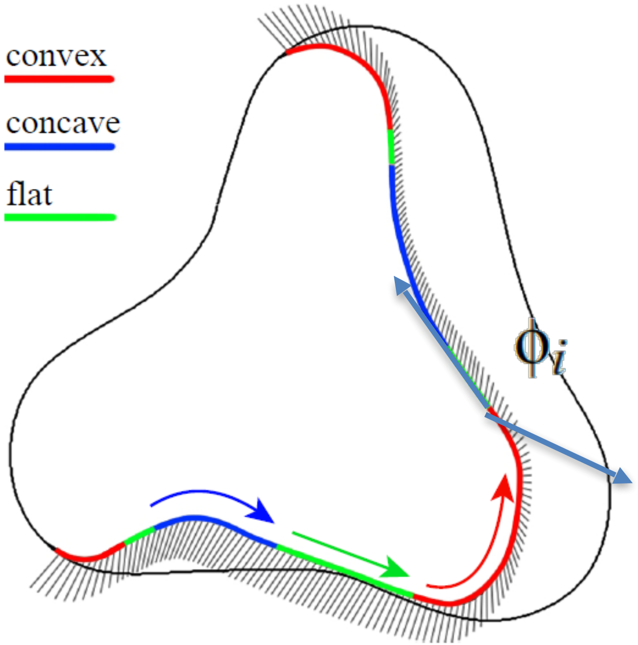
Curvature segmentation



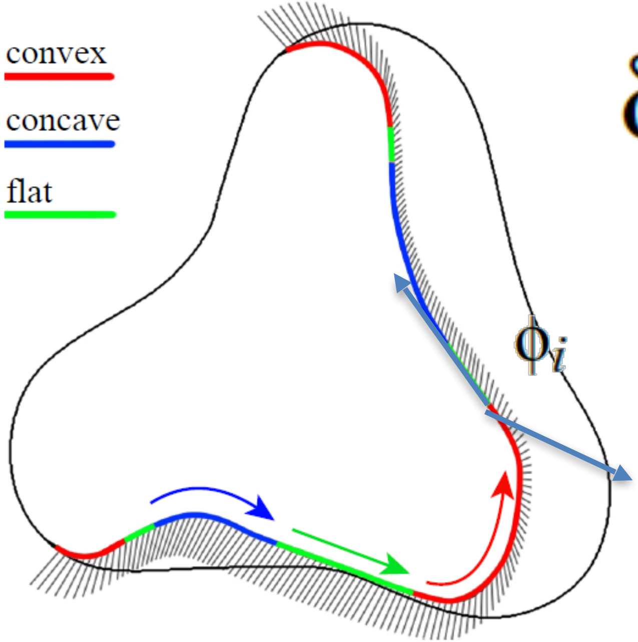
Curvature segmentation



Curvature segmentation



Curvature segmentation



$$\delta t_i = \frac{\phi_i \Delta t}{\sum_0^m \phi_i}$$

Massing Primitives

- Even 3D ellipsoids have complex non-planar 3D isophotes. ☹

- Linear 3D isophote => constant normal line on ruled surface.
- Circular 3D isophote $(0, \cos(a), \sin(a))$ => 3D normal $\frac{\langle x, \cos(a), \sin(a) \rangle}{\sqrt{1+x^2}}$

aspect and tilt angle of 2D ellipse defines 3D transform *M* to image.

If light *l* is $l' = M^{-1} l$, $$x l'_x + \cos(a) l'_y + \sin(a) l'_z = k\sqrt{1+x^2}$$

solve for *x*!

2D ellipse fitting

Fit a minimal number of 2D ellipses to each convex/concave isophote segment.
Each ellipse segment maps to 4 normal choices (2 tilt directions, and convex/concave).

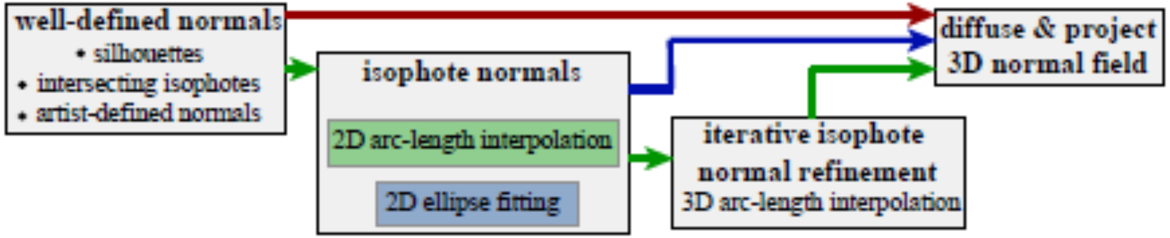
Globally optimize the choices for:

- matching normals at shared point between adjacent segments;
- minimal normal variation within each segment;
- normals that have positive z components;

3D arc-length interpolation

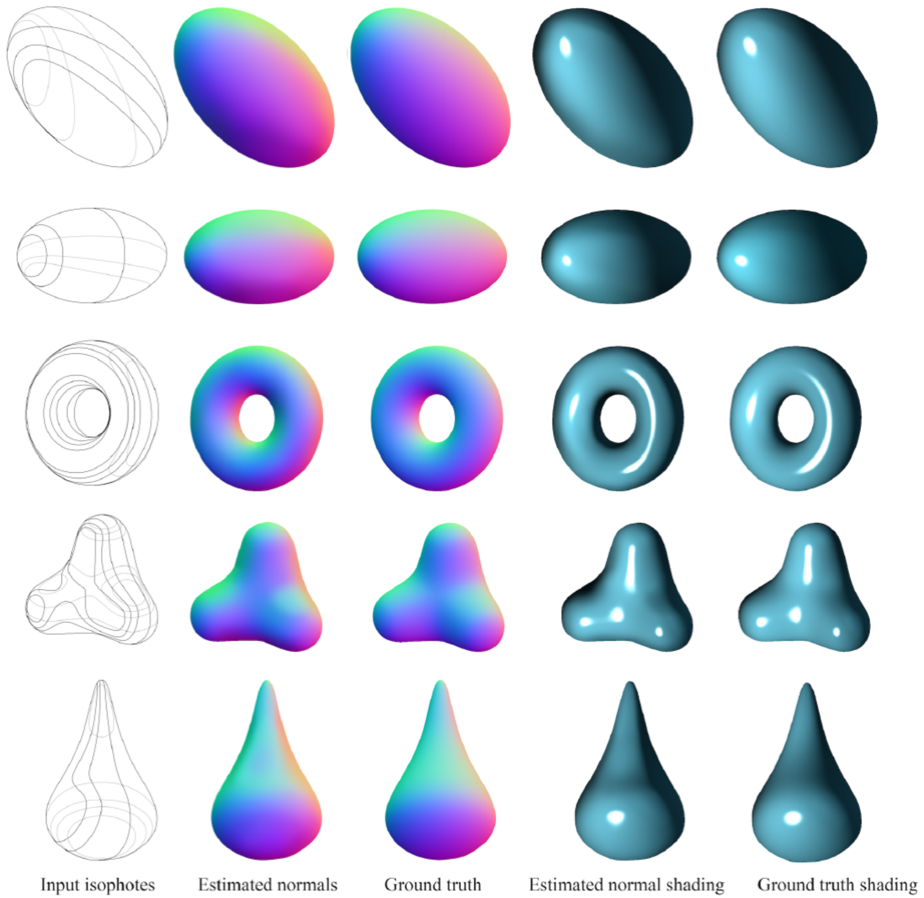
- Estimate 3D isophote tangent $\langle t_x, t_y, t_z \rangle$ from 3D normal $t_z = -\frac{n_x t_x + n_y t_y}{n_z}$.
- Iteratively re-interpolate 3D normal based on 3D arc-length.

Diffuse and Project 3D normals

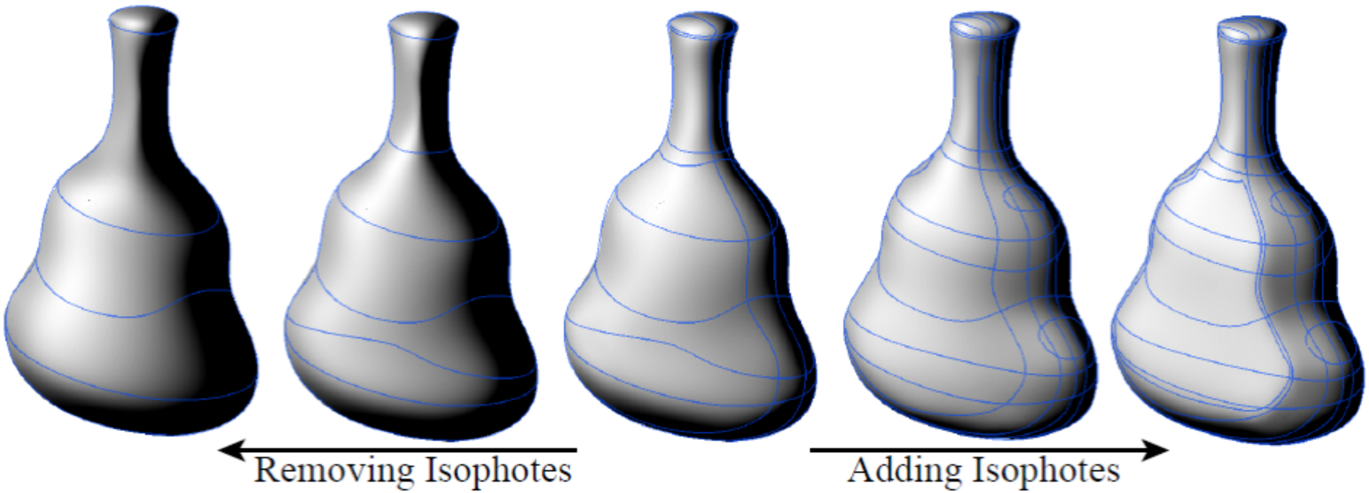


	2d		2d + 3d		ellipse fitting		ellipse + 3d		diffuse only		2d + 3d + diffuse	
	md.	std.	md.	std.	md.	std.	md.	std.	md.	std.	md.	std.
sphere	6.51	4.55	4.94	3.35	4.99	3.4	4.94	3.35	8.85	5.44	4.9	3.24
ellipsoid1	6.33	5.41	5.76	4.11	6.71	6.34	6.6	6.35	8.52	5.5	5.3	3.45
ellipsoid2	6.29	4.05	5.51	3.38	6.28	5.19	5.84	3.81	14.11	14.52	5.46	3.3
torus	7	5.3	6.06	5.09	7.9	12.97	6.27	12.31	7.6	5.05	5.97	4.89
trebol	7.21	9.21	7.04	9.57	8.15	11.63	7.39	9.69	7.7	5.73	6.4	4.63
drop	7.09	7.48	6.1	6.95	6.27	4.92	5.93	4.56	7.27	5.7	5.86	5.1

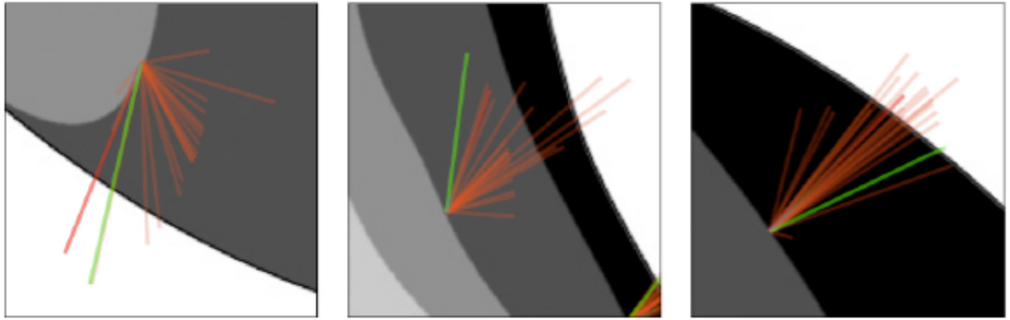
Evaluation


Input isophotes
Estimated normals
Ground truth
Estimated normal shading
Ground truth shading

Evaluation



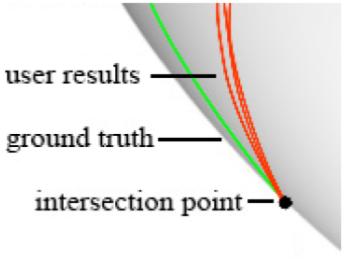
Perceptual Study #1

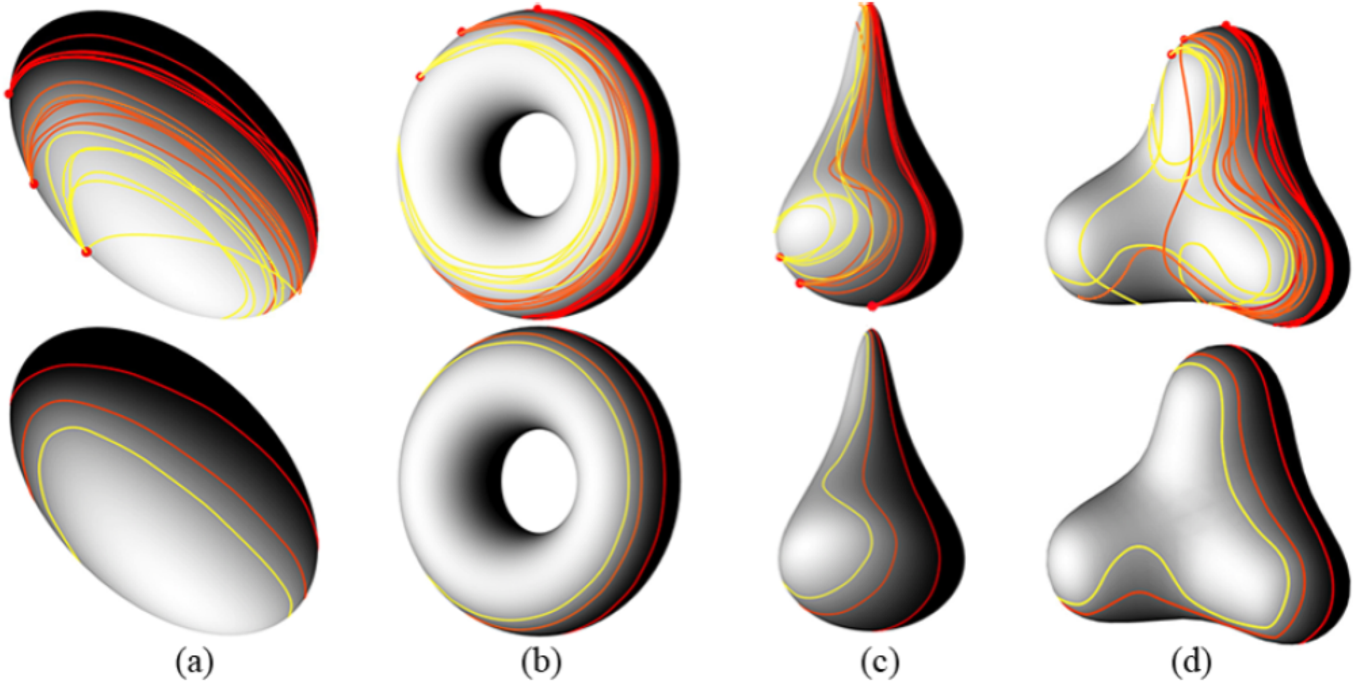


(a) (b) (c)

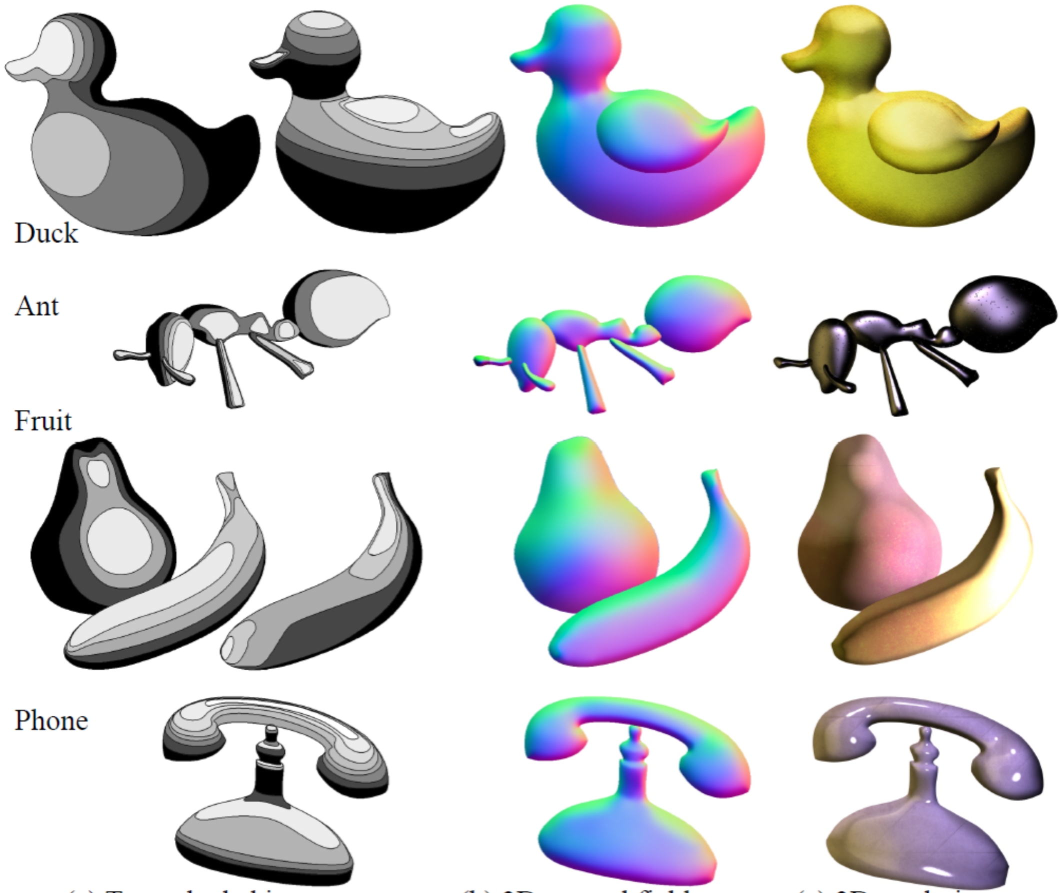
	Pers. intra user	Cons. inter user	Acc. user/GT	Acc. user/GT - outliers	Cons. user/algo	Acc. algo/GT
Complete (constrained movement)						
median	7.1	8.2	16.4	15	14.5	5.6
mean	10.1	14.1	20.2	17.9	15.6	5.8
std. dev.	16.3	17.1	16.8	13.5	13.4	4.2
samples	98	1616	314	299	314	65

Perceptual Study #2



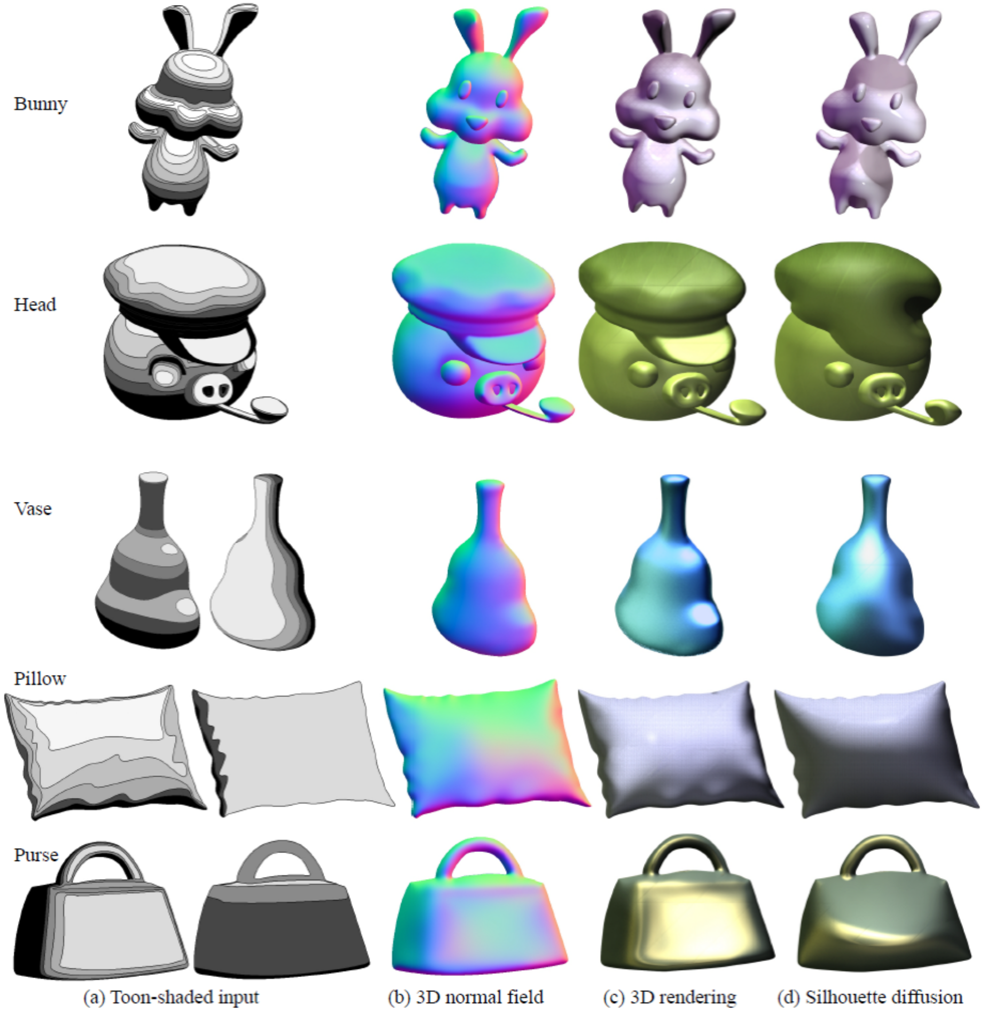


Results

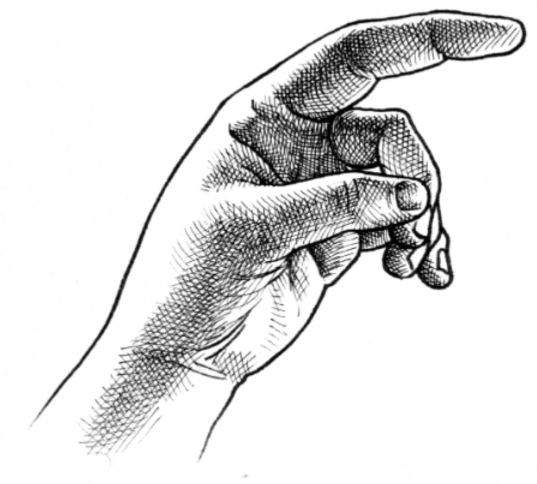


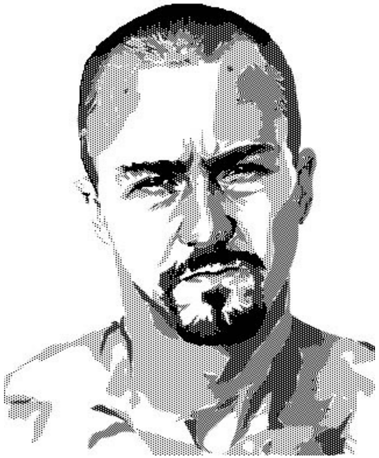
(a) Toon-shaded input (b) 3D normal field (c) 3D rendering

Results


Bunny
Head
Vase
Pillow
Purse
(a) Toon-shaded input
(b) 3D normal field
(c) 3D rendering
(d) Silhouette diffusion

Future work



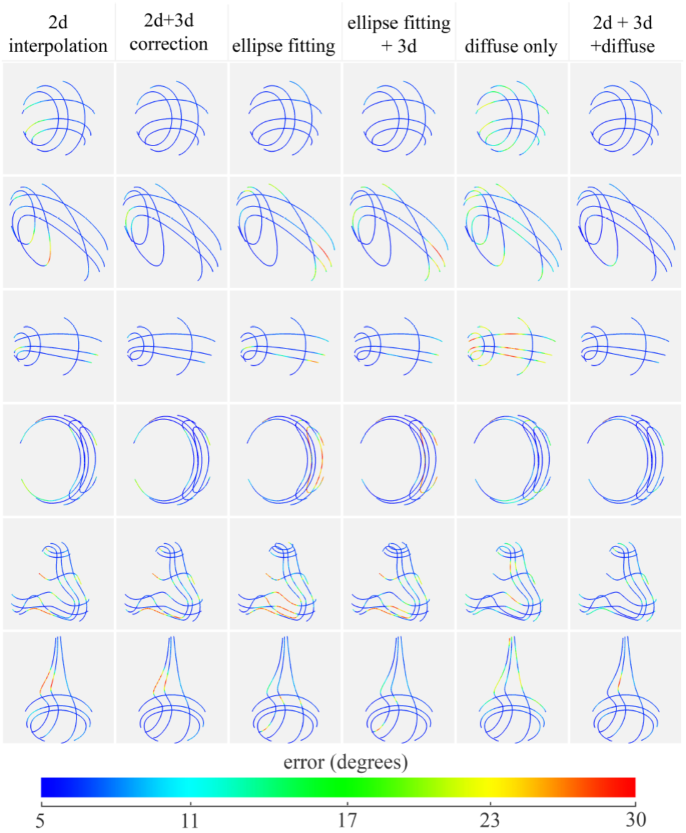


Message

Isophotes can be imagined, drawn and exploited for
3D presentation renderings!

…teşekkür ederim

Diffuse and Project 3D normals



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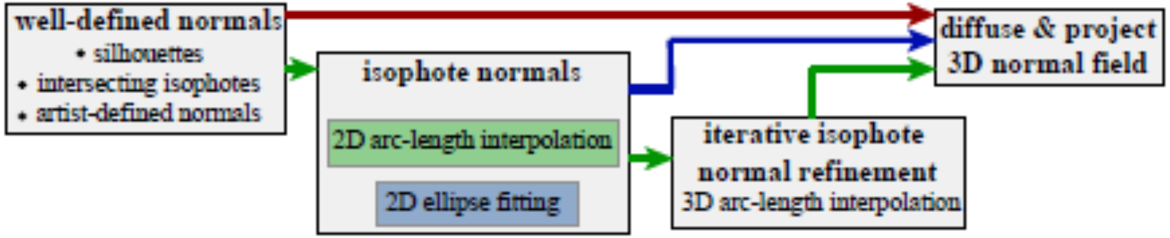

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