Isophote Distance: A Shading Approach to Artistic Stroke Thickness

Todd Goodwin, Ian Vollick, Aaron Hertzmann

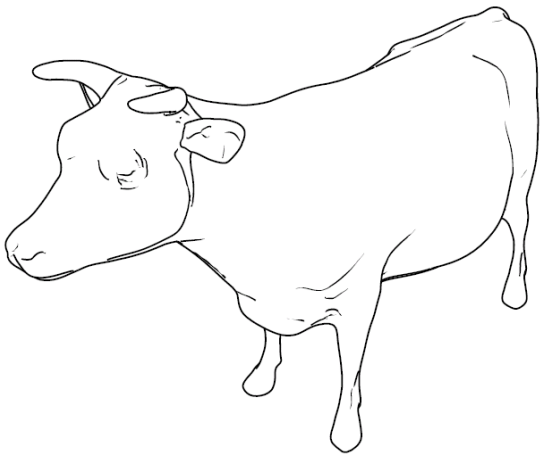
University of Toronto

[McCloud 2006]

Goals of this work

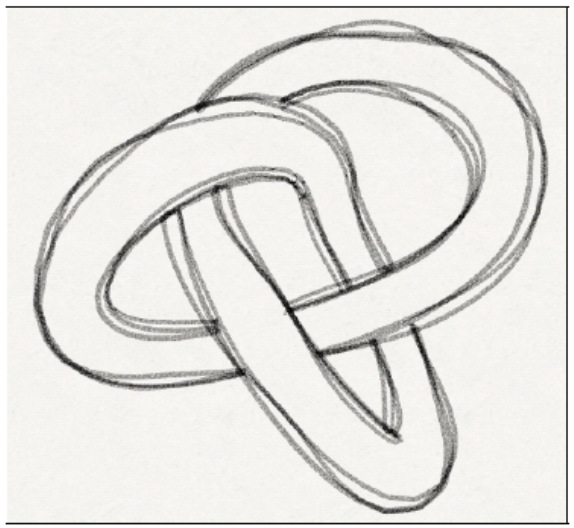
1. 3D algorithms for artistic stroke thickness
2. How do artists and illustrators use line thickness?

Previous methods: 2D



Constant

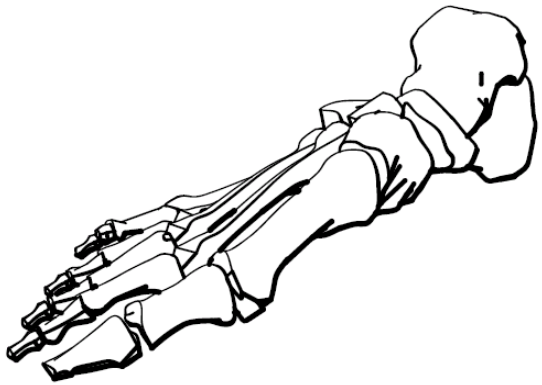
2D Tapering



Procedural
[Grabli et al. 2004]

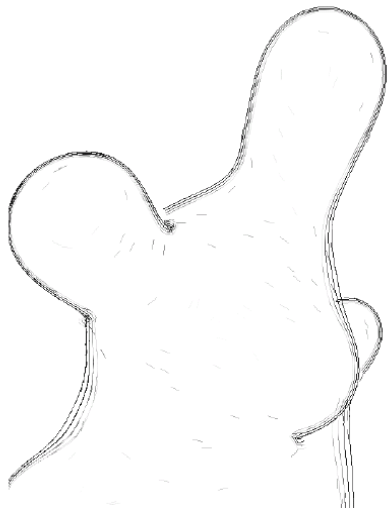
Previous methods: 3D

Depth
[Gooch et al. 99]



Lighting
[Schlectweg et al. 98]

Curvature (proportional)
[Sousa and Prusienkiewicz 2003]

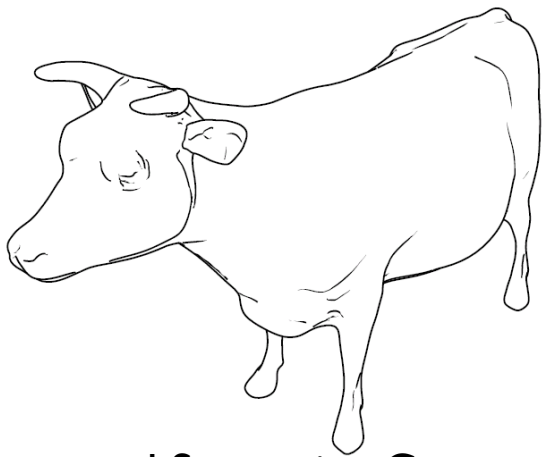


Radial Curvature (inverse)
[Bremer and Hughes 98]

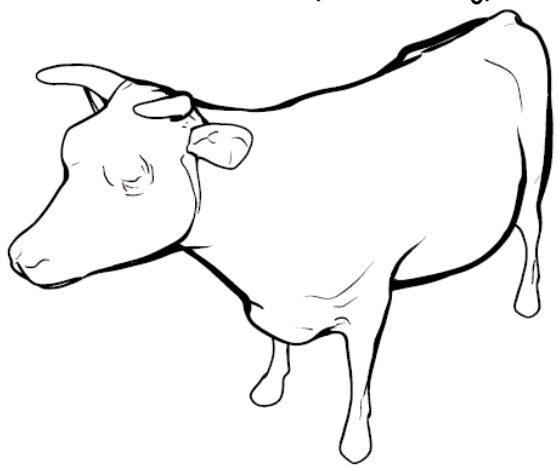
Idea

Lambertian rendering ($n \cdot v$)

Thresholded ($n \cdot v < r_0$)

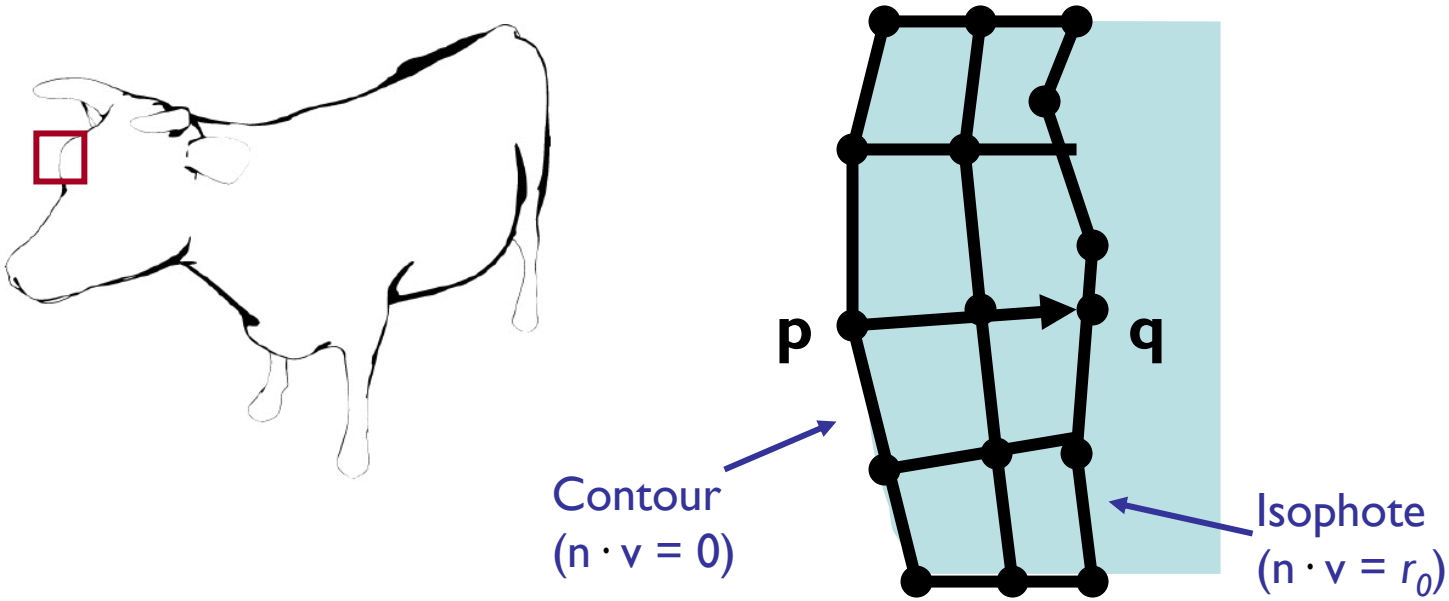


Contours and Suggestive Contours
[DeCarlo et al. 2003]



Our approach

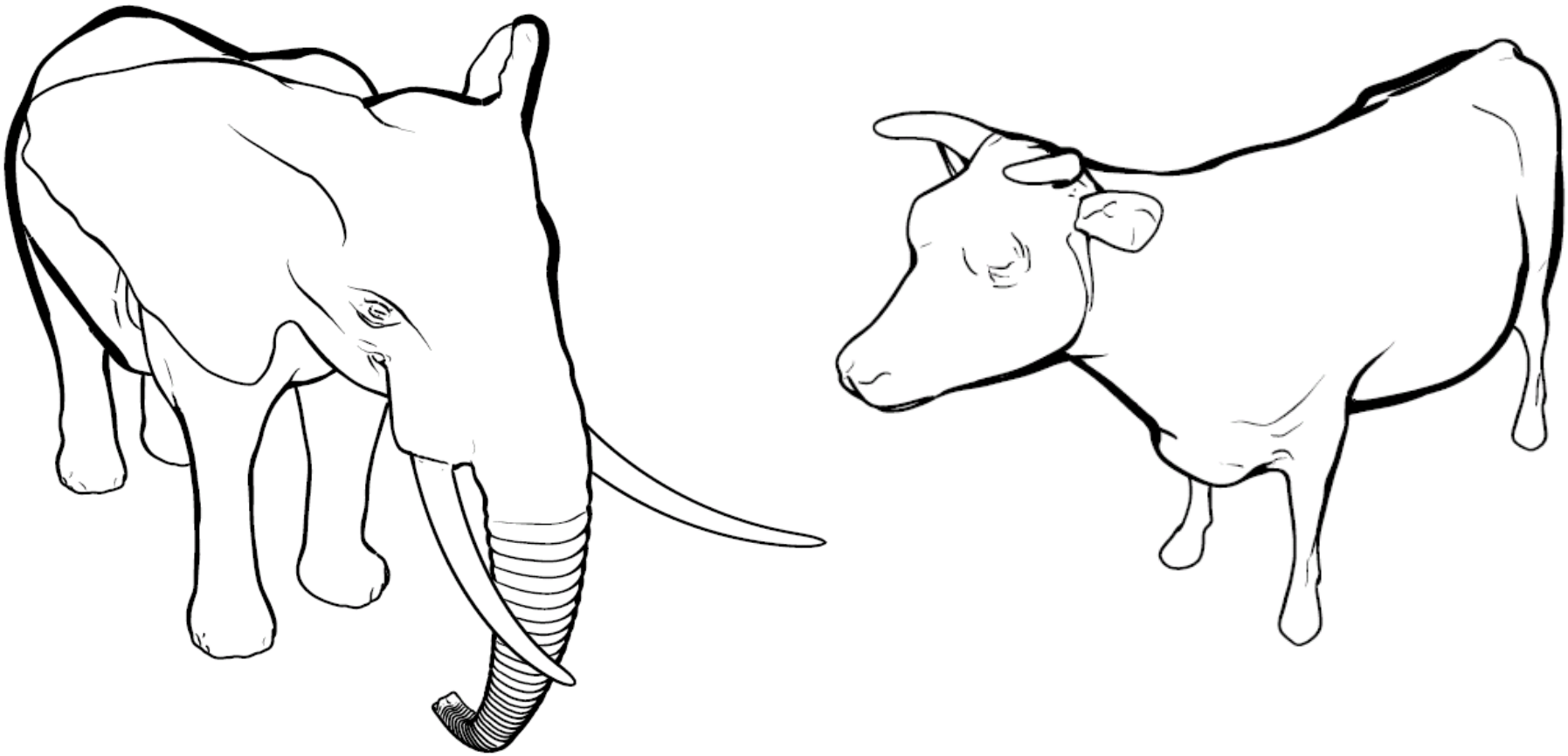
Our method



Stroke thickness is Isophote Distance: || **p - q** ||, clamped to range [T_{min}, T_{max}]

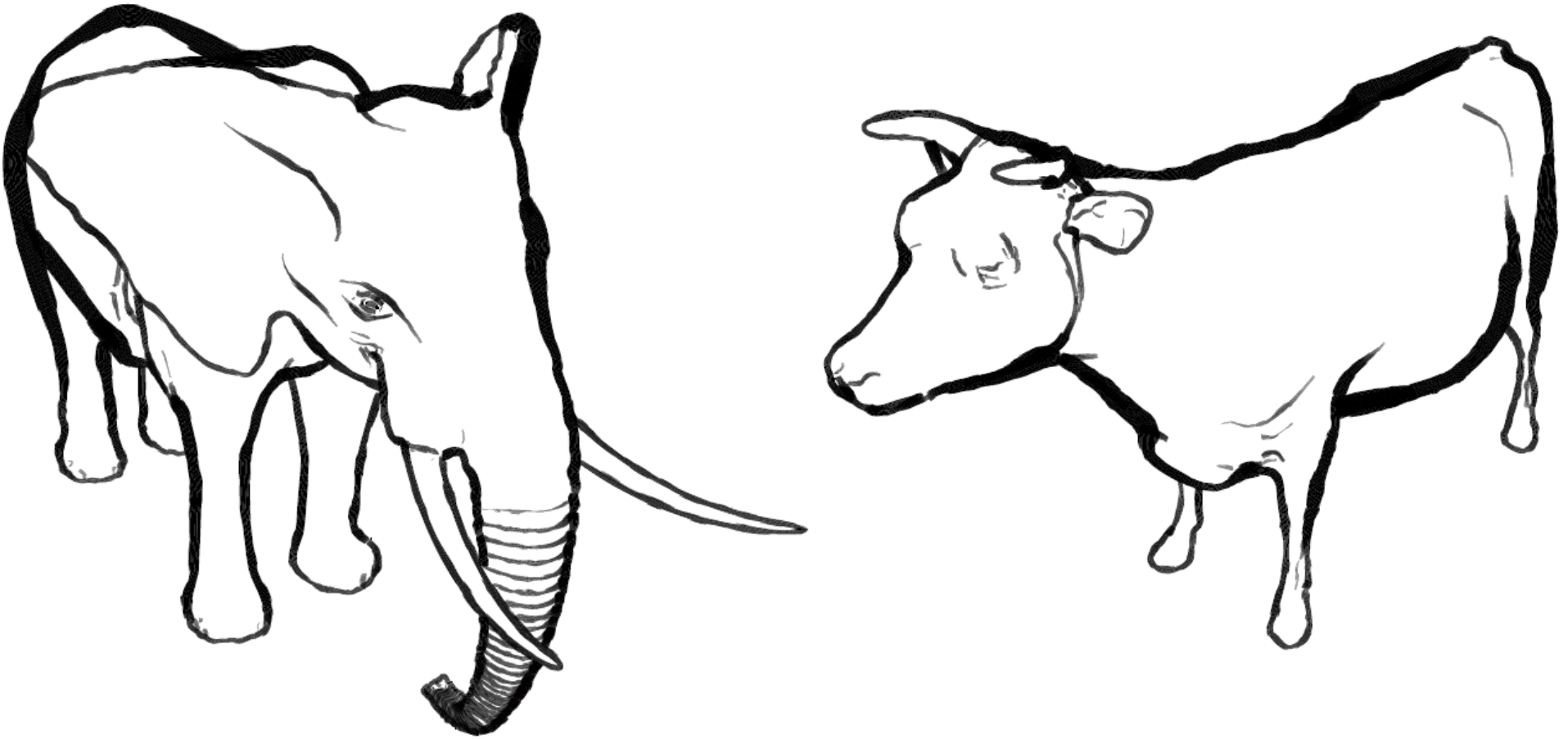
Rim lights and shadows

Ink rendering style

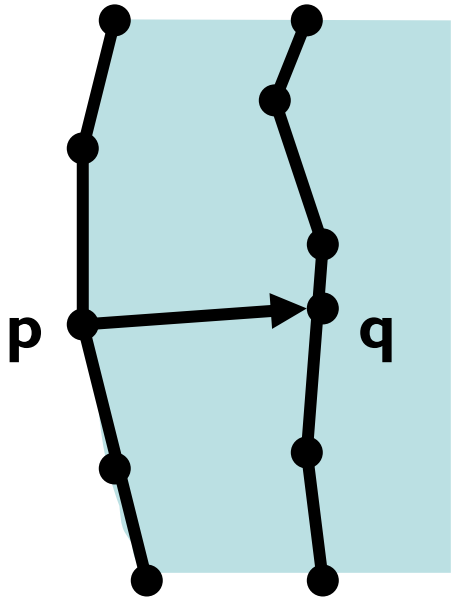


Overdraw rendering style

Brush rendering style



Analytic approximation



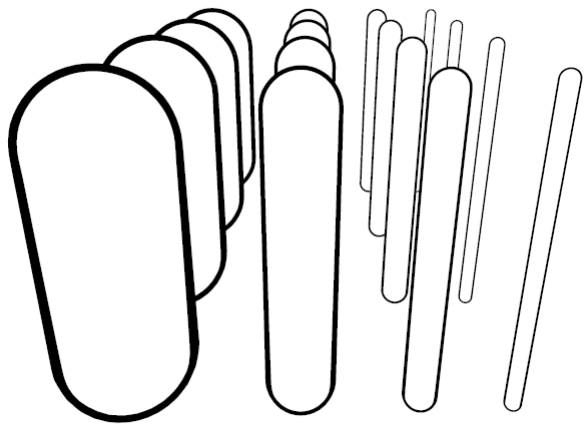
$$\| \mathbf{p} - \mathbf{q} \| \approx \frac{f}{\kappa(\mathbf{p})\|\mathbf{p}-\mathbf{c}\|} \left(\frac{r_0^2}{2(1-r_0^2)} \right)$$

Camera focal length

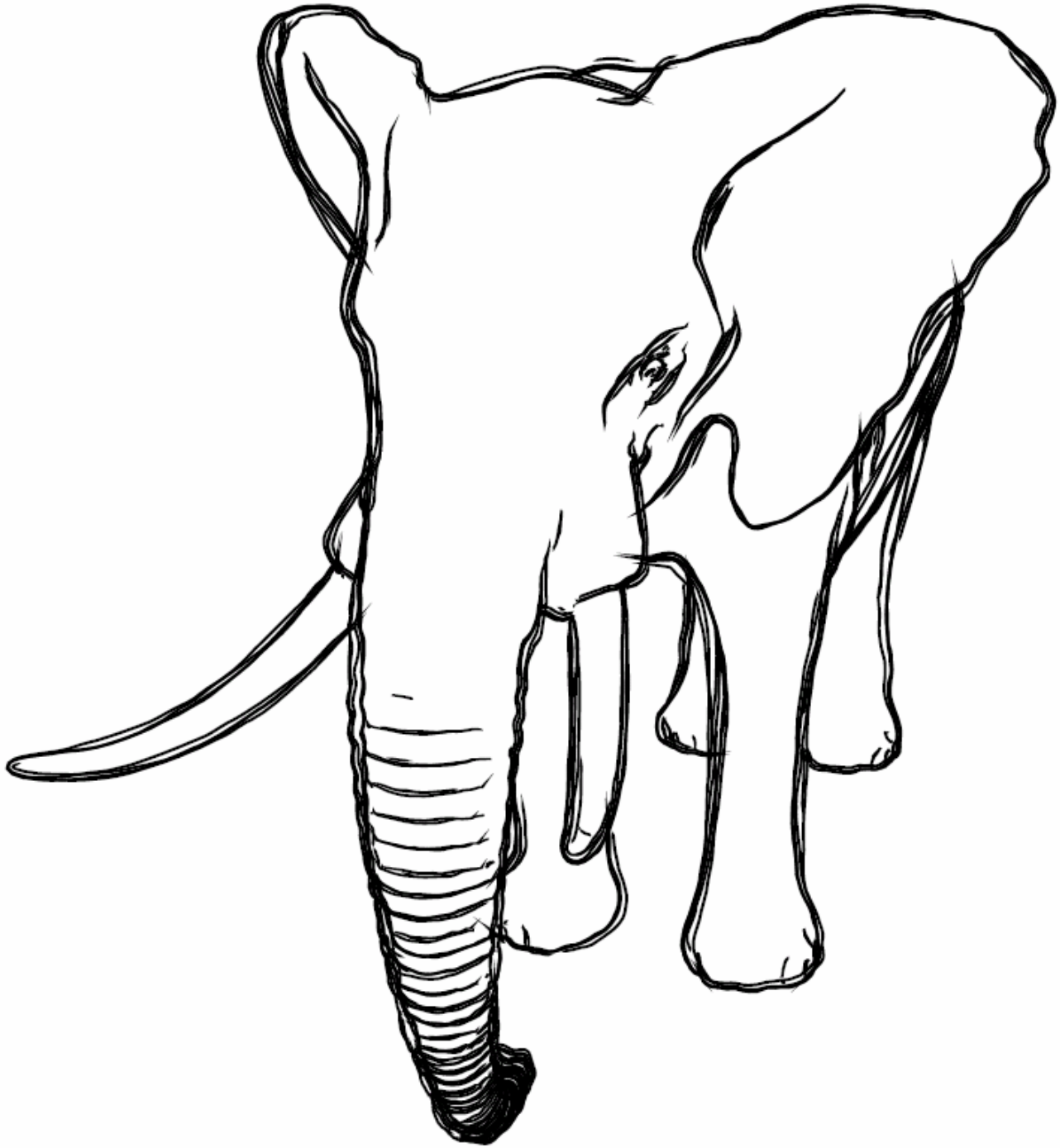
Isophote intensity

Radial curvature

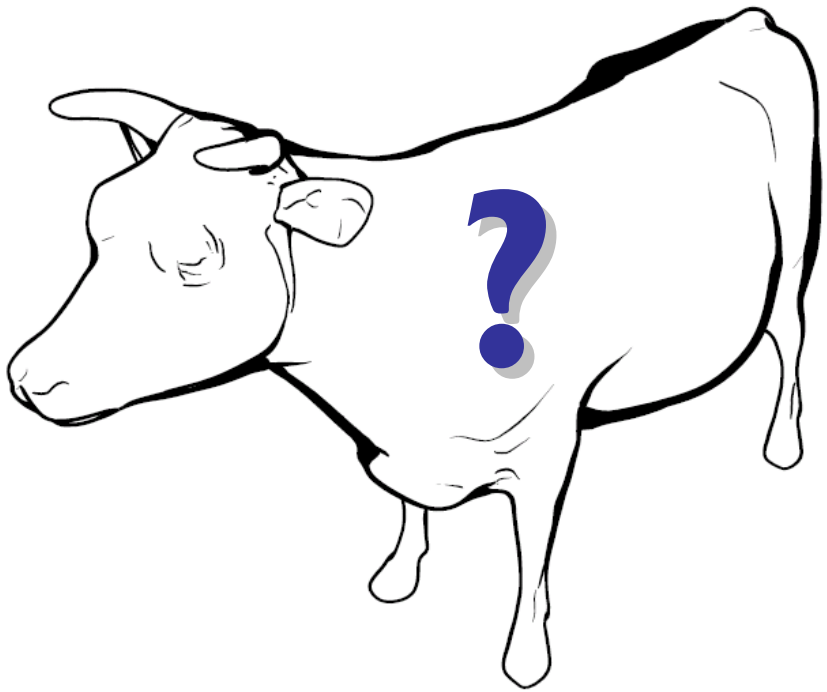
Depth



(see paper for case of moving light source)

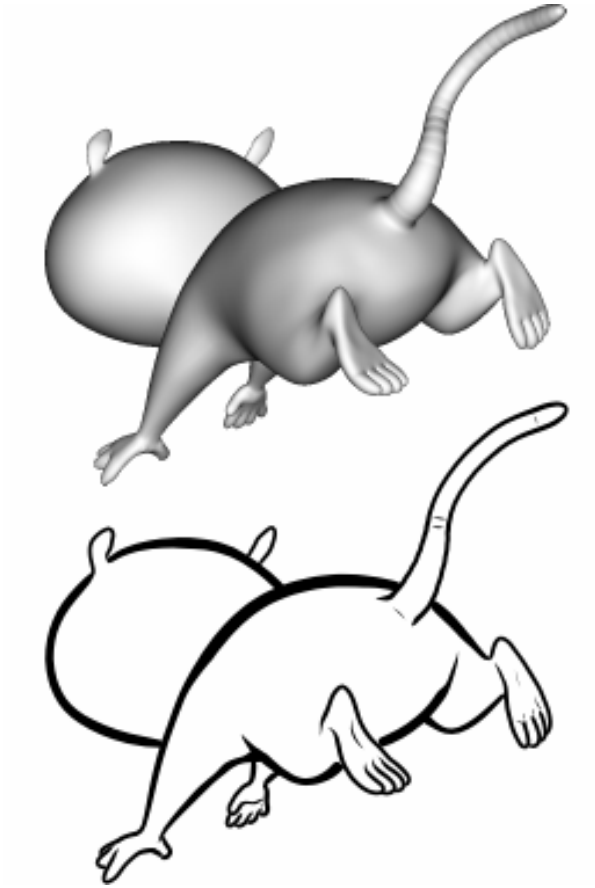


Is this a good idea?



Reproducing examples

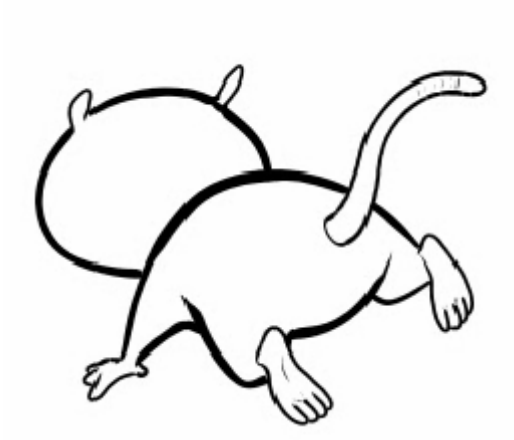
"Bone" by Jeff Smith © 2007



Our result

Reproducing examples

"Bone" by Jeff Smith © 2007



Our result

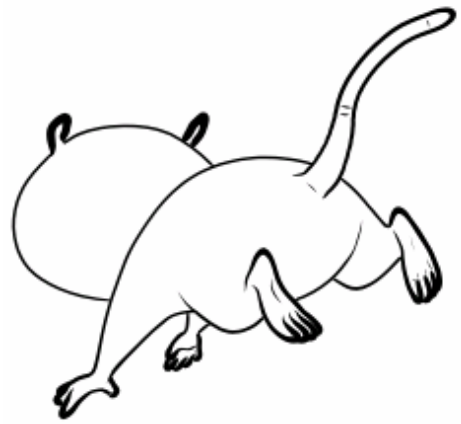
Reproducing examples

"Bone" by Jeff Smith © 2007

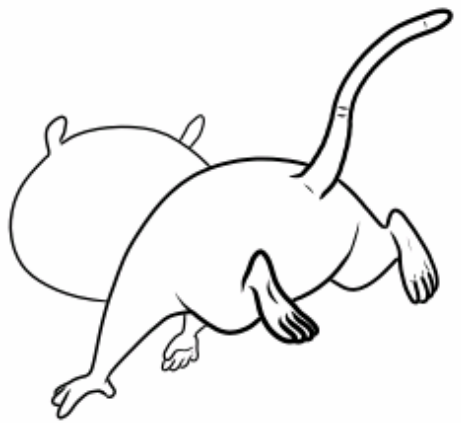
Our result

Existing methods

"Bone" by Jeff Smith © 1998

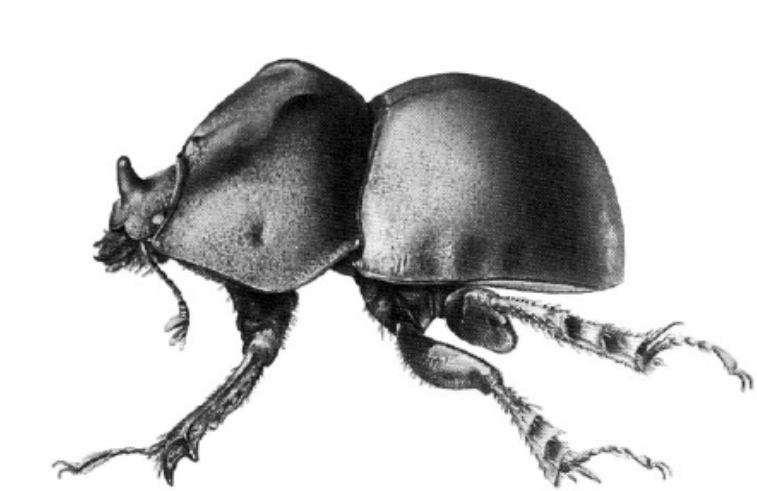


Proportional to curvature

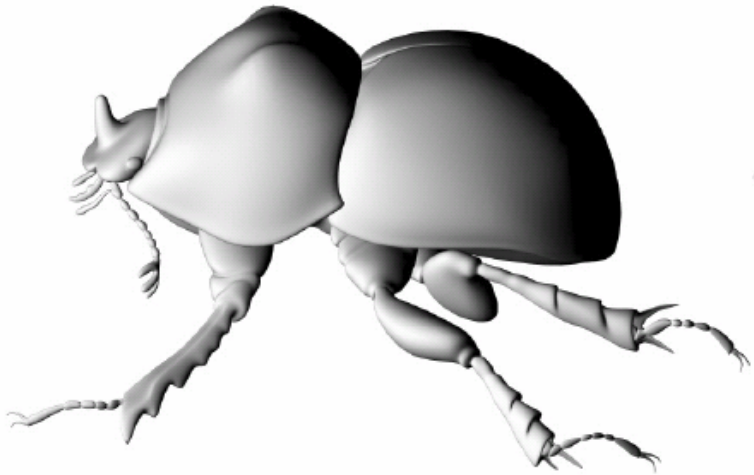


Inversely proportional to depth

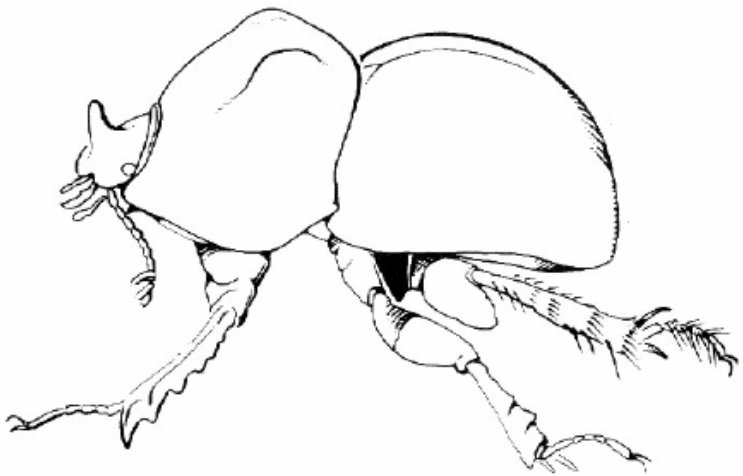
Reproducing examples



Tonal drawing



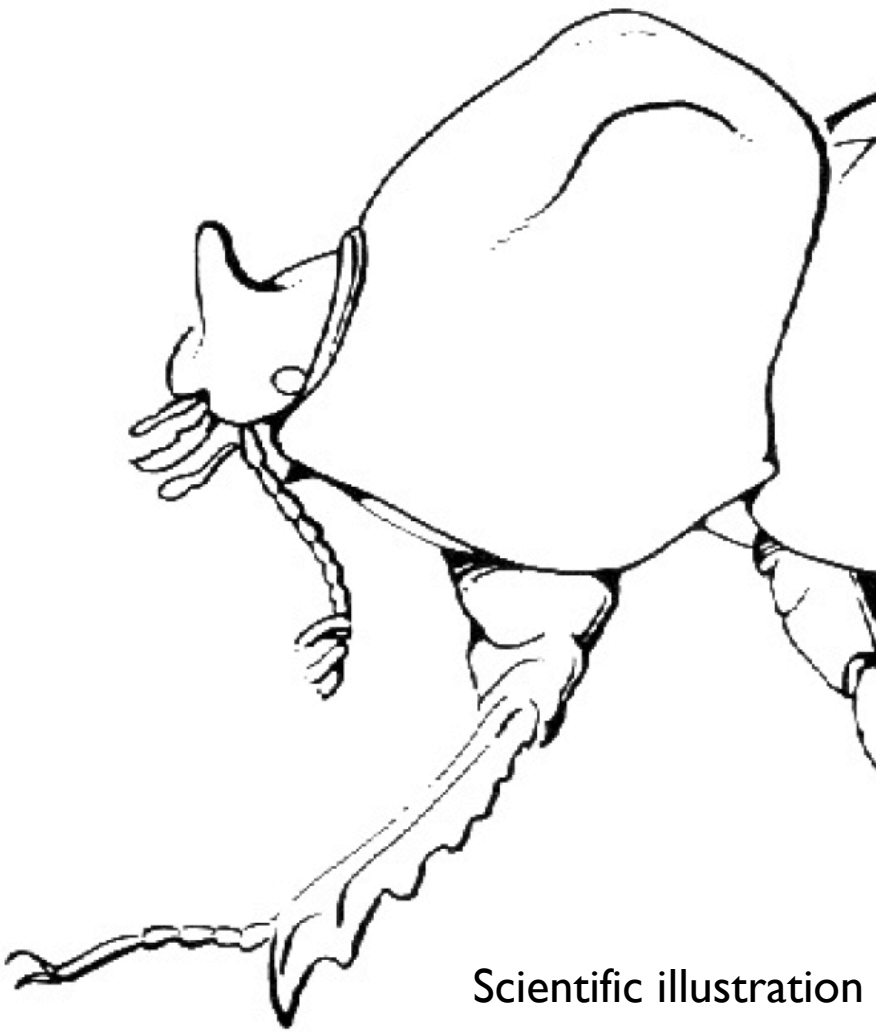
Our 3D model



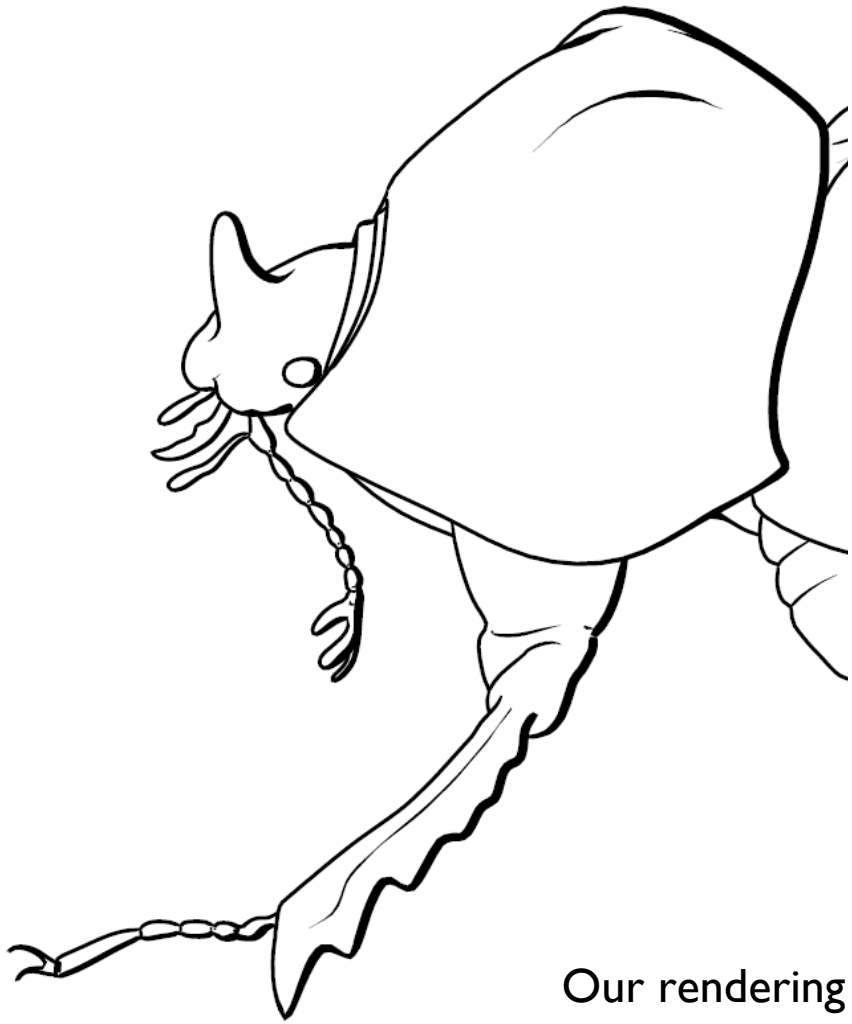
Artist drawing [Brudon]

Our rendering

Reproducing examples



Scientific illustration



Our rendering

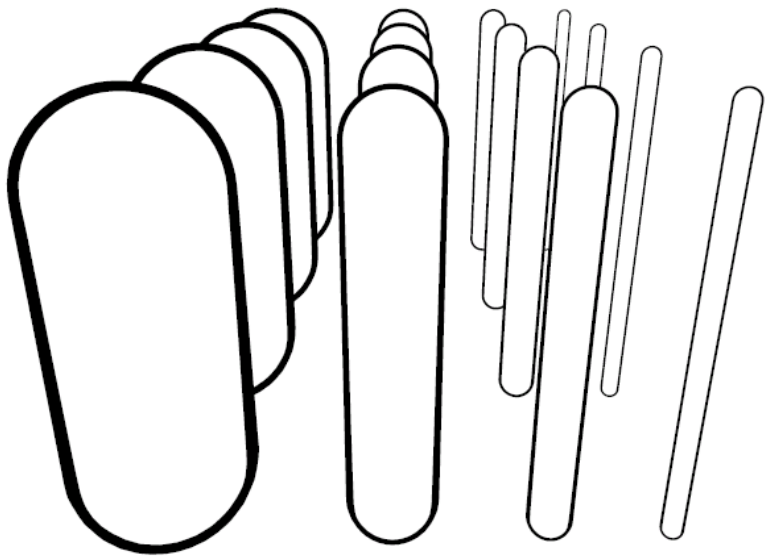
Qualitative properties

Most drawings don't quite fit our model

Can we say anything more broadly?

1. Thickness $\propto$ (depth)$^{-1}$

[Gooch et al. 99]



1. Thickness $\propto$ (depth)$^{-1}$

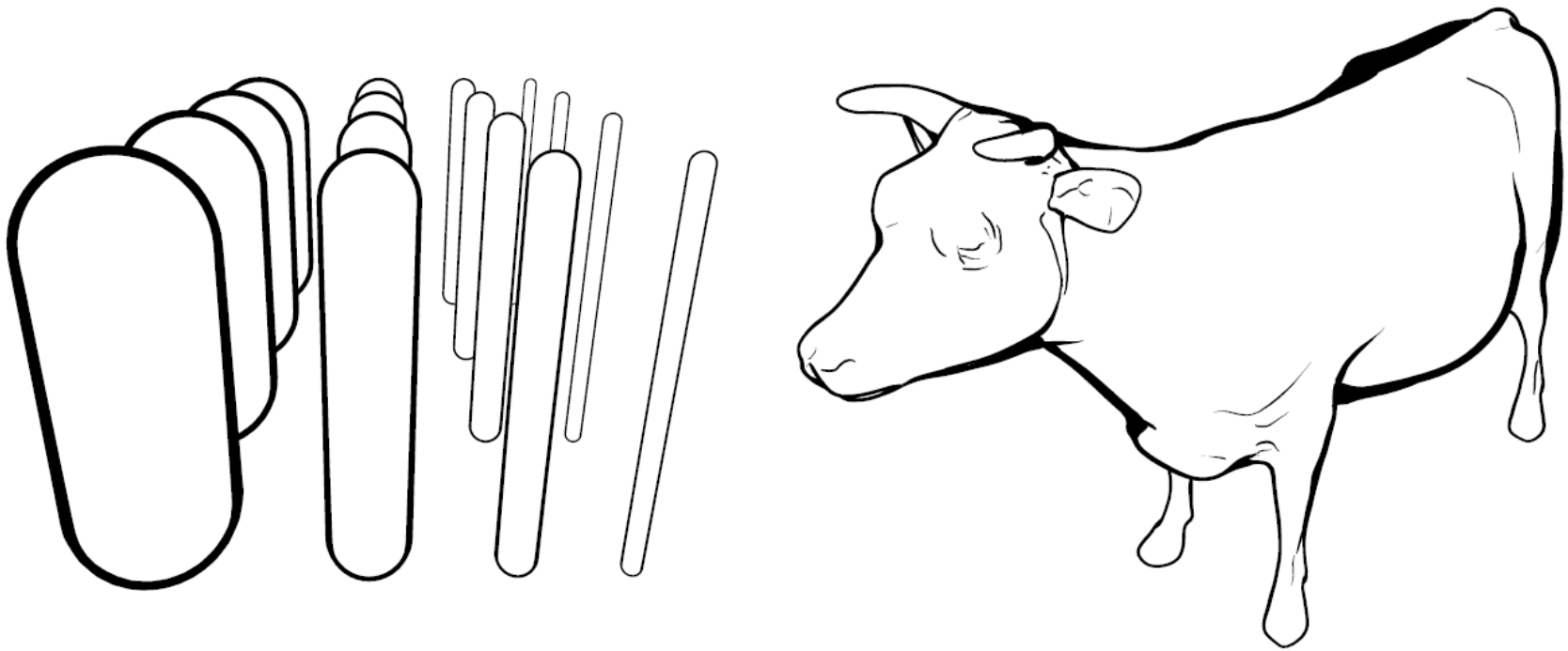
[Gooch et al. 99]

Jack Hamm, 1967

1. Thickness $\propto$ (depth)$^{-1}$

A Scanner Darkly, 2006

2. Thickness $\propto$ (radial curvature)$^{-1}$



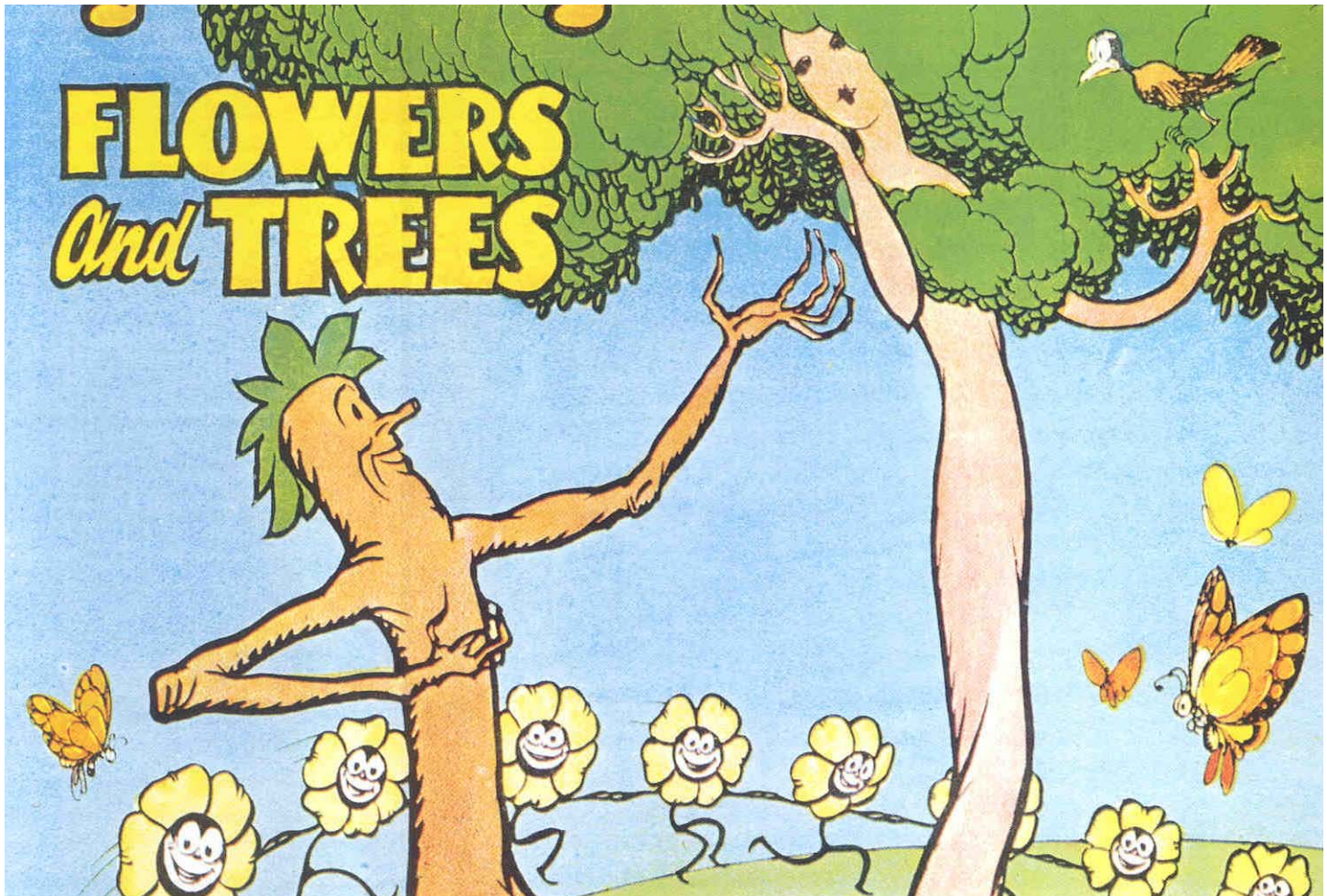
2. Thickness ∝ (radial curvature)$^{-1}$

a. Large cylindrical objects have thicker strokes (legs > arms > fingers)

Kwan Jung, 2003

2. Thickness ∝ (radial curvature)$^{-1}$

a. Large cylindrical objects have thicker strokes



Disney 1932

2. Thickness ∝ (radial curvature)$^{-1}$

b. Strokes are thicker at "bulges" (e.g., forearms)

Eisner 1991

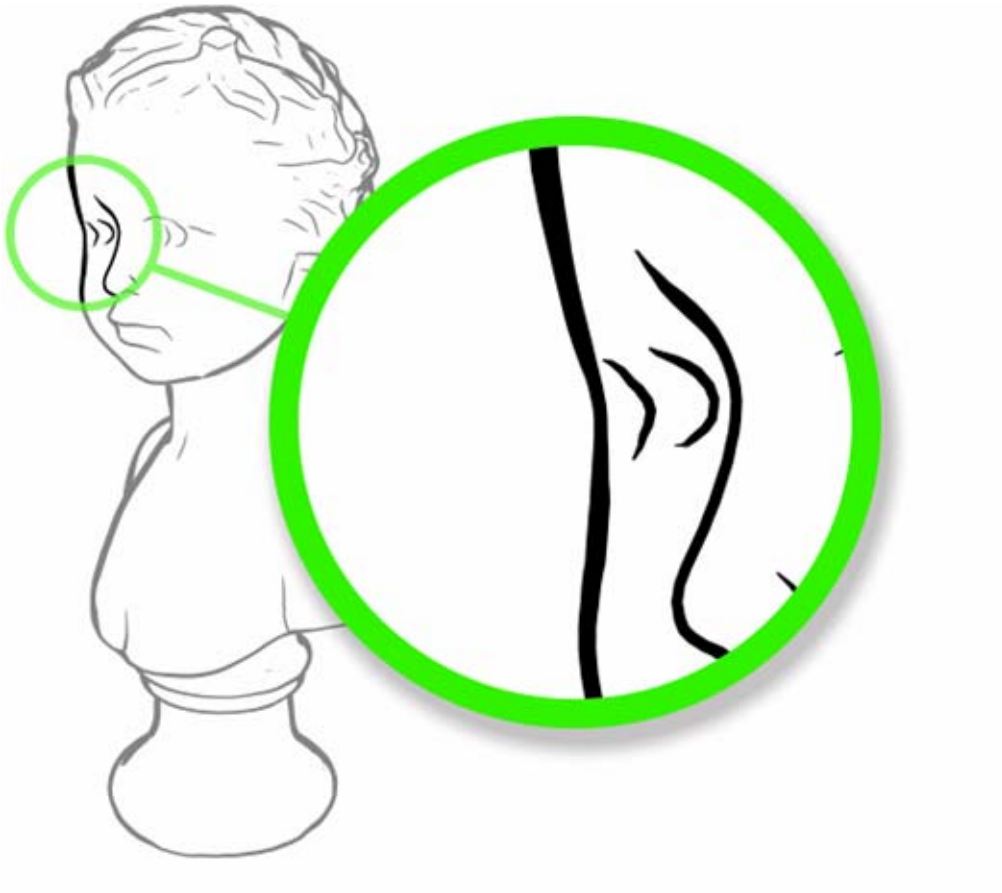
A Scanner Darkly 2006

2. Thickness $\propto$ (radial curvature)$^{-1}$

c. Foreshortened objects should be thicker…

2. Thickness $\propto$ (radial curvature)$^{-1}$

d. Thinning above the cheekbone



2. Thickness ∝ (radial curvature)$^{-1}$

d. Thinning above the cheekbone

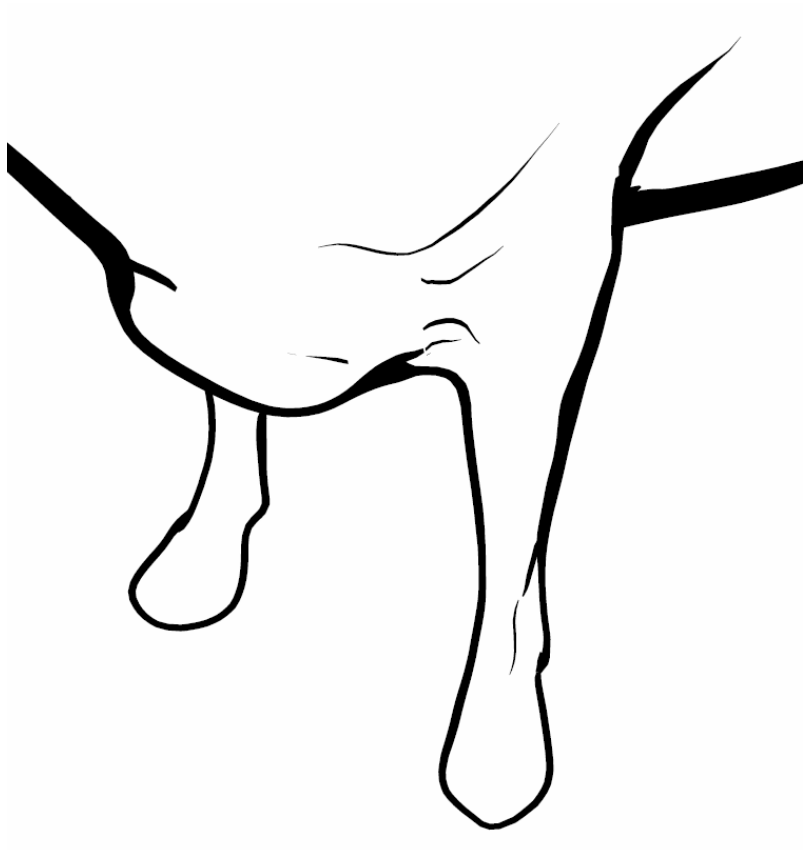
Disney 1973

Gilligan 2006

Ware 2006

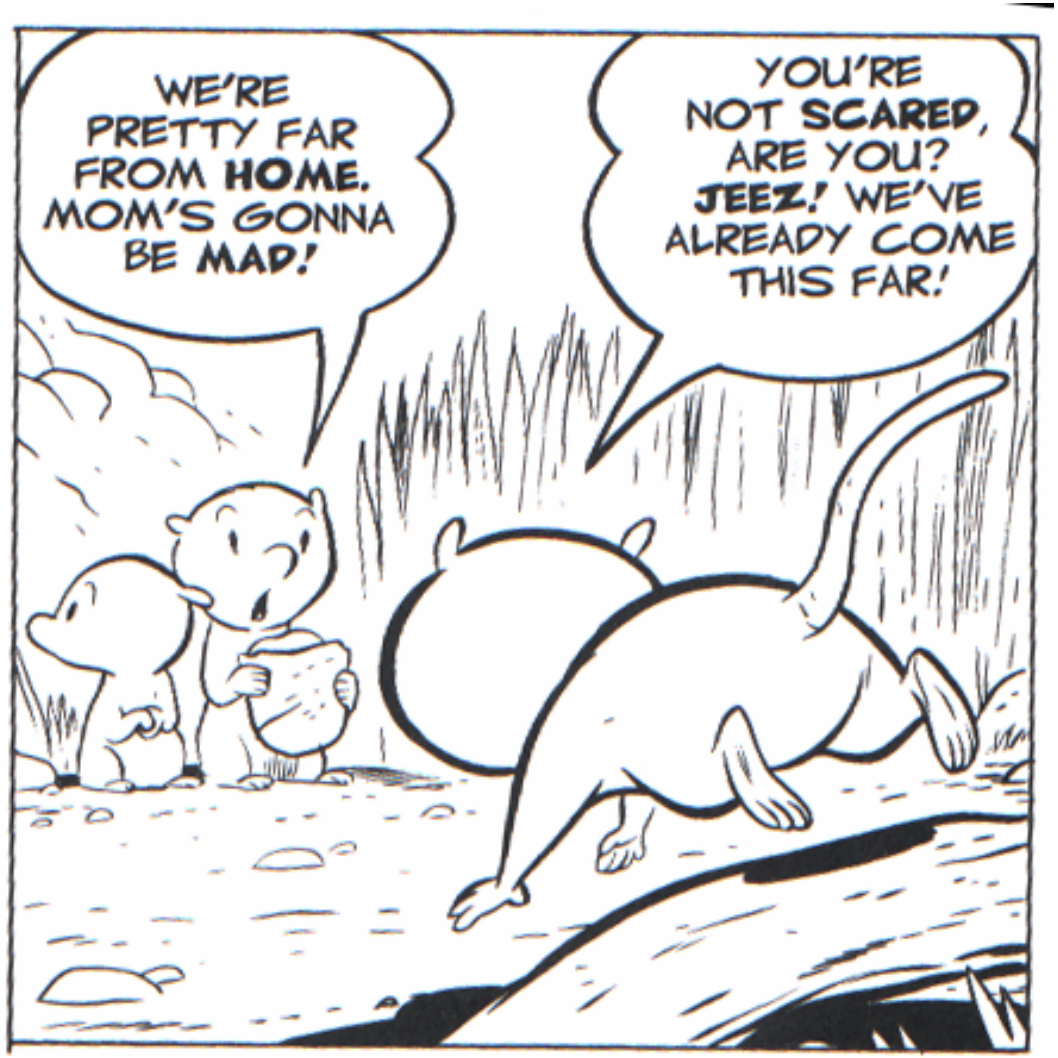
3. No tapering at contour occlusion

Uniform 2D tapering

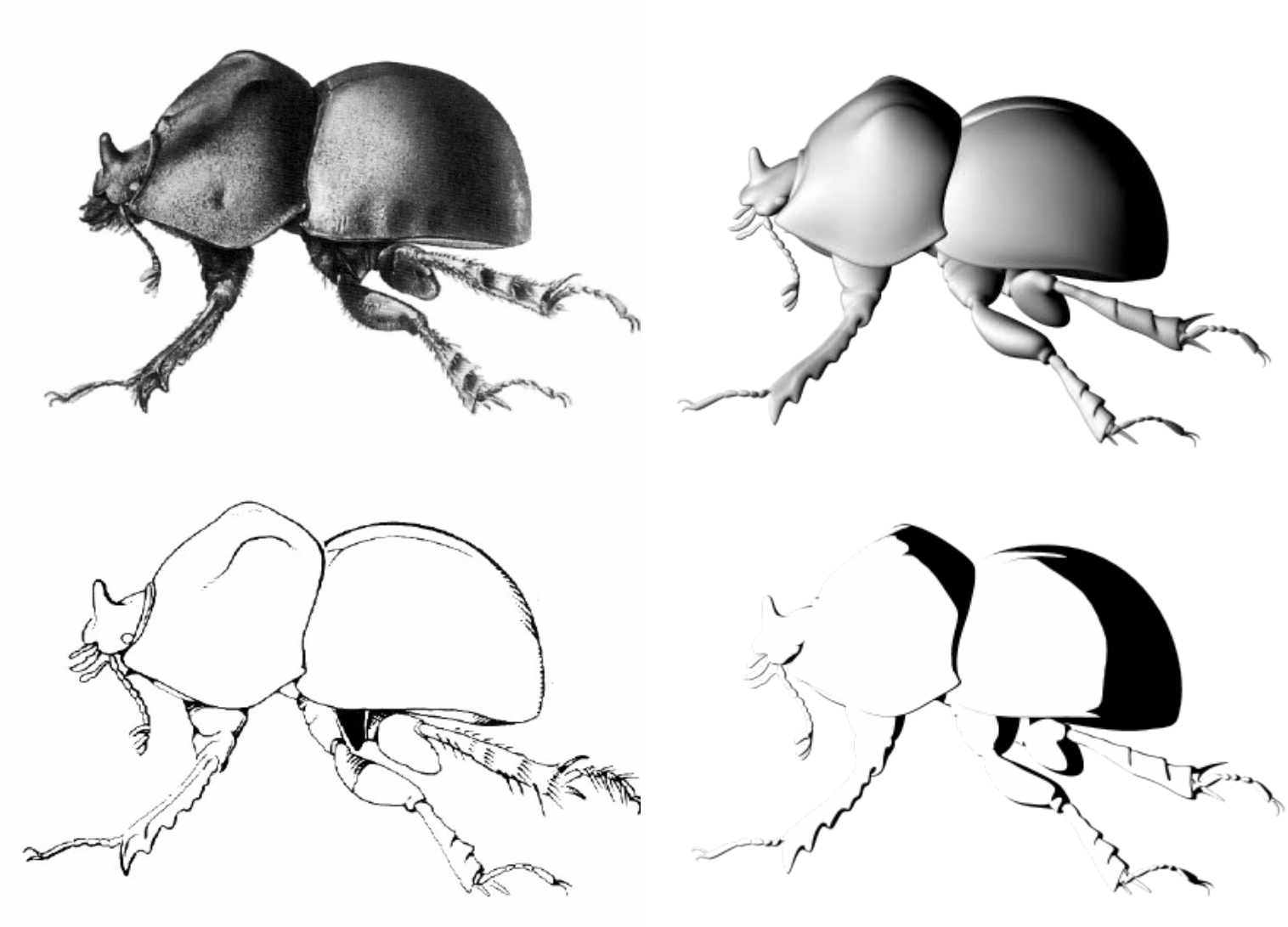


Our approach

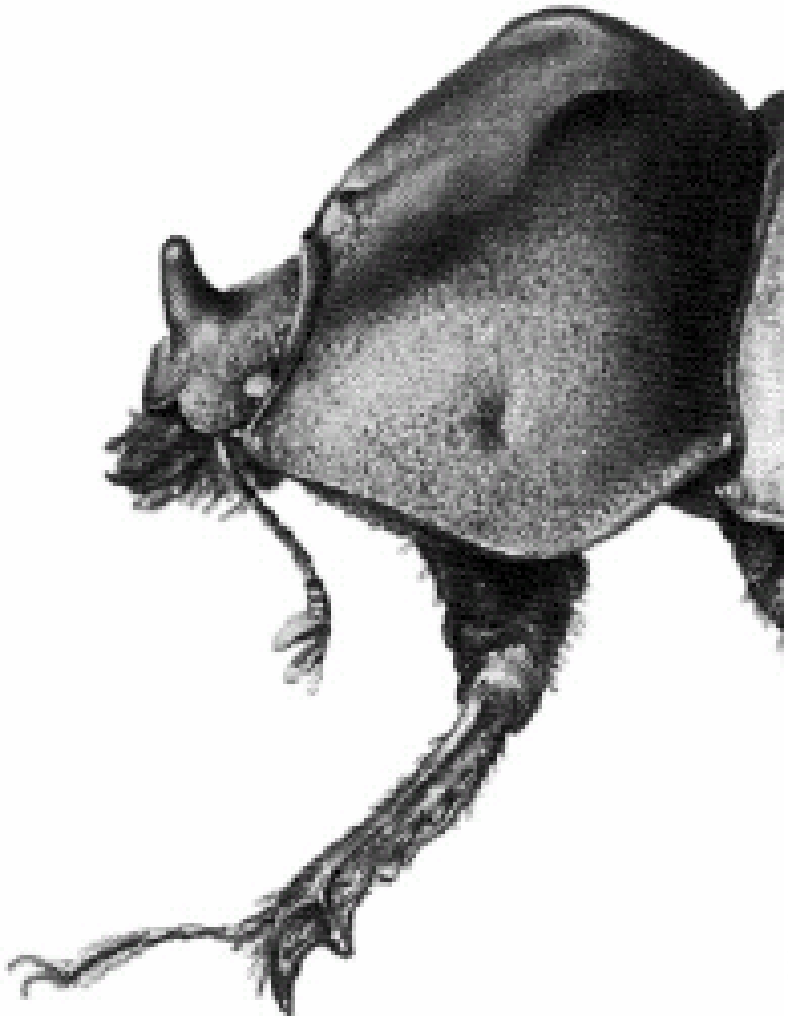
3. No tapering at contour occlusion



4. Strokes are limited in size

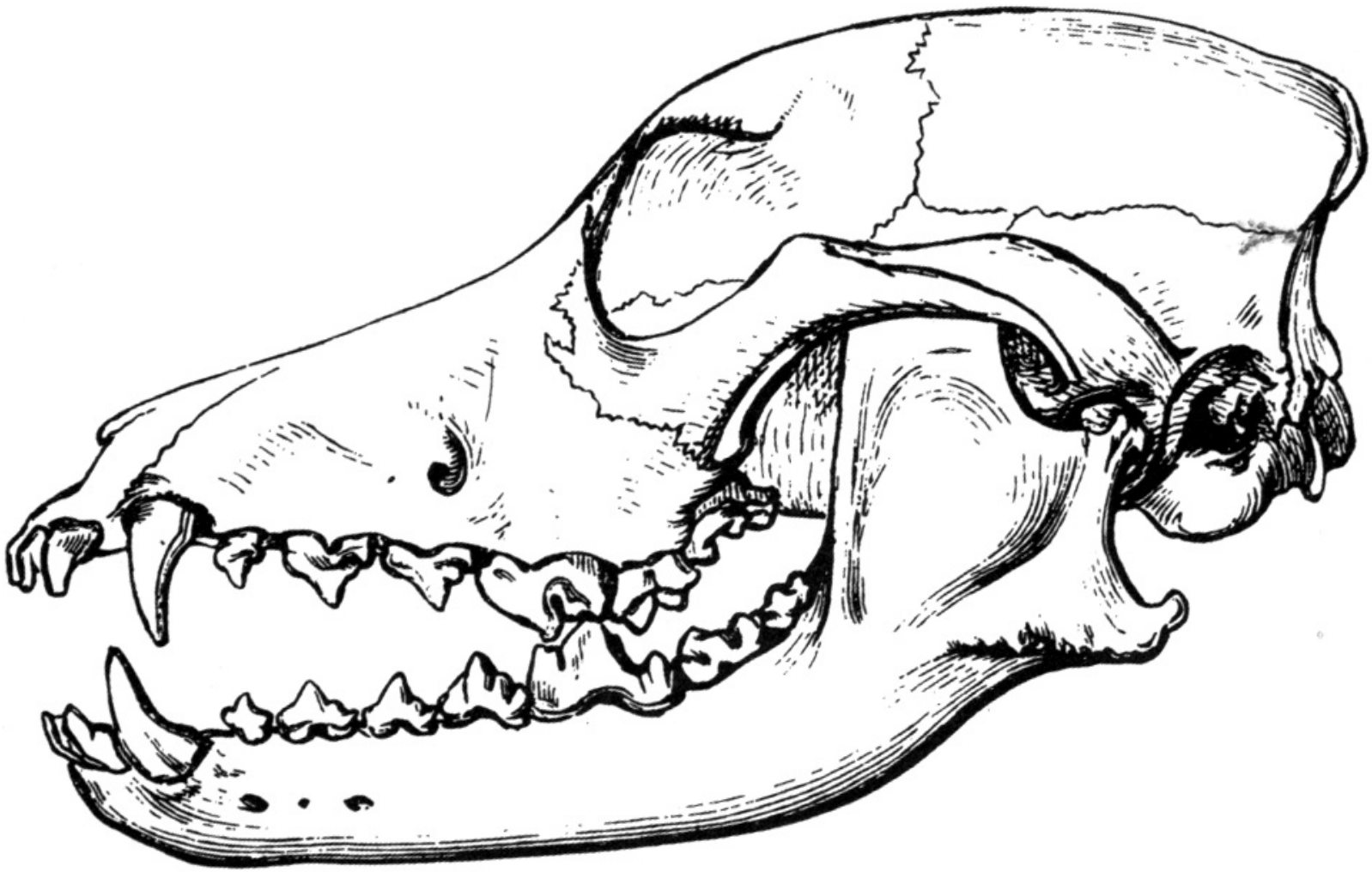


5. Lighting modulates thickness



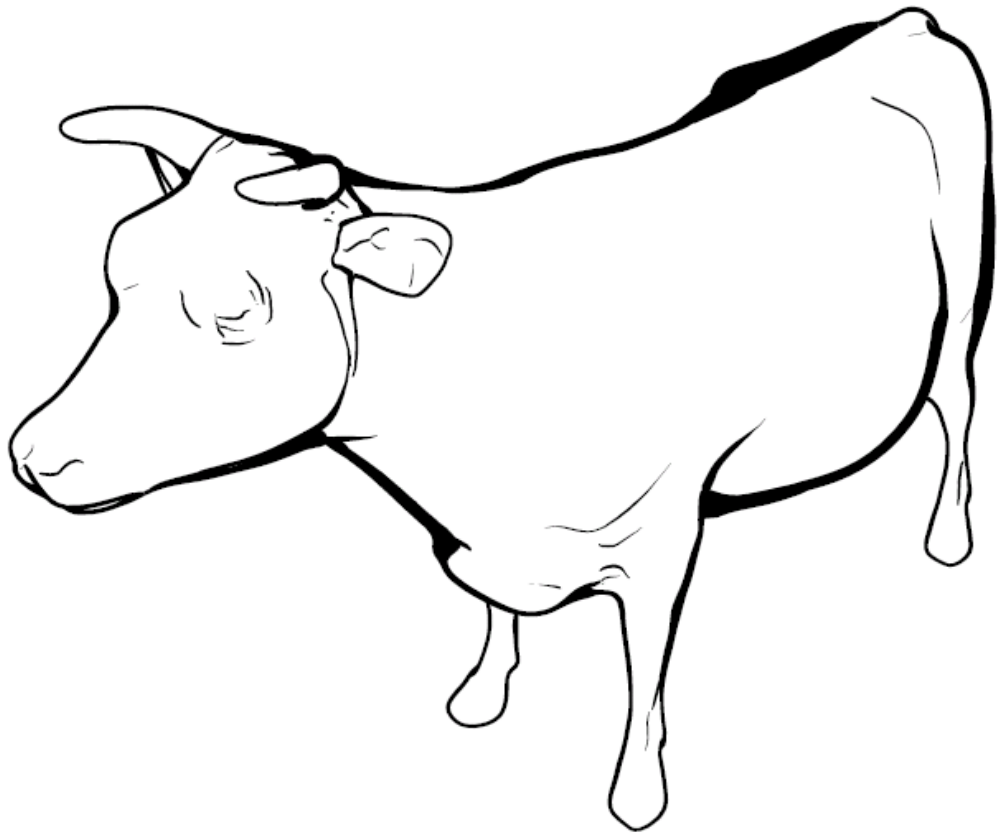
Brudon 1970

5. Lighting modulates thickness

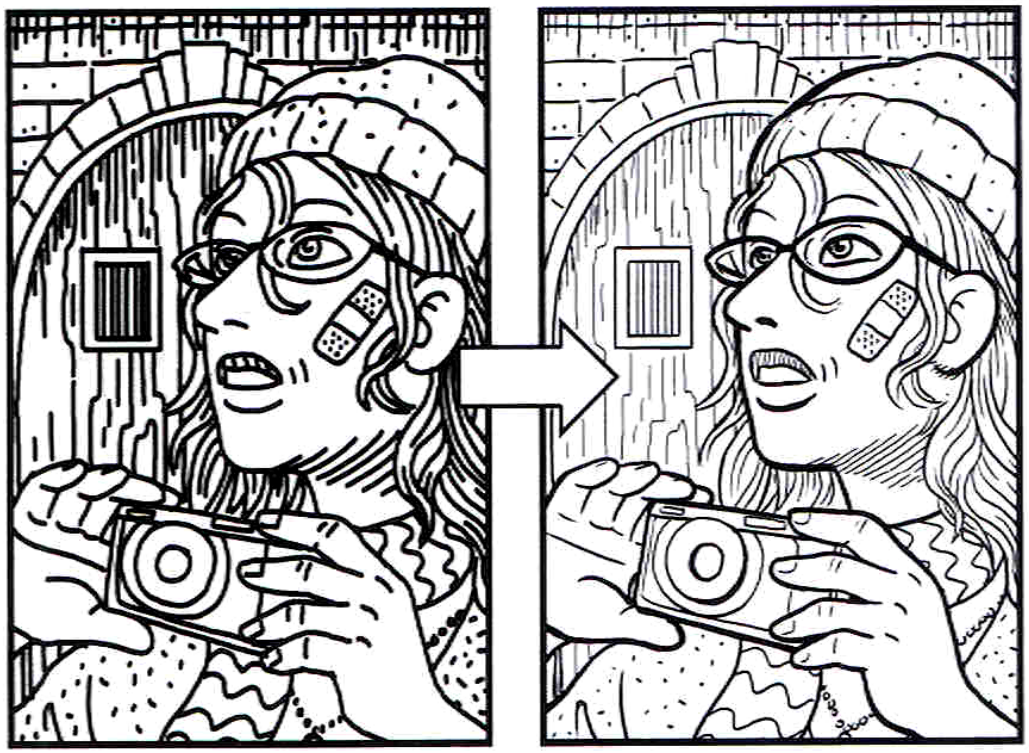


6. Interior vs. Exterior Curves

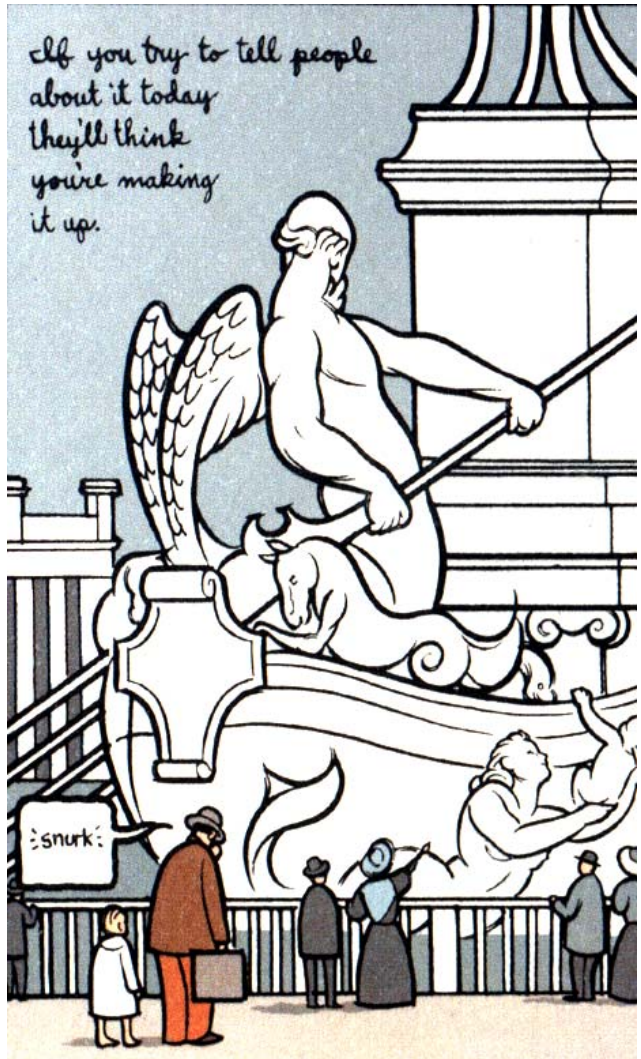
Interior ("anticipation") suggestive contours thinner



6. Interior vs. Exterior Curves

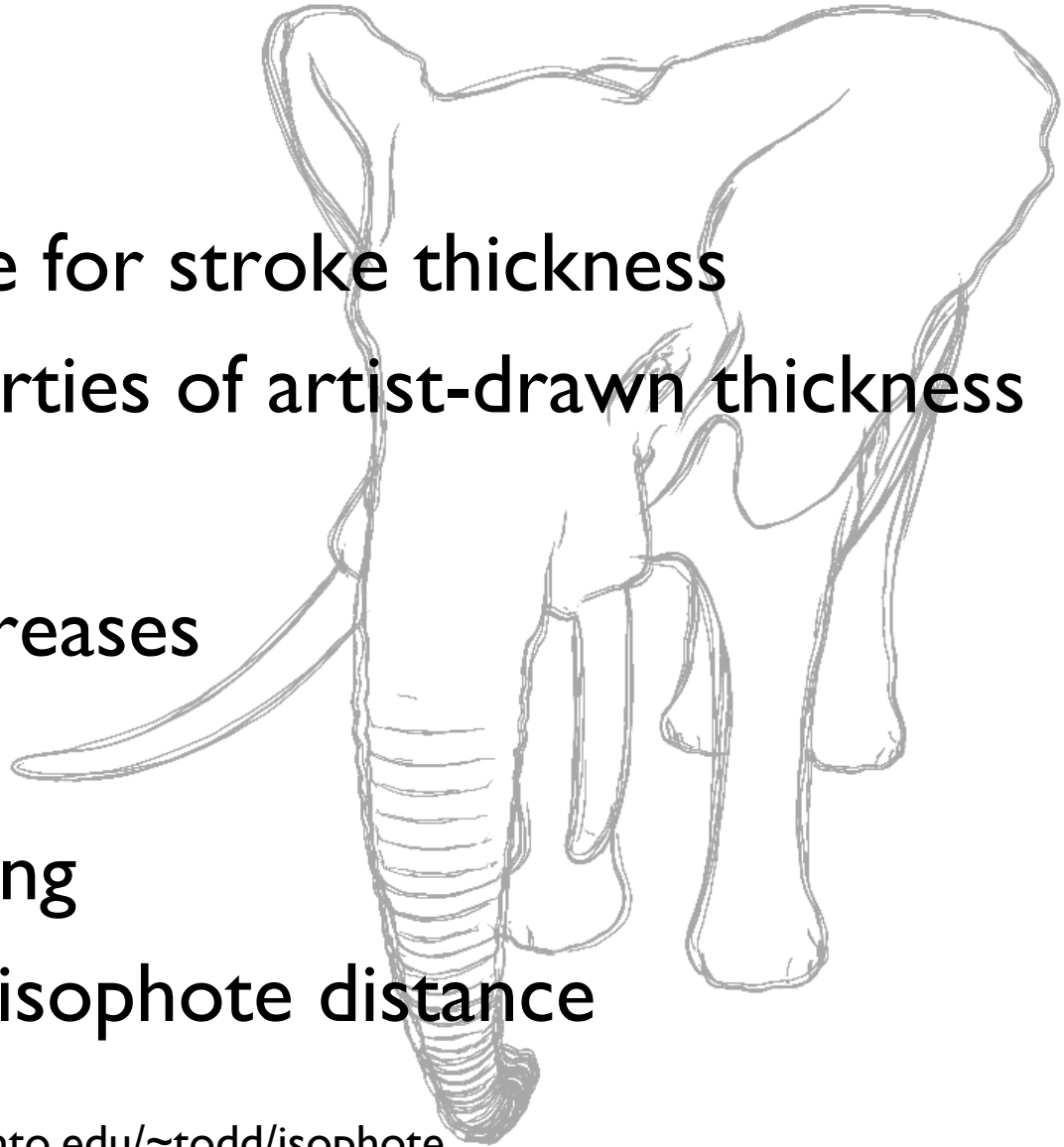


McCloud 2006



Ware 2000

Summary and Future Work



Contributions

- Isophote Distance for stroke thickness
- Qualitative properties of artist-drawn thickness

Future work

- Boundaries and creases
- "Saturation"
- Real-time rendering
- New styles using isophote distance

www.dgp.toronto.edu/~todd/isophote