Isophote Distance: A Shading Approach to Artistic Stroke Thickness

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Generally speaking, brush work tends to nudge one's artwork in a more flowing, rhythmic and sometimes "slick" direction.

Nib pen work can be quite smooth, but more often tends toward a dry, slightly edgy, brittle look.

[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 \((n \cdot v)\)

Contours and Suggestive Contours
[DeCarlo et al. 2003]

Thresholded \((n \cdot v < r_0)\)

Our approach
Our method

Stroke thickness is Isophote Distance: $|| p - q ||$, clamped to range $[T_{\text{min}}, T_{\text{max}}]$.
Rim lights and shadows
Ink rendering style
Overdraw rendering style
Brush rendering style
Analytic approximation

\[ \| p - q \| \approx \frac{f}{\kappa(p) \| p - c \|} \left( \frac{r^2_0}{2(1 - r^2_0)} \right) \]

(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

"We're pretty far from home, mom's gonna be mad!"

"You're not scared, are you? Jeez! We've already come this far!"

"We're pretty far from home, mom's gonna be mad!"

"You're not scared, are you? Jeez! We've already come this far!"

"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 $\propto (\text{depth})^{-1}$

[Gooch et al. 99]
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[Gooch et al. 99]

Jack Hamm, 1967
1. Thickness $\propto (\text{depth})^{-1}$
2. Thickness $\propto (\text{radial curvature})^{-1}$
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a. Large cylindrical objects have thicker strokes (legs > arms > fingers)
2. Thickness \( \propto (\text{radial curvature})^{-1} \)

a. Large cylindrical objects have thicker strokes
2. Thickness $\propto (\text{radial curvature})^{-1}$

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

Eisner 1991

A Scanner Darkly 2006
2. Thickness $\propto (\text{radial curvature})^{-1}$

c. Foreshortened objects should be thicker...
2. Thickness $\propto (\text{radial curvature})^{-1}$

d. Thinning above the cheekbone
2. Thickness $\propto (\text{radial curvature})^{-1}$

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
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