Exaggerated Shading for Depicting Shape and Detail

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Motivation

Style of technical, medical, and topographic illustrations is designed to communicate surface shape and detail.
Elements of Hand-Shaded Relief

- No shadows, no specular reflections
- Lighting from top (often top-left)
- Exaggeration of height
- Local adjustment of light
- Multiple scales
Goals

- Depicts detail at all surface orientations
Goals

- Depicts detail at all surface orientations
- Locally resembles directional lighting
  - Interpreted as “shading,” not “texture”
  - Exploits lack of global consistency in visual system

Mean curvature  Standard cosine shading  Exaggerated shading
Exaggerated Shading

1. Increased local contrast
2. Adjustment of light direction
3. Multiscale computation
1. Increased Local Contrast

- **Lambertian:**
  \[
  \text{clamp } n \cdot l \\
  [0..1]
  \]

- **(Unclamped) cosine shading:**
  \[
  \frac{1}{2} + \frac{1}{2} n \cdot l
  \]

- **Soft toon:**
  \[
  \frac{1}{2} + \frac{1}{2} \text{clamp } a (n \cdot l) \\
  [-1..1]
  \]
  
  \[a = 2\]  \[a = 4\]  \[a = 8\]
Effects of Increased Local Contrast

- Brings out fine details
- Equalizes emphasis on different orientations
Effects of Increased Local Contrast

- Brings out fine details
- Equalizes emphasis on different orientations

\[ a = 1 \quad a = 2 \quad a = 4 \quad a = 8 \]
2. Adjusting Light Direction

- Observation: most detail under grazing light
- Therefore, vary light direction locally:
  - Per vertex, compute normal and smoothed normal
  - Position light perpendicular to smoothed normal
2. Adjusting Light Direction

Original normals

Smoothed normals

Shading = \( f(\theta) \)

Light projected perpendicular
3. Multiscale Computation

- Scale of smoothing depends on scale of details
- Perform computation at several scales:
  - Collection of normals $n_i$ smoothed by increasing $\sigma_i$
  - Several shading passes, with pass $i$ using $n_i$ and $n_{i+1}$
  - “Base coat” using most-smoothed normals
3. Multiscale Computation

Base coat

\[ i = 3 \]

\[ i = 6 \]

\[ i = 5 \]

\[ i = 4 \]

\[ i = 3 \]

\[ i = 2 \]

\[ i = 1 \]

\[ i = 0 \]
Stylization Option:
Varying Contribution of Each Scale

\[ k_i \propto \sigma_i \]

\[ k_i = \text{const.} \]

\[ k_i \propto \sigma_i^{-1} \]

\[ k_i \propto \sigma_i^{-2} \]
Stylization Option: Point of Interest

- User-selected point
- Downweight high frequencies away from that point
- Draws attention to part of the model

[Cole et al. 06]
Stylization Option: Colormap
Algorithmic Option

- Light direction adjustment:
  - Instead of projecting light, find direction (perpendicular to smoothed normal) that maximizes local contrast
  - *Principal direction* corresponding to greatest magnitude of normal curvature
Principal Direction Adjustment

Projected light
Principal Direction Adjustment

Using principal direction
Principal Direction Adjustment

Projected light
Principal Direction Adjustment

Using principal direction
Principal Direction Adjustment

Projected light
Principal Direction Adjustment

Using principal direction
Applications

• Revealing surface texture
Applications

- Visualizing quality of geometric processing

Approximating (Loop) subdivision  Interpolating (butterfly) subdivision
Applications

- Volume rendering:
  - Standard nonrefractive transparency
  - Exaggerated shading using multi-scale gradients

Cosine shading

Our method
Comparison

Cosine shading

Accessibility
[Miller 1994]

Our method
Future Work

- What shape is perceived?
  - Is perception consistent with actual shape?
  - How much exaggeration is tolerated?
Future Work

• What shape is perceived?
  – Is perception consistent with actual shape?
  – How much exaggeration is tolerated?

• Consistent with artistic technique?

Roy Lichtenstein  Exaggerated shading  Suggestive contours
Future Work

• Other data types: images, images+normals, etc.
Summary

Interactive technique for conveying shape and detail

– Increased local contrast
– Adjustment of light direction
– Multiscale computation
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Source Code

http://xshade.cs.princeton.edu/