Conveying Shape: Shading, Lighting and Texture

Maneesh Agrawala

CS 294-10: Visualization
Spring 2010

Final project

Design new visualization method
- Pose problem, Implement creative solution

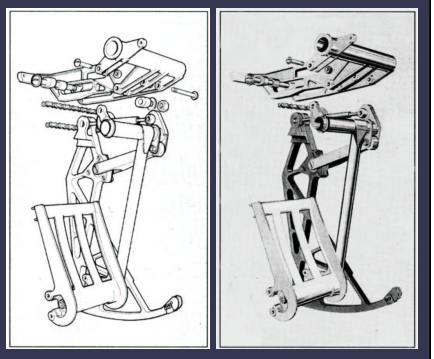
Deliverables
- Implementation of solution
- 8-12 page paper in format of conference paper submission
- 2 design discussion presentations

Schedule
- Project proposal: 3/29
- Initial problem presentation: 3/31 (Wed)
- Final presentation: In class 4/26 and 4/28
- Final paper: Friday 5/7

Grading
- Groups of up to 3 people, graded individually
- Clearly report responsibilities of each member

Conveying shape

Lines
Shading



From Gooch[2]

Topics

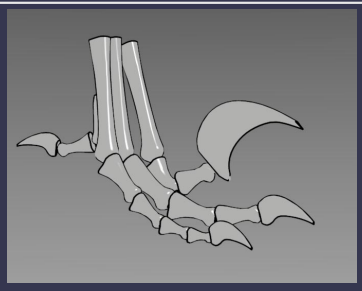
Shading
Shape from shading
Lighting
Texture

Shading

Diffuse shading [Gooch et al. 99]

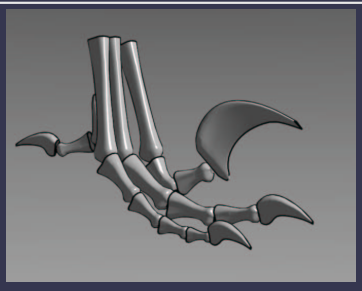
Dark regions hide details
Gray silhouettes merge with background
Surface orientation not emphasized

Edges + highlights



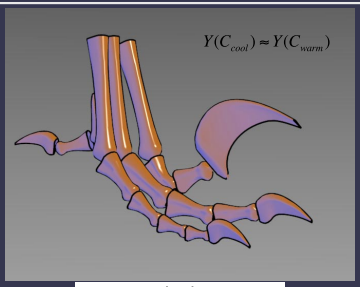
Edge lines divide object into parts
Highlights convey light direction and curvature
Can't see some regions of high curvature

Edges + highlights + diffuse + ambient



Some details lost in dark gray regions, but can see curvature better in claws

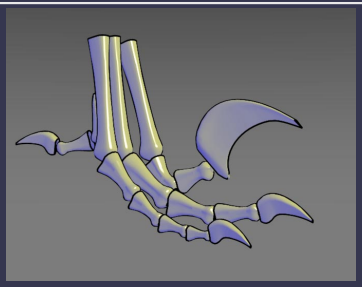
Constant luminance tone rendering



$$L = \text{lerp}(\frac{1 + \hat{\mathbf{N}} \bullet \hat{\mathbf{L}}}{2}, C_{cool}, C_{warm})$$

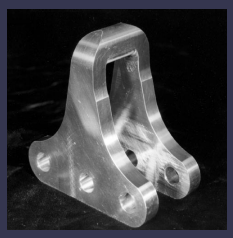
Cool colors (blue green) recede, warm colors (red, orange) approach
Hue shift conveys subtle sense of depth

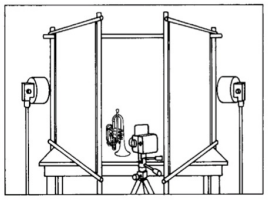
Luminance and hue/tone



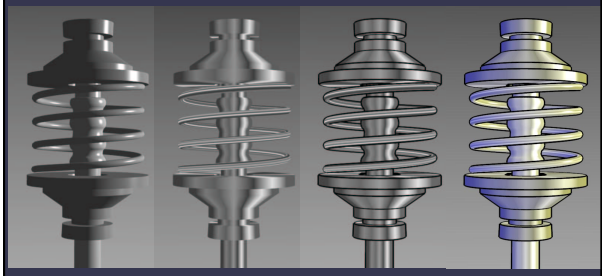
Shifting luminance and hue/tone gives stronger sense of depth

Anisotropic metallic objects





Metallic shading



Phong | Metal | Metal+Edges | Metal+Tone

Reflection lines

From Farin and Harnsford

Photo-retouching

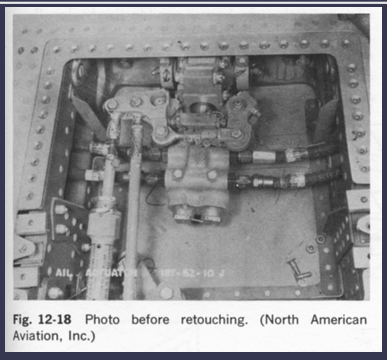


Fig. 12-18 Photo before retouching. (North American Aviation, Inc.)

T. A. Thomas, Technical illustration

Photo-retouching

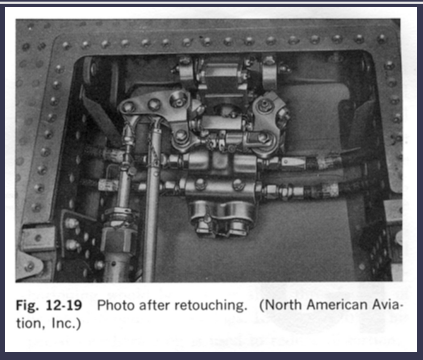
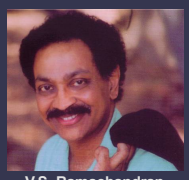


Fig. 12-19 Photo after retouching. (North American Aviation, Inc.)

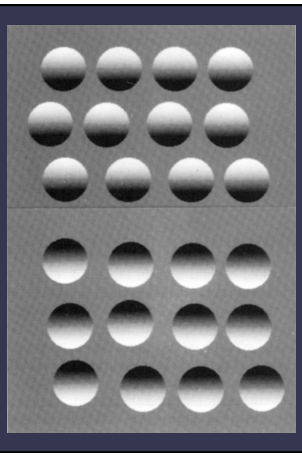
T. A. Thomas, Technical illustration

Shape from Shading

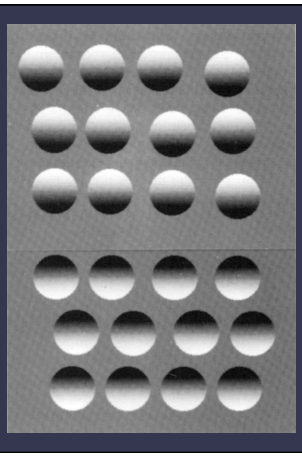


V.S. Ramachandran

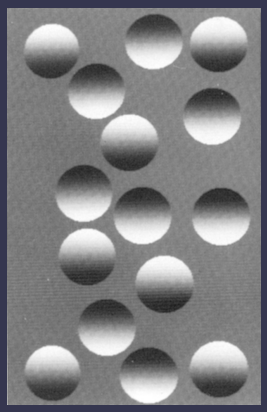
Spheres or cavities?



Brain assumes light comes from above



Separating convex/concave is very fast – preattentive?



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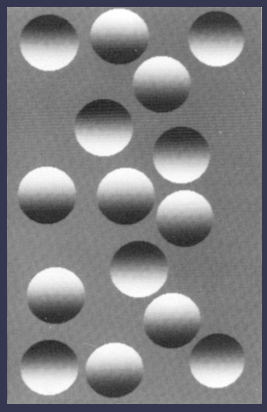
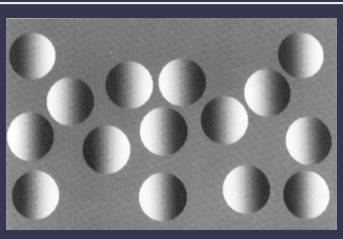


Effect diminishes at 90° rotation

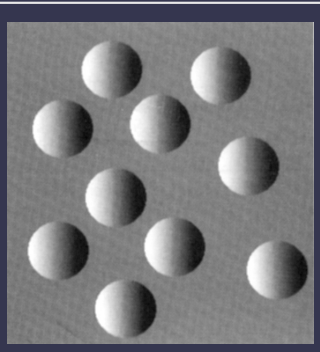


More difficult to separate convex/concave

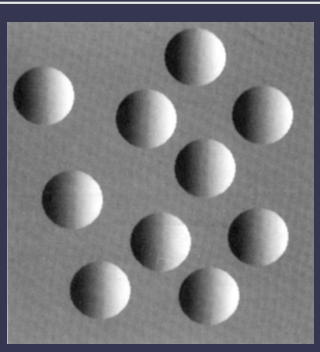
Rotation of head l/r set preference for light direction l/r

- Preference based on retinal orientation, not vestibular orientation
- Shape from shading is relatively early in visual system

Spheres or cavities

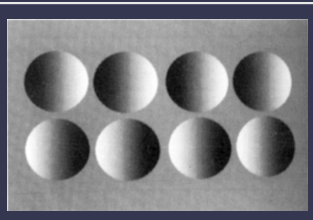


Spheres or cavities



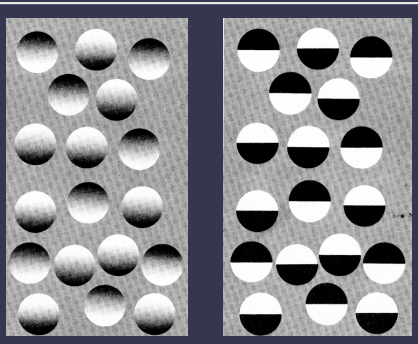
Common fate: All are convex or all are concave

Single light source constraint

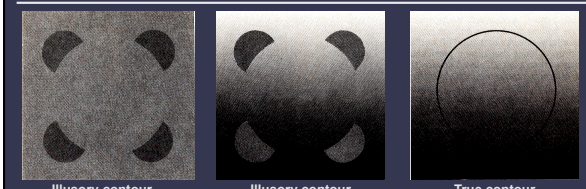


Difficult to see all objects as convex or as concave
When one row is convex the other row is always concave
Brain only accepts 1 light source for entire image

Effect diminishes without gradients

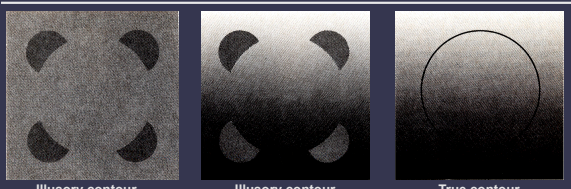


Illusory contours and gradients



Illusory contour | Illusory contour with background gradient | True contour with background gradient

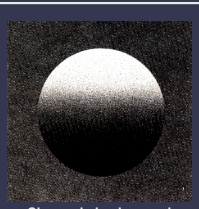
Illusory contours and gradients



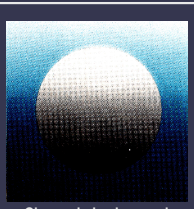
Illusory contour | Illusory contour with background gradient | True contour with background gradient

Edges interact with interpretation of shape from shading
Partial occlusion stronger evidence for existence of object than mere outline

Background brightness & color

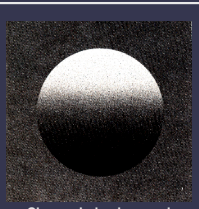


Change in background brightness

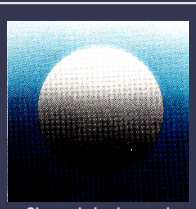


Change in background hue, brightness constant

Background brightness & color



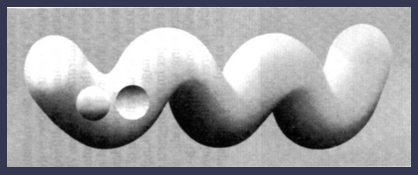
Change in background brightness



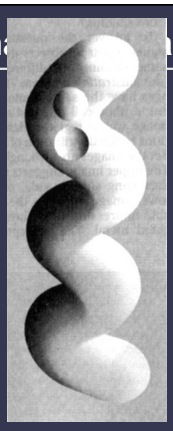
Change in background hue, brightness constant

Effect strong when edge defined by change in brightness
Diminishes when change is due to hue, not brightness

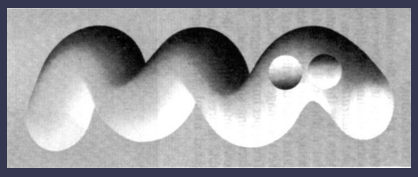
Complex shape seen as convex



Complex sh s convex

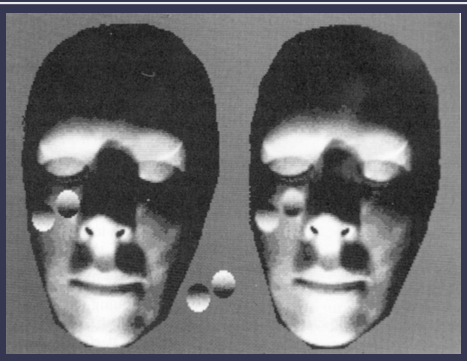


Complex shape seen as convex



Boundary occlusions reinforce convex interpretation
Disks interpreted with respect to lighting of tube

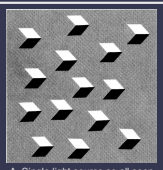
Hollow masks lit from above



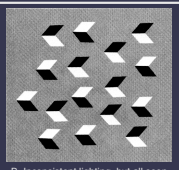
Mask lit from right side

http://www.kyb.tuebingen.mpg.de/bu/demo/mask/index.html

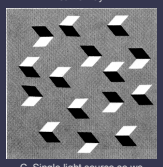
Single light source and pointing



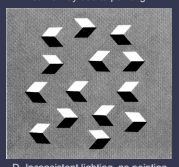
A. Single light source so all seen same way



B. Inconsistent lighting, but all seen same way due to pointing

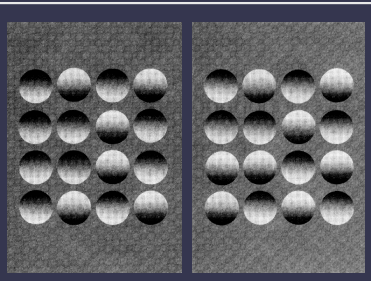


C. Single light source so we can see mixture

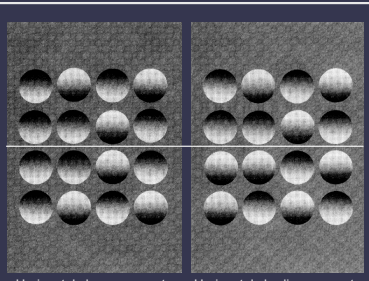


D. Inconsistent lighting, no pointing so difficult to interpret 3D shape – seen as 2D

Symmetry



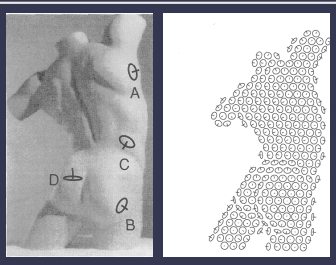
Symmetry



Horizontal shape symmetry Horizontal shading symmetry

Shape from shading extracted before symmetry

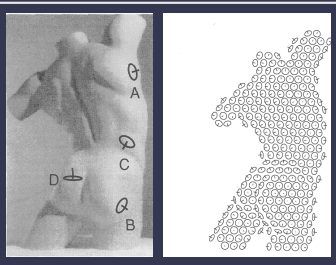
Estimating orientation



From Koenderink, van Doorn, Kappers [1992, 1996]

Subject place gauge figures on photo so that ellipse appears to lie flat
Results from one subject averaged over several sessions
Integrate normals to get surfaces (i.e. depth estimates)

Results of estimating orientation



From Koenderink, van Doorn, Kappers [1992, 1996]

Little variability between subjects estimates of surface orientation
Variability independent of subjects familiarity with object
Subjects use global information over significant portion of object surface

Lighting

Categories of light

Single source light
Double source light
Flat, diffused light
Moonlight
Sculptural light
…

B. Hogarth. Dynamic Light and Shade

Goals of lighting

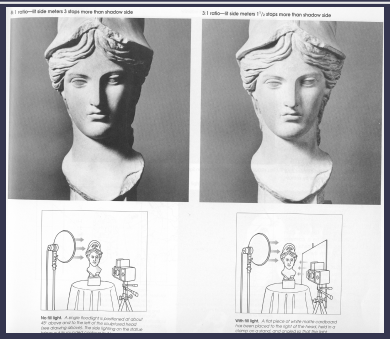
Power of lighting

- Show form and orientation of surface
- Emphasize high curvature with highlights
- Show silhouette clearly
- Separate object from background
- Rake bumps and surface textural details

Unintended side effects

- Over- and under-exposure
- Unintended shadows
- Distracting highlights and glare

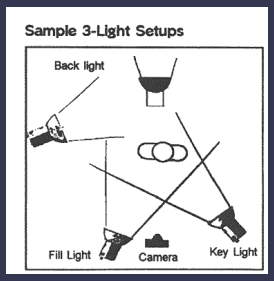
Lighting design



From *Photography*, 5th Ed., by London & Upton. Harper Collins. 1992.

Lighting design

Multiblitz lighting system, RTS Inc.

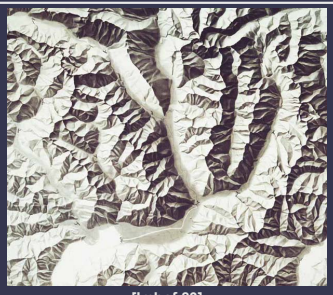


Basic Portrait Lighting Set-Up Guide, Warehouse Photography

Highlights and Shadows

Remove distracting highlights and shadows

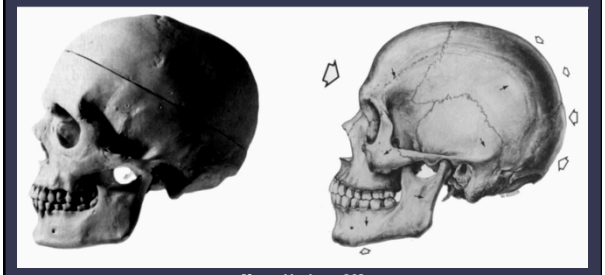
Creases, Ridges and Valleys



[Imhof 83]

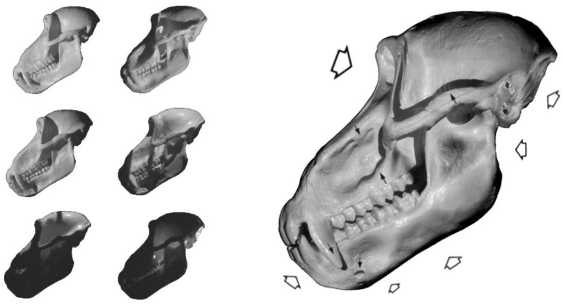
Sharp dark/light transitions to emphasize boundaries [www.shadedrelief.com]

Silhouettes

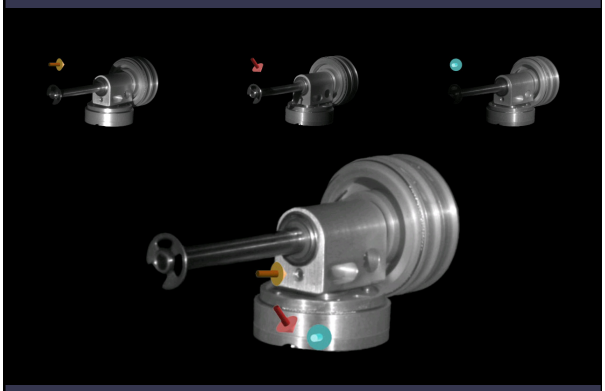


[from Hodges 89]

Constrains shape of surface → important shape cue
Increase contrast at silhouettes to emphasize shape



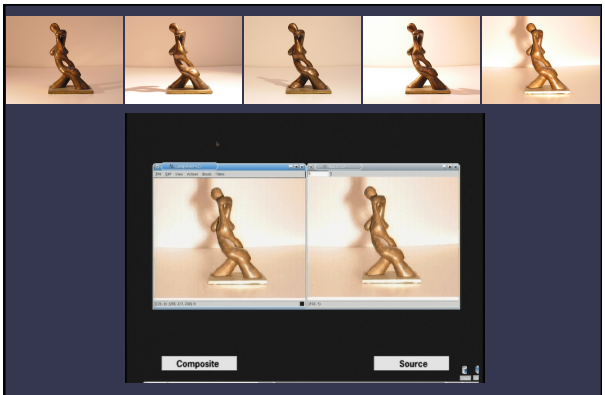
Conveying Shape and Features with Image-Based Relighting [Akers 03]



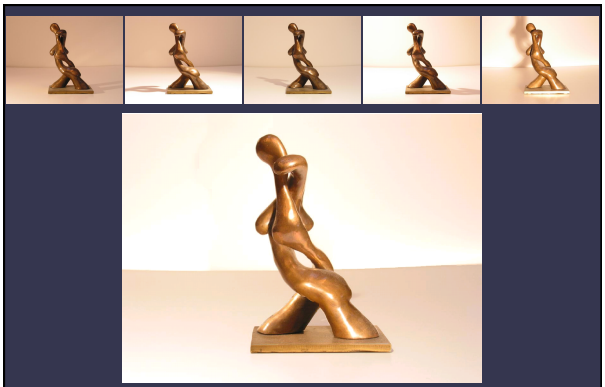
Conveying Shape and Features with Image-Based Relighting [Akers 03]

Conveying Shape and Features with Image-Based Relighting

Online Submission Id: 0338



Interactive Digital Photomontage [Agarwala 04]



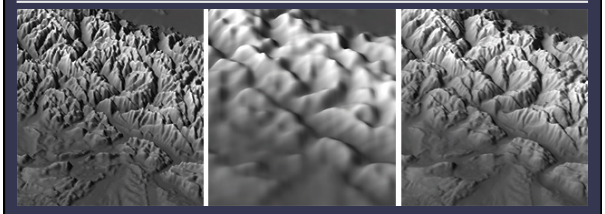
Photomontage composite

Input images from Debevec

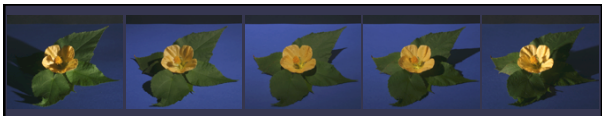
Glamorous **Frightening**

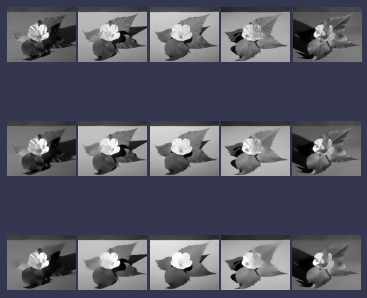
Interactive Digital Photomontage [Agarwala 04]

Multiple Scales

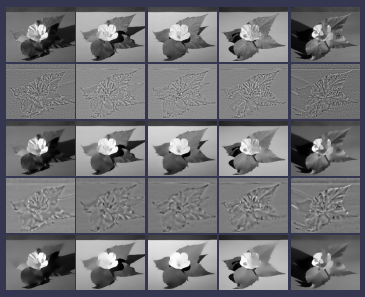


Blend between depictions at multiple scales [www.shadedrelief.com]

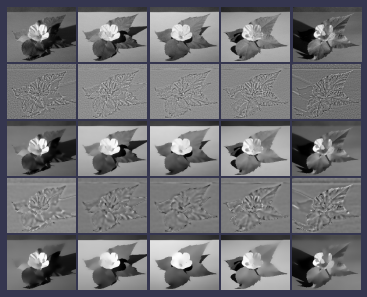


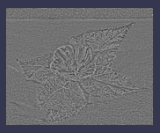


Multiscale bilateral decomposition

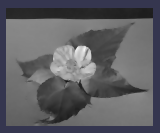


Differences between successive levels

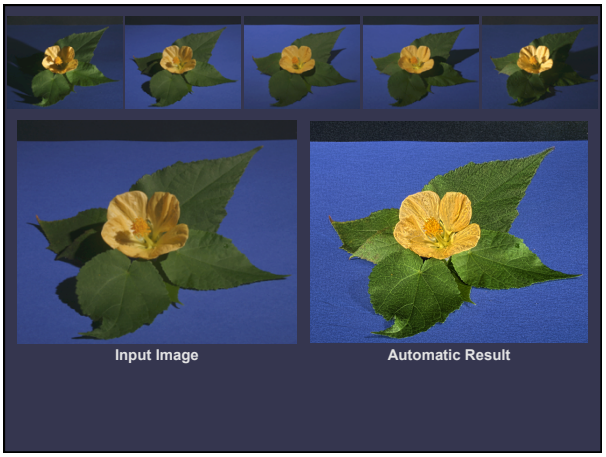


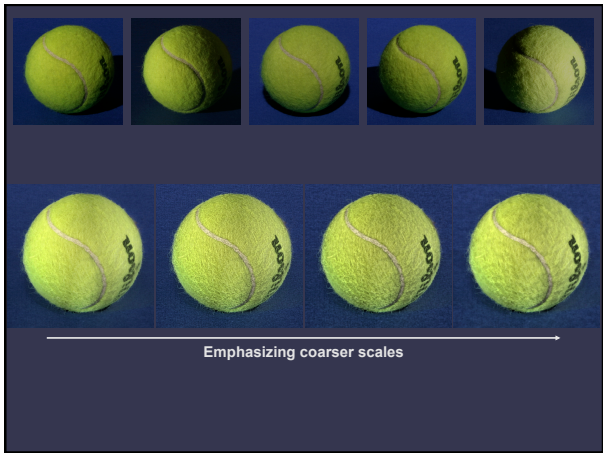


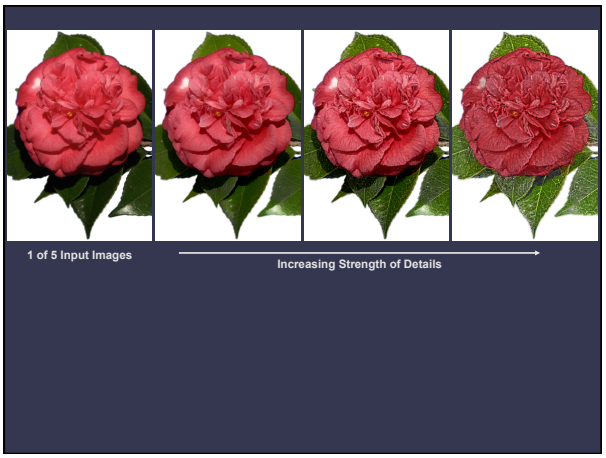
+

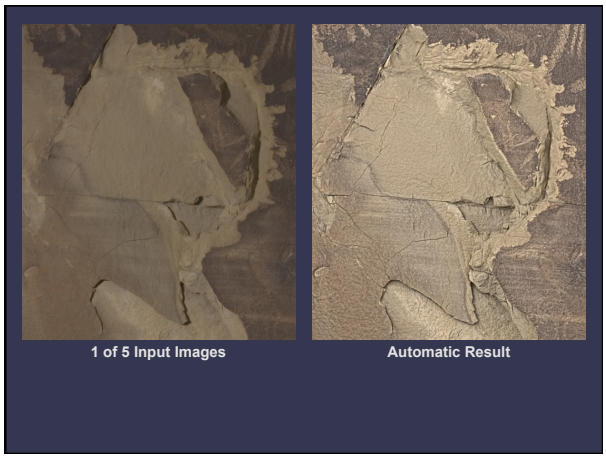


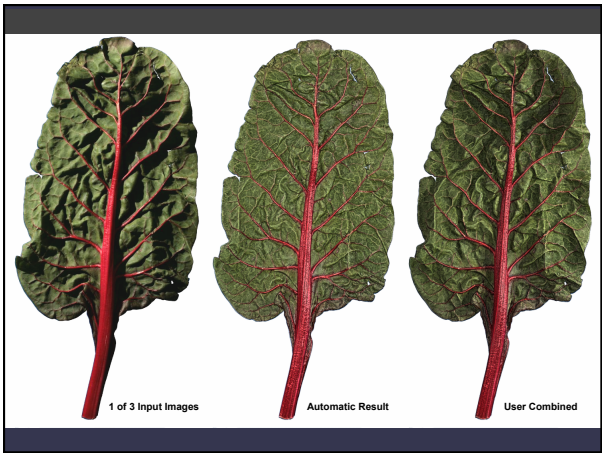
Detail reconstruction + base image


Input Image
Automatic Result

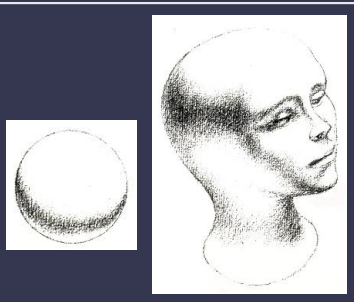

Emphasizing coarser scales


1 of 5 Input Images
Increasing Strength of Details


1 of 5 Input Images
Automatic Result

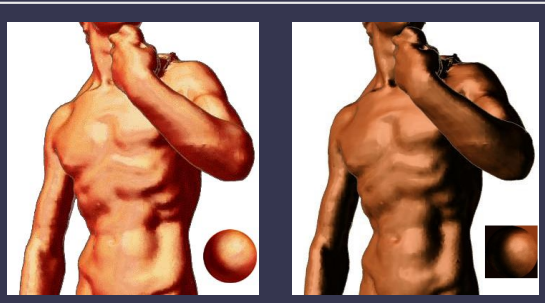


The lit sphere [Sloan et al. 01]



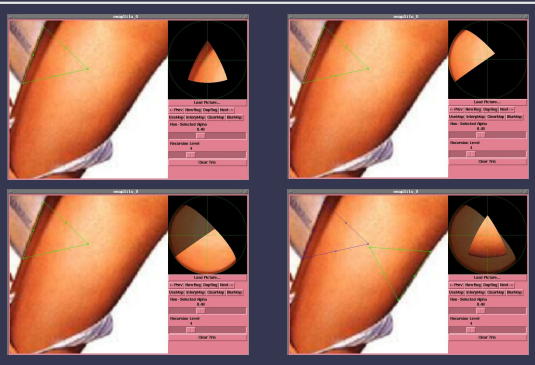
Artists often creating shading studies a sphere
Shows shading for all visible surface orientations
Then adapt shading to complex surface

Applying idea to 3D models



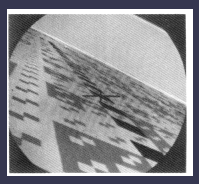
After drawing sphere by hand, can look up surface color based on normal to render 3D model

Extracting sphere from 2D image



Texture

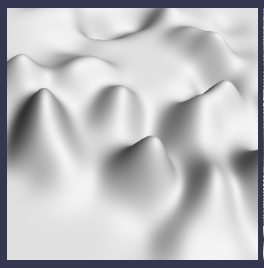
Visual cues



SGI flight 1987

GE Apollo Simulator 1963

Texturing

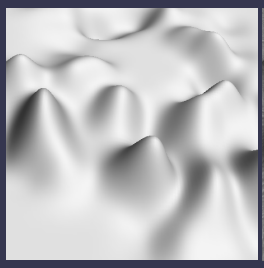


Diffuse shading only

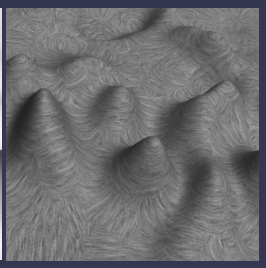
Lines in one direction of principal curvature

From V. Interrante
http://www-users.cs.umn.edu/~interran/texture/index.html

Texturing



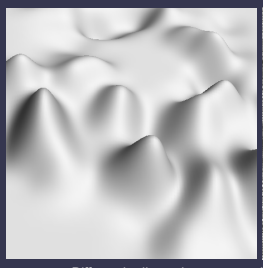
Diffuse shading only



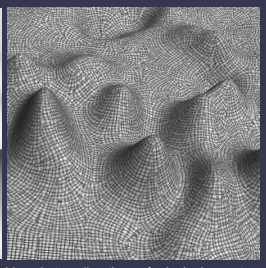
Lines in one direction of principal curvature generated using line integral convolution (LIC)

From V. Interrante
http://www-users.cs.umn.edu/~interran/texture/index.html

Texturing



Diffuse shading only



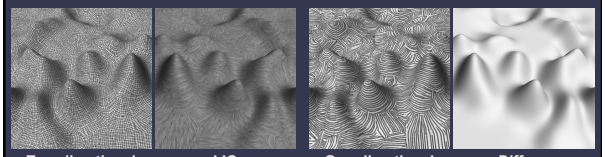
Lines in two directions of principal curvature

From V. Interrante
http://www-users.cs.umn.edu/~interran/texture/index.html

Texturing results

Gauge figure studies

Significant main effect of texture type (p=0.0002843)



Two-directional
BEST

LIC

One-directional

Diffuse
WORST

From V. Interrante
http://www-users.cs.umn.edu/~interran/texture/index.html

Summary

Goals of lighting and shading

- Reveal shape
- Separate foreground from background
- Show surface detail

Lighting design is extremely challenging

Surface-oriented texture is powerful cue