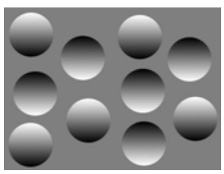
3-D Shape from Shading

Algorithm and perception



CS332 Visual Processing
Department of Computer Science
Wellesley College

Simplified Ikeuchi & Horn algorithm

Construct initial solution with $f = g = 0$ everywhere, except at points of known surface orientation (e.g. occluding boundary)

Let $f_i(x,y)$ & $g_i(x,y)$ denote surface orientations at iteration i

To determine $f_{i+1}(x,y)$ & $g_{i+1}(x,y)$:

For each location (x,y)

(1) Compute the average value of $f_i(x,y)$ in a neighborhood around (x,y): f^*

(2) Compute the average value of $g_i(x,y)$ in a neighborhood around (x,y): g^*

(3) Find the contour of possible f and g values in $R(f,g)$ that are consistent with $I(x,y)$

(4) Find the point on this contour that is closest to the surface orientation given by (f^*,g^*) – the coordinates of this point represent the new surface orientation for location (x,y): $f_{i+1}(x,y)$ & $g_{i+1}(x,y)$

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image of shaded sphere

0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0
0	0	0	0	0.2	0.4	0.4	0.3	0.2	0.1	0	0
0	0	0	0.2	0.3	0.5	0.7	0.6	0.3	0.2	0.1	0
0	0	0	0.2	0.3	0.6	0.8	0.9	0.6	0.2	0.2	0
0	0	0	0.3	0.4	0.7	0.9	1.0	0.8	0.5	0.3	0
0	0	0	0.3	0.4	0.7	0.9	1.0	0.8	0.5	0.3	0
0	0	0	0.2	0.3	0.6	0.8	0.9	0.6	0.2	0.2	0
0	0	0	0.2	0.3	0.5	0.7	0.6	0.3	0.2	0.1	0
0	0	0	0	0.2	0.4	0.4	0.3	0.2	0.1	0	0
0	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0

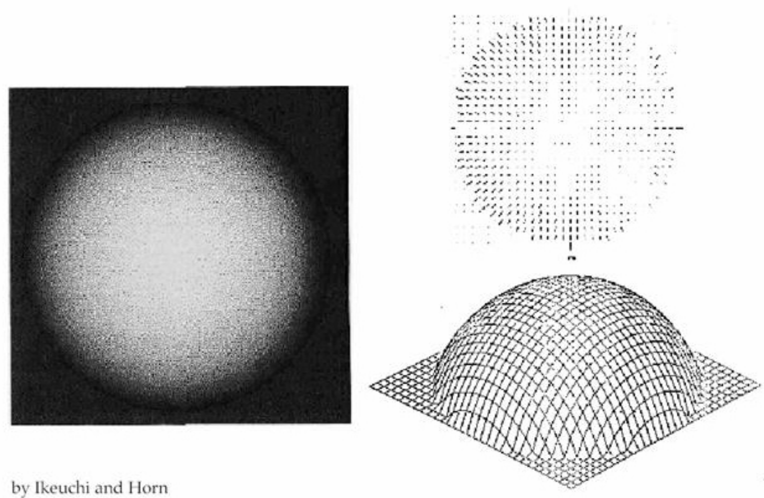
surface orientation

(f,g)

initial state

(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,2)	(0,2)	(*,*)	(0,0)	(0,0)	(0,0)	(0,0)
(0,0)	(0,0)	(0,0)	(0,0)	(*,*)	(0,0)	(0,0)	(0,0)	(*,*)	(0,0)	(0,0)	(0,0)
(0,0)	(0,0)	(0,0)	(*,*)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(*,*)	(0,0)	(0,0)
(0,0)	(0,0)	(0,0)	(*,*)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(*,*)	(0,0)
(0,0)	(0,0)	(*,*)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(*,*)
(0,0)	(0,0)	(*,*)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(2,0)
(0,0)	(0,0)	(*,*)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(2,0)
(0,0)	(0,0)	(*,*)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(*,*)
(0,0)	(0,0)	(0,0)	(*,*)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(*,*)	(0,0)
(0,0)	(0,0)	(0,0)	(*,*)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(*,*)	(0,0)	(0,0)
(0,0)	(0,0)	(0,0)	(0,0)	(*,*)	(0,0)	(0,0)	(0,0)	(*,*)	(0,0)	(0,0)	(0,0)
(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,-2)	(0,-2)	(*,*)	(0,0)	(0,0)	(0,0)	(0,0)

Ikeuchi & Horn - sample results

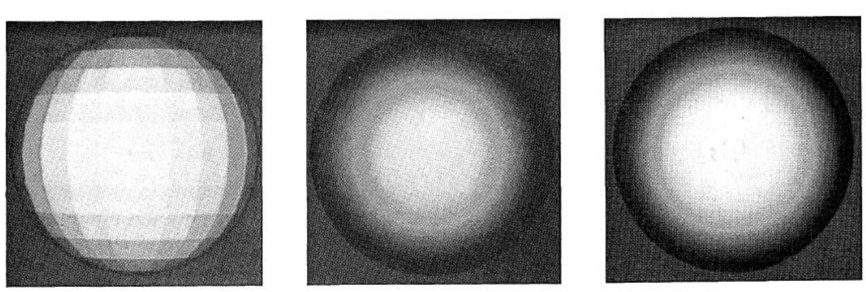


by Ikeuchi and Horn

1-5

Perception of shape from shading

H. H. Bülthoff and H. A. Mallot   Vol. 5, No. 10/October 1988/J Opt. Soc. Am. A   1751



(a) (b) (c)

Fig. 2. Flat- and smooth-shaded surfaces. (a), (b) Discontinuous and smooth intensity variations in images of polyhedra and ellipsoids provide cues for edge-based stereo, shape-from-disparate-shading, and shape-from-shading (experiment 1). (c) A smooth ellipsoid with sparse edge information has been used in experiments on the interaction of edge-based stereo and shape-from-shading (experiment 3). All images could be displayed as stereograms or as pairs of identical images. In image (c) the disparities of shading and edge token (ring) could be varied independently.

Bulthoff & Mallot examined interaction of stereo and shading
-- stereo probe used to specify perceived surface

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Bulthoff & Mallot - empirical results

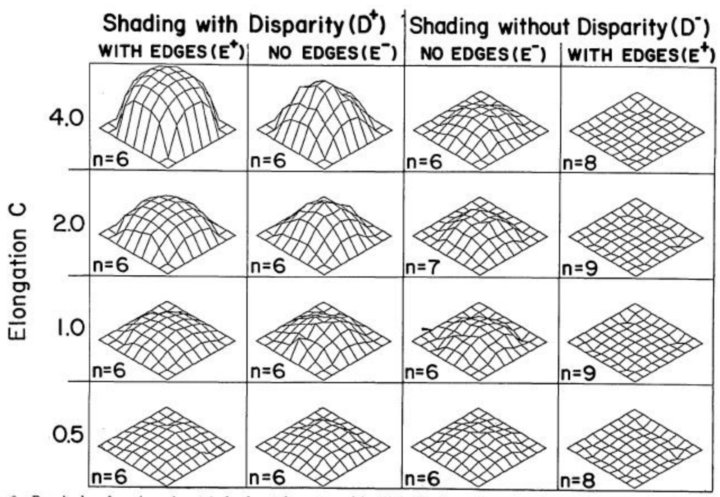
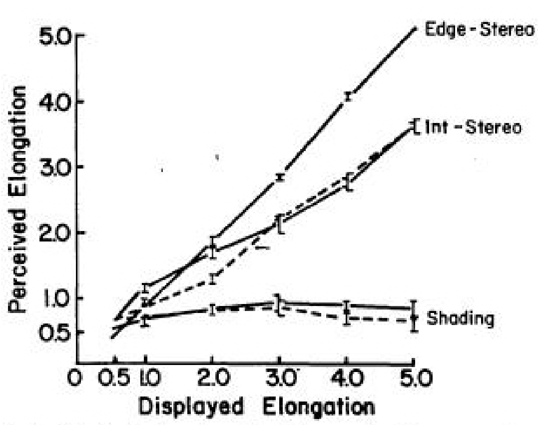


Fig. 3. Perceived surfaces (experiment 1; depth not drawn to scale). Each plot shows the average of 6–9 sessions from three subjects. Perceived depth decreases with the following sequence of cue combinations: disparity, edges, and shading (D^+E^+); disparity and shading but no edges (D^+E^-); shading only (D^-E^-); contradictory disparity and shading (D^-E^+).

Bulthoff & Mallot - empirical results



Conclusions:

Edge-based stereo yields most accurate 3-D shape

Intensity-based stereo yields good sense of 3-D shape

Shape from shading alone yields least accurate shape

Koenderink & colleagues

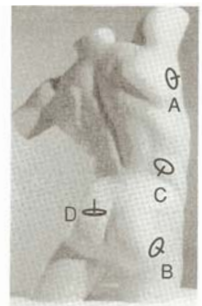


Figure 5.5.26 Studying the perception of surface orientation from shading. Subjects saw this picture of a male torso and adjusted the shape and orientation of oval test figures so that they looked like circles lying flat on the surface (A and B) rather than askew (C and D). (Courtesy of J. J. Koenderink.)

Figure 5.5.27 Local surface orientations reported by one subject. The average ovals produced by one subject for every point tested on the surface of the male torso shown in Figure 5.5.26. (From Koenderink, van Doorn, & Kappers, 1996.)

Subjects' qualitative impressions of shape were consistent, but subjects differed quantitatively in amount of depth perceived

Analysis is not strictly local – global factors play a role

1-9

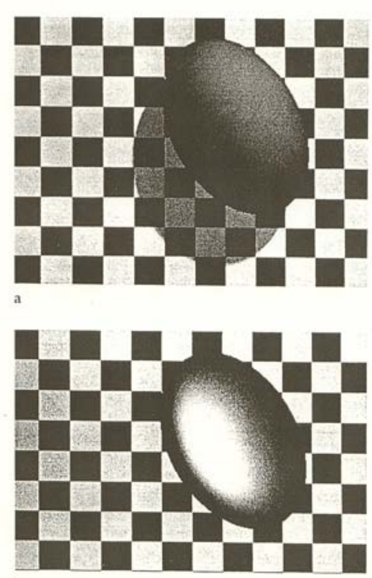
Mingolla & Todd

What assumptions do we make regarding surface reflectance characteristics?

performance was the same for shiny and dull surfaces

Is an estimate of light source direction needed for recovery of 3-D shape?

errors in 3-D shape not correlated with errors in light source direction



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