Local 3D shape and reflectance statistics of natural surfaces

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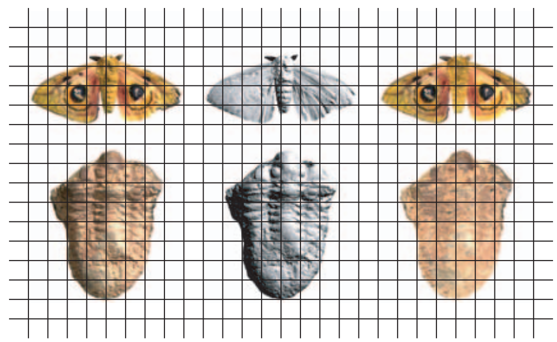
Shape from shading is an underconstrained problem: any 2D image could have been generated by any of a wide range of 3D scenes.

Strazza, *The veiled virgin.*

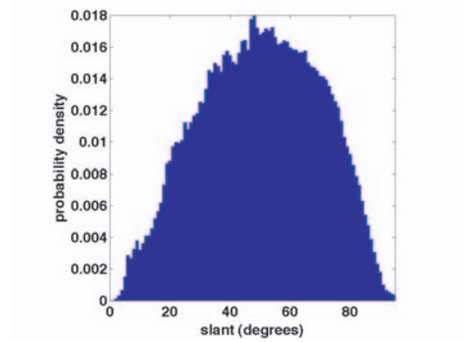
∴ Any natural or artificial visual system must make assumptions about what object shapes and surface reflectance patterns are likely or unlikely, in order to recover shape from shading.

What statistical regularities are available in real objects, that observers can rely on in order to perceive 3D shape?

We examined the statistics of 3D digital scans of real objects, viewed through a 128 x 128 pixel virtual camera.

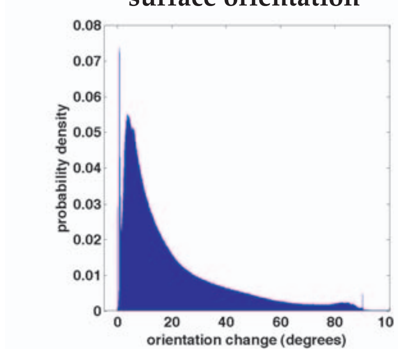


Surface orientation



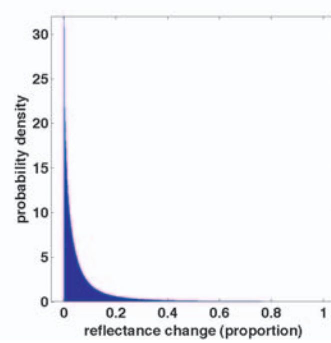
This distribution is expected simply from the geometry of projection.

Pixel-to-pixel changes in surface orientation



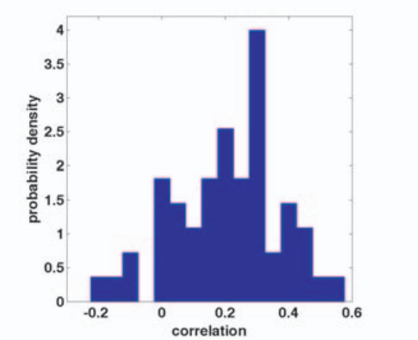
The distribution peaks at 0º, slightly above 0º, and near 90º.

Pixel-to-pixel changes in surface reflectance



The modal change is zero, with a very sharp falloff.

Correlation between changes in orientation and reflectance



For most objects, there is a small but nonzero correlation.

LOCAL 3D SHAPE AND REFLECTANCE STATISTICS OF NATURAL SURFACES

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Shape from shading is an under-constrained problem, so in order to perceive 3D object shape from image shading, observers must make assumptions about what surface shape and reflectance patterns are likely or unlikely. We examined some statistical properties of natural surfaces.

Method We measured selected statistical properties of 3D digital scans of fifty-five randomly selected objects. The data was provided by Arius3D, Inc. The scans included naturally occurring objects and man-made objects. We viewed each virtual object through a 256 x 256 pixel virtual camera. The objects were rotated to a random orientation, and scaled so that they spanned the image matrix. Because these were virtual objects, it was possible to determine the orientation and reflectance of the 3D surface patch that corresponded to each pixel, and thus to examine how 3D surface properties changed from pixel to pixel of the 2D image.

Results (a) Changes in surface orientation from pixel to pixel followed a well-defined distribution, with peaks at 0º and 5º, and a smaller peak at 90º. (b) Changes in surface reflectance from pixel to pixel also followed a well-defined distribution, with a sharp peak at zero change, and a rapid falloff at higher changes. (c) Changes in orientation were more likely than corresponding changes in reflectance, which may explain why we generally perceive flat images as renderings of 3D scenes. (d) Changes in orientation and reflectance were moderately correlated. It is unknown whether the human visual system exploits this fact when reconstructing 3D shapes from 2D images.