Shading

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For other uses, see Shade (disambiguation).

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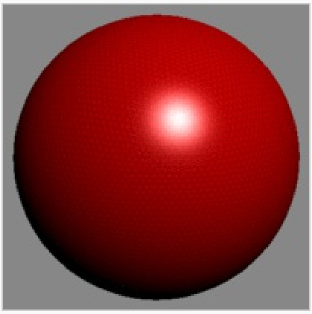
Shading refers to depicting depth perception in 3D models or illustrations by varying levels of darkness.



Gouraud shading, developed by Henri Gouraud in 1971, was one of the first shading techniques developed in computer graphics.

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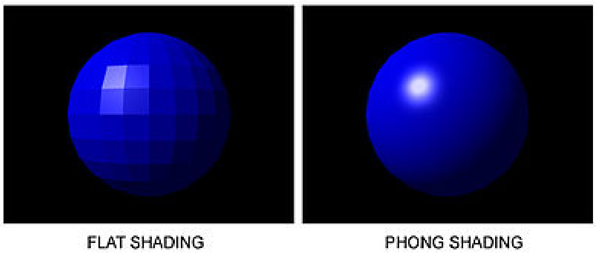
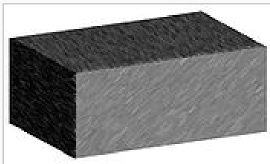


Example of flat shading vs. Phong shading interpolation. Phong shading is a more realistic shading technique, developed by Bui Tuong Phong in 1973.

Drawing [edit]



Example of shading.

Shading is used in drawing for depicting levels of darkness on paper by applying media more densely or with a darker shade for darker areas, and less densely or with a lighter shade for lighter areas. There are various techniques of shading including cross hatching where perpendicular lines of varying closeness are drawn in a grid pattern to shade an area. The closer the lines are together, the darker the area appears. Likewise, the farther apart the lines are, the lighter the area appears.

Light patterns, such as objects having light and shaded areas, help when creating the illusion of depth on paper.[1][2]

Powder shading is a sketching shading method. In this style, the stumping powder and paper stumps are used to draw a picture. This can be in color. The stumping powder is smooth and doesn't have any shiny particles. The poster created with powder shading looks more beautiful than the original. The paper to be used should have small grains on it so that the powder remains on the paper.

Computer graphics [edit]

In computer graphics, shading refers to the process of altering the color of an object/surface/polygon in the 3D scene, based on its angle to lights and its distance from lights to create a photorealistic effect. Shading is performed during the rendering process by a program called a shader.

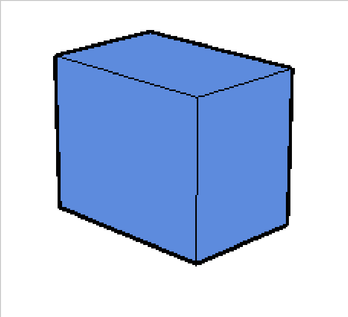
Angle to light source [edit]

Shading alters the colors of faces in a 3D model based on the angle of the surface to a light source or light sources.

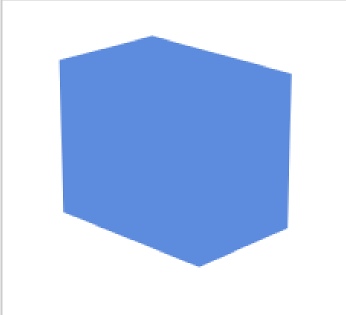
The first image below has the faces of the box rendered, but all in the same color. Edge lines have been rendered here as well which makes the image easier to see.

The second image is the same model rendered without edge lines. It is difficult to tell where one face of the box ends and the next begins.

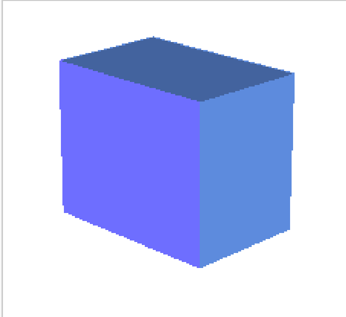
The third image has shading enabled, which makes the image more realistic and makes it easier to see which face is which.



Rendered image of a box. This image has no shading on its faces, but uses edge lines to separate the faces.



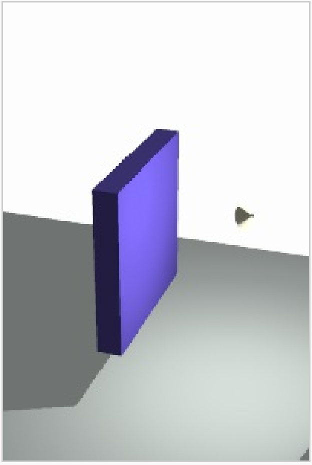
This is the same image with the edge lines removed.



This is the same image rendered with shading of the faces to alter the colors of the 3 faces based on their angle to the light sources.

Lighting [edit]

Shading is also dependent on the lighting used. Usually, upon rendering a scene a number of different lighting techniques will be used to make the rendering look more realistic. Different types of light sources are used to give different effects.



Shading effects from floodlight.

Ambient lighting [edit]

An ambient light source represents a fixed-intensity and fixed-color light source that affects all objects in the scene equally. Upon rendering, all objects in the scene are brightened with the specified intensity and color. This type of light source is mainly used to provide the scene with a basic view of the different objects in it. This is the simplest type of lighting to implement and models how light can be scattered or reflected many times producing a uniform effect.

Ambient lighting can be combined with ambient occlusion to represent how exposed each point of the scene is, affecting the amount of ambient light it can reflect. This produces diffuse, non-directional lighting throughout the scene, casting no clear shadows, but with enclosed and sheltered areas darkened. The result is usually visually similar to an overcast day.

Directional lighting [edit]

A directional light source illuminates all objects equally from a given direction, like an area light of infinite size and infinite distance from the scene; there is shading, but cannot be any distance falloff.

Point lighting [edit]

Light originates from a single point, and spreads outward in all directions.

Spotlight lighting [edit]

Models a Spotlight. Light originates from a single point, and spreads outward in a cone.

Area lighting [edit]

Light originates from a small area on a single plane. A more accurate model than a point light source.

Volumetric lighting [edit]

Light originating from a small volume, an enclosed space lighting objects within that space.

Shading is interpolated based on how the angle of these light sources reach the objects within a scene. Of course, these light sources can be and often are combined in a scene. The renderer then interpolates how these lights must be combined, and produces a 2d image to be displayed on the screen accordingly.

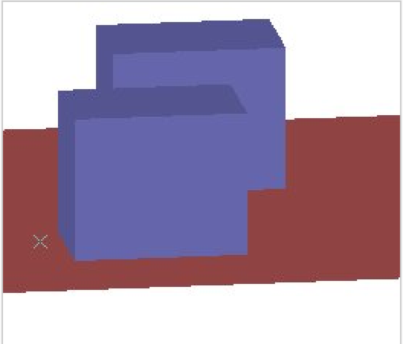
Distance falloff [edit]

Theoretically, two surfaces which are parallel, are illuminated the same amount from a distant light source, such as the sun. Even though one surface is further away, your eye sees more of it in the same space, so the illumination appears the same.

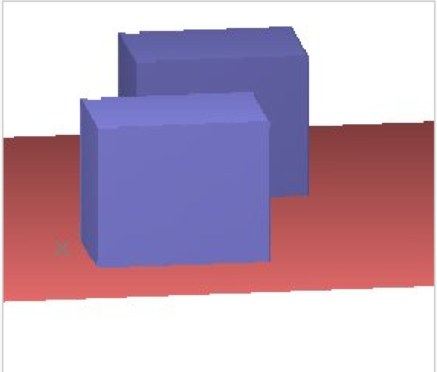
Notice in the first image that the color on the front faces of the two boxes is exactly the same. It appears that there is a slight difference where the two faces meet, but this is an optical illusion because of the vertical edge below where the two faces meet.

Notice in the second image that the surfaces on the boxes are bright on the front box and darker on the back box. Also the floor goes from light to dark as it gets farther away.

This distance falloff effect produces images which appear more realistic without having to add additional lights to achieve the same effect.



Two boxes rendered with an OpenGL renderer. Note that the colors of the two front faces are the same even though one box is farther away.



The same model rendered using ARRIS CAD which implements "Distance Falloff" to make surfaces that are closer to the eye appear brighter.

Distance falloff can be calculated in a number of ways:

- *None* - The light intensity received is the same regardless of the distance between the point and the light source.
- *Linear* - For a given point at a distance *x* from the light source, the light intensity received is proportional to $1/x$.
- *Quadratic* - This is how light intensity decreases in reality if the light has a free path (i.e. no fog or any other thing in the air that can absorb or scatter the light). For a given point at a distance *x* from the light source, the light intensity received is proportional to $1/x^2$.
- *Factor of n* - For a given point at a distance *x* from the light source, the light intensity received is proportional to $1/x^n$.
- Any number of other mathematical functions may also be used.

Flat shading [edit]

Flat shading is a lighting technique used in 3D computer graphics to shade each polygon of an object based on the angle between the polygon's surface normal and the direction of the light source, their respective colors and the intensity of the light source. It is usually used for high speed rendering where more advanced shading techniques are too computationally expensive. As a result of flat shading all of the polygon's vertices are colored with one color, allowing differentiation between adjacent polygons. Specular highlights are rendered poorly with flat shading: If there happens to be a large specular component at the representative vertex, that brightness is drawn uniformly over the entire face. If a specular highlight doesn’t fall on the representative point, it is missed entirely. Consequently, the specular reflection component is usually not included in flat shading computation.

Smooth shading [edit]

In contrast to flat shading with smooth shading the color changes from pixel to pixel. It assumes that the surfaces are curved and uses interpolation techniques to calculate the values of pixels between the vertices of the polygons.

Types of smooth shading include:

- Gouraud shading [3]
- Phong shading [4]

Gouraud shading [edit]

1. Determine the normal at each polygon vertex
2. Apply an illumination model to each vertex to calculate the vertex intensity
3. Interpolate the vertex intensities using bilinear interpolation over the surface polygon

Data structures [edit]

- Sometimes vertex normals can be computed directly (e.g. height field with uniform mesh)
- More generally, need data structure for mesh
- Key: which polygons meet at each vertex

Advantages [edit]

- Polygons, more complex than triangles, can also have different colors specified for each vertex. In these instances, the underlying logic for shading can become more intricate.

Problems [edit]

- Even the smoothness introduced by Gouraud shading may not prevent the appearance of the shading differences between adjacent polygons.
- Gouraud shading is more CPU intensive and can become a problem when rendering real time environments with many polygons.
- T-Junctions with adjoining polygons can sometimes result in visual anomalies. In general, T-Junctions should be avoided.

Phong shading [edit]

Phong shading is similar to Gouraud shading, except that the Normals are interpolated. Thus, the specular highlights are computed much more precisely than in the Gouraud shading model:

1. Compute a normal N for each vertex of the polygon.
2. From bilinear interpolation compute a normal, Ni for each pixel. (This must be renormalized each time)
3. From Ni compute an intensity Ii for each pixel of the polygon.
4. Paint pixel to shade corresponding to Ii.

Other Approaches [edit]

Both Gouraud shading and Phong shading can be implemented using bilinear interpolation. Bishop and Weimer [5] proposed to use a Taylor series expansion of the resulting expression from applying an illumination model and bilinear interpolation of the normals. Hence, second degree polynomial interpolation was used. This type of biquadratic interpolation was further elaborated by Barrera et al.,[6] where one second order polynomial was used to interpolate the diffuse light of the Phong reflection model and another second order polynomial was used for the specular light.

Spherical Linear Interpolation (Slerp) was used by Kuij and Blake [7] for computing both the normal over the polygon as well as the vector in the direction to the light source. A similar approach was proposed by Hast,[8] which uses Quaternion interpolation of the normals with the advantage that the normal will always have unit length and the computationally heavy normalization is avoided.

Flat vs. smooth shading [edit]

Flat	Smooth
Uses the same color for every pixel in a face - usually the color of the first vertex.	Smooth shading uses linear interpolation of colors between vertices
Edges appear more pronounced than they would on a real object because of a phenomenon in the eye known as lateral inhibition	The edges disappear with this technique
Same color for any point of the face	Each point of the face has its own color
Individual faces are visualized	Visualize underlying surface
Not suitable for smooth objects	Suitable for any objects
Less computationally expensive	More computationally expensive

See also [edit]

- 3D computer graphics
- Shader
- List of common shading algorithms
- Zebra striping (computer graphics)

Computer graphics portal

References [edit]

1. ^ "Drawing Techniques". Drawing With Confidence. Retrieved 19 September 2012.
2. ^ "Shading Tutorial, How to Shade in Drawing". Dueysdrawings.com. 2007-06-21. Retrieved 2012-02-11.
3. ^ Gouraud, Henri (1971). "Continuous shading of curved surfaces". *IEEE Transactions on Computers* **C–20** (6): 623–629. doi:10.1109/T-C.1971.223313.
4. ^ B. T. Phong, Illumination for computer generated pictures, *Communications of ACM* 18 (1975), no. 6, 311–317.

5. ^ Gary Bishop and David M. Weimer. 1986. Fast Phong shading. *SIGGRAPH Comput. Graph.* 20, 4 (August 1986), 103-106.
6. ^ T. Barrera, A. Hast, E. Bengtsson. Fast Near Phong-Quality Software Shading. *WSCG'06*, pp. 109-116. 2006
7. ^ Kuijk, A. A. M. and E. H. Blake, Faster Phong shading via angular interpolation. *Computer Graphics Forum* 8(4):315-324. 1989
8. ^ A. Hast. Shading by Quaternion Interpolation. *WSCG'05*. pp. 53-56. 2005.

Further reading [edit]

- Introduction to Shading.

v · t · e **Color topics (Index)** [hide]

Red · Orange · Yellow · Green · Cyan · Blue · Violet · Purple · Magenta · Pink · Brown · White · Gray · Black

Color science	**Color physics**	Electromagnetic spectrum (Light · Rainbow · Visible) · Spectral colors · Chromophore (Structural coloration · Animal coloration) · On Vision and Colors · Metamerism (Spectral power distribution)
	Color perception	Color vision (Color blindness · test) · Tetrachromacy (Color constancy · Color term) · Color depth (Color photography · Spot color · Color printing · Web colors · Color mapping · Color code · Color management · Chrominance · False color) · Chroma key · Color balance · Color cast · Color temperature
	Color psychology	Color symbolism · Color preferences · Lüscher color test · Kruithof curve · Political colour · National colours · Chromophobia · Chromotherapy
Color philosophy	**Color space**	Color model (additive · subtractive) · Color mixing (Primary color · Secondary color · Tertiary color (intermediate) · Quaternary color · Quinary color · Aggressive color (warm) · Receding color (cool)) · Pastel colors · Color gradient
	Color scheme	Color tool (Monochromatic colors · Complementary colors · Analogous colors · Achromatic colors (Neutral) · Polychromatic colors) · Impossible colors · Light-on-dark · Tinctures in heraldry
	Color theory	Chromaticity diagram · Color solid · Color wheel · Color triangle · Color analysis (art) · Color realism (art style)
Color terms	**Basic terms**	Red · Green · Yellow · Blue · Orange · Purple · Pink · Brown · Black · Gray · White
	Cultural differences	Linguistic relativity and the color naming debate (Distinction of blue and green in various languages) · Color history (Color in Chinese culture · Traditional colors of Japan · Human skin color)
	Color dimensions	Hue (Dichromatism) · Colorfulness (chroma and saturation) · Tints and shades · Lightness (tone and value) · Grayscale
Color organizations		Pantone · Color Marketing Group · The Color Association of the United States · International Colour Authority · International Commission on Illumination (CIE) · International Color Consortium · International Colour Association
Lists		List of colors: A–F · List of colors: G–M · List of colors: N–Z · List of colors (compact) · List of color palettes · List of color spaces · List of Crayola crayon colors (history · pencil colors · marker colors) · Color chart · List of fictional colors
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