Lighting and Shadows in Computer Graphics

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Previously...
What is lighting?

Point
Directional
Spotlight
Ambient

Diffuse
Ambient
Specular
What is lighting?

Point - lightbulb
Directional - sun
Spotlight - flashlight
Ambient - ?

Diffuse
Ambient
Specular
Flat Shading
Flat Shading

Polygons drawn the same colour.

Lighting equation used once per polygon.

One normal for the entire polygon.

Cost-effective.
Gouraud Shading
Gouraud Shading

Colours are interpolated across the polygon.
Lighting equation used at each vertex.
Normal different for each vertex.
Phong Shading
Phong shading

- Light intensity per pixel = \( \cos(\alpha) = l \cdot n \)
Phong shading

- Light intensity per pixel = \( \cos(\alpha) = I \cdot n \)
Phong Lighting Model

\[
L_{Acv} \cdot M_{Acv} + n^T \cdot I \cdot L_{Dcv} \cdot M_{Dcv} + (r^T \cdot v)^c \cdot L_{Scv} \cdot M_{Scv}
\]

\(cv = \) colour value

(red, green, blue)
Phong Lighting Model

\[ L_{Acv} \cdot M_{Acv} + n^T \cdot I \cdot L_{Dcv} \cdot M_{Dcv} + (r^T \cdot v)^c \cdot L_{Scv} \cdot M_{Scv} \]

\( cv = \) colour value (red, green, blue)

Source emitted light
Phong Lighting Model

\[
\mathbf{L}_{Acv} \cdot \mathbf{M}_{Acv} + n^T \cdot \mathbf{L}_{Dcv} \cdot \mathbf{M}_{Dcv} + (r^T \cdot \mathbf{v})^c \cdot \mathbf{L}_{Scv} \cdot \mathbf{M}_{Scv}
\]

Material reflected light

\( cv = \) colour value (red, green, blue)
Phong Lighting Model

\[ \text{cv} = \text{colour value} \]

\[ \begin{align*} \mathbf{L}_{\text{Acv}} \cdot \mathbf{M}_{\text{Acv}} & + \mathbf{n}^T \cdot \mathbf{l} \cdot \mathbf{L}_{\text{Dcv}} \cdot \mathbf{M}_{\text{Dcv}} + (\mathbf{r}^T \cdot \mathbf{v})^c \cdot \mathbf{L}_{\text{Scv}} \cdot \mathbf{M}_{\text{Scv}} \end{align*} \]
Phong Lighting Model

\[ L_{Acv} \cdot M_{Acv} + n^T \cdot I \cdot L_{Dcv} \cdot M_{Dcv} + (r^T \cdot v)^c \cdot L_{Scv} \cdot M_{Scv} \]

Material shininess

cv = colour value
(red, green, blue)
Phong Lighting Model

\[ \mathbf{L}_{Acv} \cdot \mathbf{M}_{Acv} + \mathbf{n}^T \cdot \mathbf{I} \cdot \mathbf{L}_{Dcv} \cdot \mathbf{M}_{Dcv} + (\mathbf{r}^T \cdot \mathbf{v})^c \cdot \mathbf{L}_{Scv} \]

- Ambient light
- Diffuse reflectance
- Specular reflectance term

\( cv = \text{colour value} \)
(red, green, blue)
Blinn-Phong Lighting Model

\[ L_{Acv} \cdot M_{Acv} + n^T \cdot I \cdot L_{Dcv} \cdot M_{Dcv} + (n \cdot h)^c \cdot L_{Scv} \]

- Ambient light
- Diffuse reflectance
- Specular reflectance term

\( cv = \text{colour value} \) (red, green, blue)

\( n \) halfway between viewer and light source
\( h \) reflected light direction
\( v \) direction towards viewer
\( \alpha \) direction towards light source
\( \beta \) scattered light
Why?

Phong
round highlight
often used

Blinn-Phong
thin elongated highlight
more efficient
approaching infinity
Lighting effects
Opaque

impenetrability to electromagnetic ect radiation
Translucent

Allows some light to pass through
Transparent

Allows light to pass through
Caustics

Reflections through mediums
Particle effects

Emitter

Simulation

Render
Subsurface scattering

Light interacting with a translucent object
Global Illumination
Global Illumination

More accurate to reality, but expensive and slower.

Indirect illumination.
Ray tracing

Simulates rays of light hitting virtual objects.

High (light) realism, not suited for real-time applications.
Path tracing

Using random directions, ray bounces calculate colour.

A lot of times per pixel.

soft shadows, depth of field, motion blur, caustics, ambient occlusion, indirect lighting
Path tracing

Shooting rays vs gathering rays
Path tracing

Energy redistribution
Metropolis light transport

Bidirectional path tracing

Distribution of brightness

Explore nearby paths
Photon mapping

Great for caustics, works with specular

Rays from the light source, rays from the camera

Photon map

Ray tracing until intersection
Lightcut

Light source clusters

Error map

More lights, less noise
Point based global illumination

Point cloud of the directly illuminated geometry in the scene.

Ray tracing, disk approximation and clusters
Radiosity

Patches

View factor

Light bounces
Radiosity
Ambient occlusion
Casts no clear shadows
Real-time applications
Voxel-based global illumination
opacity map, emittance map
3D clipmap
Diffuse, specular cones
Real-time applications
Shadows
What is it?

Light source blocked by an opaque object

Hard shadow

Soft shadow
Shadow Map

Z-buffer

Multiple lights - multiple maps

Compare coordinates to test

Draw object
Shadow Volume

Shadow geometry

Silhouette edge

Closed volume

shadowed scene

wireframe shadow volumes
Thank you for listening!